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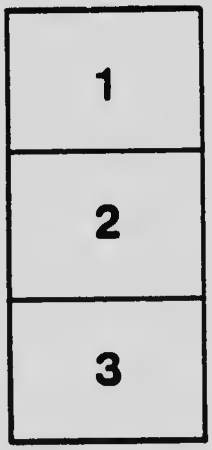
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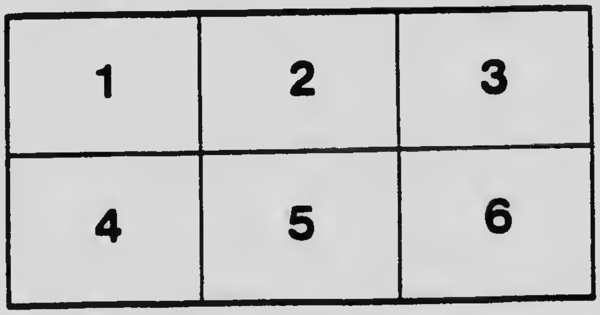
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Dr W. H. Collins

with compliments of

W. A. Johnston

PLATE I.

Terrace, in marine clay, along Russell road near Hawthorne.

CANADA
DEPARTMENT OF MINES
HON. ARTHUR MEIGHEN, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER.

GEOLOGICAL SURVEY
WILLIAM MCINNES, DIRECTING GEOLOGIST.

MEMOIR 101

No. 84, GEOLOGICAL SERIES

Pleistocene and Recent Deposits in the Vicinity of Ottawa, with a Description of the Soils

BY

W. A. Johnston

OTTAWA
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CONTENTS.

Illustrations.

Pleistocene and Recent Deposits in the Vicinity of Ottawa, with a Description of the Soils.

CHAPTER I.

INTRODUCTION.

GENERAL STATEMENT.

The object of this report and accompanying map is to present the results of an investigation of the superficial deposits, of Pleistocene and Recent ages, in the district surrounding Ottawa. These deposits are of importance economically because they contain large deposits of brick and tile clays and sands and gravels used for ballast and various structural purposes. Their study is also of importance because practically all the soils of the district are developed on these deposits, and the proper understanding and mapping of the various soils must necessarily be based upon the physical character and mode of origin of the deposits from which the soils have formed.

The map which accompanies this report is on the scale of 1 mile to 1 inch. The topographical base of the map is reproduced with minor additions and corrections from the topographical map of the district issued by the Department of Militia and Defence. The colours shown on the map represent the different soils and also the different unconsolidated rocks of the superficial deposits upon which the soils are developed. The descriptive names of the different soils are based on the relative proportions of the various sized particles comprising the soils, as determined by mechanical analysis. The classification of soil material as adopted by the United States Bureau of Soils has been followed.

The field work upon which the present report is based was done during the field season of 1915.

LOCATION AND AREA.

The area mapped is bounded by latitudes 45° 15′ and 45° 30′ and longitudes 75° 30′ and 76° 00′ and includes an area of 419 square miles. The district lies along Ottawa river, about 100 miles above the junction of the Ottawa with its trunk stream, the St. Lawrence, and is hence within the St. Lawrence drainage basin.

PREVIOUS WORK.

The published results of geological work previously done in Ottawa district, referring only to the main observations made with regard to the superficial deposits, may be briefly summarized as follows:

In the "Geology of Canada," 1863, reference is made to the stratified, marine sands and clays in the Ottawa district. These deposits are referred to as "Champlain sands and clays," following the nomenclature of the Vermont geologists. The occurrence of concretionary nodules, often containing fossils, in the Champlain clays along Ottawa river is also noted.

Sir William Dawson, who laid the foundation of our knowledge of the Champlain deposits in Canada, divided these deposits into the Leda clay and Saxicava sands, naming them after the commonest fossils occurring in each. In his "Canadian Ice Age," Dawson refers to the occurrence of the Leda clay and Saxicava sands along Ottawa river. He states that "Greens creek, a little below Ottawa city, has become celebrated for the occurrence of hard calcareous nodules in the clay, containing not only the ordinary shells of this deposit, but also well-preserved skeletons of the Capelin (*Mallotus*), of the Lump-sucker (*Cyclopterus*) and of a species of Stickleback (*Gasterosteus*), of a Cottus and of a species of seal."[1]

Ottawa was one of the localities in northeastern America examined in 1891 by Baron Gerard De Geer of Sweden, with the view of determining the limit of marine submergence during late Glacial time. The results of De Geer's researches are contained in a well-known paper entitled "On Pleistocene changes of level in eastern North America," published in the Proceedings of the Boston Society of Natural History, vol. XXV, 1892, pp. 454–477.

In the Annual Report of the Geological Survey of Canada for 1897, R. Chalmers referred to the occurrence of remarkable boulder ridges in the city of Hull and offered an explanation of their mode of origin. He also referred to the occurrence at high altitudes of marine shore-lines near Kingsmere mountain north of the city of Ottawa.

A report now out of print, published in 1901 by the Geological Survey of Canada on the "Geology and natural resources of the area included in the map of the city of Ottawa and vicinity," by R. W. Ells, gives a short account of the surface geology of the area. An appendix to this report, by H. M. Ami, gives lists of fossils from the Pleistocene and Recent deposits of the district. The lists of fossils from these deposits in the vicinity of Ottawa includes most of the species as determined from large collections made by different members of the Geological Survey and by private citizens.

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[1] Dawson, Sir J. W., "The Canadian Ice Age," 1893, p. 203.

A. P. Coleman in a report entitled "Sea beaches of eastern Ontario," Report of the Bureau of Mines, Toronto, Ontario, 1901, gives results of an investigation of the marine deposits in the vicinity of Ottawa and in the eastern portion of Ontario.

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CHAPTER II.

PHYSICAL FEATURES.

GENERAL ACCOUNT.

The Ottawa area lies at the southern margin of the Pre-Cambrian upland region which extends over the greater part of northeastern Canada and is known as the Laurentian plateau or Canadian shield. The map-area includes in its northern part a small portion of the Pre-Cambrian upland at its southern border. South of this border the area is underlain largely by Palæozoic rocks or by glacial and marine deposits of Pleistocene age, the general surface of which has an altitude of several hundred feet below that of the upland area and has, in general, less relief; hence, there are two contrasting types of topography. The lowland area has for the most part a gently sloping or undulating surface and over considerable portions the surface is nearly level. In places, particularly in the northwestern part of the area where the drift deposits are relatively thin, broad rock valleys with sloping sides occur. In the northeastern and eastern part, where the drift deposits are relatively thick, narrow steep-sided valleys are developed. In places, as in the vicinity of Ottawa and in the southwestern part of the area, rock hills or small upland areas within the lowland present steep scarp-like fronts facing towards the north or northeast and slope gradually toward the south or southwest. In the northeastern part of the area the lowland area abuts directly against the precipitous slopes of the Pre-Cambrian upland which rises considerably above the lowland and presents in its irregular hummocky surface a marked difference in topography. The steep scarp or cliff which marks the boundary between the lowland and upland in the northeastern part of the area forms the most striking topographical feature in the region. The scarp extends for a considerable distance towards the northwest and forms the natural southern boundary of the Laurentian plateau or Canadian shield in this region. In the area east of Gatineau river the rise from lowland to upland is more gradual and no marked scarp occurs.

RELIEF.

The general slope of the northern part of the area is toward the south and southeast and that of the southern part towards the north and northeast to the depression or valley occupied by the Ottawa rive but many local irregularities of slope occur owing chiefly to the irregular deposition of the drift deposits. The general slope of the bedrock valleys and consequently that of the bedrock surface is towards the southeast.

The highest part of the area is on the Pre-Cambrian upland, about one mile northwest of Kingsmere, where the highest part of the "mountain" has an altitude of nearly 1,220 feet above the sea. The lowest part is in the valley of Ottawa river below the city of Ottawa, where the surface of the water at low stages has an altitude of 127 to 132 feet above the sea. In the city of Ottawa the highest part of Parliament hill has an altitude of nearly 300 feet. The lowland in the northwestern part of the area north of Ottawa river has a general altitude of 300 to 450 feet, the highest part 3 miles northwest of the town of Aylmer rising to nearly 475 feet. South of Ottawa river, in the southwestern part of the area the general altitude is from 250 to 350 feet, but isolated hills rise somewhat higher, the highest point 3 miles west of Stittsville having an altitude of nearly 470 feet. In the southeastern part of the area the highest part of a drift ridge which extends southeastward from Bowesville has an altitude of 405 feet, but the general altitude along Rideau river is about 100 feet lower. The drift ridge near Bowesville ends rather abruptly on the east side of the Rideau valley between Black rapids and Rideau junction but continues at a lower altitude on the west side of the river, from the vicinity of Merivale to near Bells Corners. In the eastern part of the area, deeply underlain by drift, the general relief is less and the general altitude is from 225 to 275 feet.

DRAINAGE.

The area is drained by Ottawa river and its tributaries. Ottawa river is the main stream of the region and flows in a general easterly direction across the area. The river has not an even gradient, but consists of a series of lake-like expansions or stretches where the gradient is very low, separated by falls and rapids. At Chaudiere falls near Ottawa the river falls 25 to 30 feet over flat-lying limestone and, above the falls, a series of rapids separated by short stretches of slack water occurs. Above Deschênes rapids near Britannia the river occupies in part a broad rock valley and forms a lake-like expansion which extends to the northwestern corner of the area. Below the city of Ottawa the river has a very low gradient and flows in a valley largely underlain by marine clays, the bedrock being rarely exposed. Gatineau river, the second largest stream in the area, coming from the north joins the Ottawa opposite the city of Ottawa. In the upper part of its course it flows in a deep rock valley cut in the Pre-Cambrian upland and is characterized by rapids and falls with intervening stretches where the flow of the water is relatively slow because of the low gradient. For a few miles above its junction with the Ottawa the banks of the river are formed of marine clay and the gradient of the river is very slight.

Rideau river, coming from the south enters the Ottawa at the city of Ottawa where it falls nearly 50 feet over the limestone escarpment which forms the south bank of the Ottawa. Throughout the greater part of its course in the area the Rideau occupies a valley which is floored by drift deposits, the bedrock outcropping at only a few places. Rapids and falls occur at places where the bedrock outcrops, as at Hogsback and Black rapids.

Numerous small streams which, especially in their lower portions and in the areas where the drift deposits are thick, occupy narrow steep-sided valleys also occur, as is well seen in Chelsea brook in the norther part of the area, in Greens creek in the eastern part, and in the creek near Breckenridge in the northwestern part of the area. Much of the drift-covered portions of the area are, however, only slightly dissected by stream erosion and there are comparatively large areas in which the nearly level surface of the drift deposits is almost entirely untrenched by streams.

Terraces (Plate I) cut chiefly in the marine sands and clays occur along the valleys and at considerable heights above the present drainage channels in the eastern part of the area. They occur along the lower portions of the Gatineau and Ottawa River valleys, along the Rideau valley, and in the area drained by Greens creek. They are especially well developed in the southern part of the city of Ottawa and along the Ottawa valley and its tributaries below the city of Ottawa.

The lakes of the area are not numerous. The largest, known as lake Deschênes, is an expansion of the Ottawa river. There are two small lakes in the Pre-Cambrian upland area. In the lowland area, except for the lake-like expansions of the Ottawa river, there are only a few small ponds or lakes, the largest of which is Constance lake.

MODE OF ORIGIN OF PHYSICAL FEATURES.

The present physical features are of varied origin and are the result of erosion and deposition by various agencies. During a long period of time previous to Pleistocene or Glacial time, the region was above sea-level, as is shown by the absence of marine Tertiary deposits and by the development of stream valleys partly filled with Pleistocene deposits. During this time the major features of the bedrock topography were formed by processes of weathering and stream erosion. During Pleistocene time the region was invaded by one or more ice-sheets advancing from the north. The pre-Glacial land surface was modified by glacial erosion and by deposition, in places, of material eroded by the ice-sheet. Near the close of Pleistocene time when the ice-sheet began to retire, the area was, in large part, below sea-level so that as the ice retired or melted back, the sea entered and overspread the Ottawa valley to a depth, in places, of several hundred feet. In this arm of the sea, known as the Champlain sea, thick deposits of sand, silt, and clay were laid down. As the ice-sheet still further retired, uplift took place, the land gradually emerged from the sea, and stream erosion again became effective and has continued until the present time; but, owing to the comparatively short time, geologically, since the land emerged from the sea, only a small amount of erosion has been accomplished.

The physical features of the bedrock surface are largely the result of processes of weathering and stream erosion during pre-Glacial time. It is probable that glacial erosion modified these features to some extent but there can be little doubt that the main features of the bedrock topography are pre-Glacial in origin and were not greatly modified by glacial erosion. This seems to be borne out by the fact that glacial striæ in places pass up over the faces of the escarpments facing the north and northwest, as at a point 1½ miles northeast of Gatineau Point station, and by the character of the rock valleys which have not the typical U-shape of glacially eroded valleys. Glacial erosion was undoubtedly effective in almost entirely removing the loose mantle of weathered material, in smoothing off irregularities of the surface, and in eroding in places the solid rock. Erosion of the solid rock is shown by the appearance of the side wall of the small valley leading up from the Ottawa at Sussex street in the city of Ottawa (Plate II), but the character of the sides of the valley in places also shows that the valley existed before the advance of the ice-sheet and was only slightly modified by ice erosion. The partial filling of many of the rock valleys by glacial deposits shows also that the valleys were largely formed in pre-Glacial time.

The lowland, developed chiefly on Palæozoic rocks but partly as in the vicinity of South March on Pre-Cambrian rocks, forms a large part of the area and is largely the result of subaerial processes of erosion in pre-Glacial time. A characteristic feature of the general lowland area as distinct from the Pre-Cambrian upland is the occurrence of minor upland areas developed on Palæozoic rocks within the lowland. These minor upland areas, one of which occurs along the south side of Ottawa river at Ottawa, have steep faces fronting the north towards the Pre-Cambrian "old land" and slope gently towards the south and form what have been named cuestas. They are somewhat irregularly distributed; they are developed on different kinds of rocks and occur at varying distances from the contact of the Palæozoic and Pre-Cambrian, being best developed usually at a distance of several miles from the actual contact. The region has been much affected by normal faulting[1]

[1] Ells, R. W., "Formations, faults, and folds of the Ottawa district," Ottawa Naturalist, vol. XI, No. 16, 1898, pp. 177-189.

but the scarp-like fronts of the cuestas are, in their mode of origin, not directly connected with the faults. They are largely independent of the faults and clearly owe their origin to differential weathering and stream erosion. The faulting long antedated the Pleistocene period and any scarps which may have directly resulted from the faulting had a short-lived existence. One result of the faulting, however, was the irregularity in the development and distribution of the cuestas and their development on rocks of different ages. Escarpments of Palæozoic rocks are usually not well developed near the actual contact of the Palæozoic and Pre-Cambrian rocks at the southern margin of the upland region; but, on the other hand, in the northern part of the area, west of Gatineau river, a marked escarpment of the Pre-Cambrian rocks occurs. This escarpment is probably, as has been pointed out by Kindle and Burling[1], a "fault-line scarp," the result of faulting and differential erosion of rocks, of varying degrees of resistance to erosion, involved in the faulting.

The pre-Glacial drainage of the area was somewhat different from the present. The general trend of the bedrock valleys is towards the southeast and this was the general direction of the pre-Glacial drainage. In pre-Glacial time there was probably not a river comparable in size and general position to Ottawa river, but a series of rivers or streams existed parts of whose valleys are at present occupied by Ottawa river. In the northwestern part of the area, Ottawa river forms a lake-like expansion occupying a broad rock valley which trends towards the southeast and whose lower portion southeast of the lake is drift-filled. From Deschênes rapids at the foot of the lake the river flows in a shallow, poorly defined valley across an interstream area to join the old Gatineau valley at Ottawa, its course between the two old valleys being entirely post-Glacial. The pre-Glacial valley occupied by Gatineau river in its lower portion turns toward the east near the city of Ottawa, and is partly filled in this portion by glacial and marine deposits, in which the present river has cut a shallow trench. Rideau river occupies a valley which is almost entirely post-Glacial in origin, for the river throughout the greater part of its course flows over drift deposits. In the southwestern part of the area a rock valley, filled in places to over a depth of 100 feet by drift deposits, is occupied by Carp and Jock rivers. This valley trends towards the southeast and roughly parallels the broad valley occupied by the lake-like expansion of the Ottawa.

The principal fall in the Ottawa river occurs at Chaudiere falls at Ottawa where the water falls over a low escarpment of Trenton limestone. A series of narrow gorge-like channels below the falls, the largest one being

[1] Kindle, E. M., and Burling, L. D., "Structural relations of the Pre-Cambrian and Palæozoic rocks north of the Ottawa and St. Lawrence valleys," Geol. Surv., Can., Mus. Bull. . 3, 1915.

occupied by the main volume of the river, shows the distance the falls have receded in post-Glacial time. The total distance is only about one-quarter mile. The maintenance of the falls is owing to the well jointed character of the rocks which permits large masses to be separated by widening of the joints and finally to be worn away, leaving a still nearly vertical front over which the water falls. The general uniformity of hardness of the beds, however, has prevented a rapid recession of the falls. It is probable also hat for a considerable length of time after the disappearance of the marine waters the river channel at and above the falls was obstructed by accumulations of bouldery drift, upon the erosion of which the energy of the river was employed or a considerable length of time. This is borne out by the presence of large quantities of coarse river gravels in the city of Hull below the falls. Hence the short distance, as compared with other well-known cases, to which the falls have receded in post-Glacial time may be owing to several causes.

No true rock basin lakes are known to occur in the area. Kingsmere lake in the Pre-Cambrian upland occupies the upper part of a rock valley the lower part of which is blocked by a deposit of boulder clay. Fairy lake and lake Mackay in the lowland area are partly enclosed by bedrock and partly by glacial and marine deposits. The presence of marine clays, forming parts of the borders of the lakes and rising to altitudes of 20 feet or more near the margins of the lakes, seems to show that the basins have been partly excavated in the marine clays. It is possible that they formed "plunge pools" into which the water flowed at a time during the period of emergence of the land when the flow of Ottawa river was much more extensive and widespread than at present.

Terraces cut chiefly in the marine clay, at various altitudes from 150 feet to 250 feet above the sea, occur along Gatineau and Rideau rivers and in the eastern part of the area. They are, apparently, river terraces, but their precise mode of origin is not clearly apparent. They are well developed along Rideau river in the southern part of the city of Ottawa and north of the city along the sides of Gatineau valley. They also occur along the Ottawa below the city of Ottawa and in general along the valleys throughout the greater portion of the area lying east of the city of Ottawa. It is clear they are erosion forms; for the horizontically bedded marine clays, in most places, form the bluffs which rise abruptly at the sides of the valleys to a height of 20 feet or more. It is also clear that they are not, for the most part, alluvial terraces, that is, terraces formed by meandering streams eroding the sides of the valley and constructing a valley flat by erosion and deposition of flood-plain deposits: for the valleys are for the most part floored by marine clays, the valley bottoms are not level but slope gently, and the uninterrupted continuation of individual terraces, in places for several miles, shows that they were not formed by meandering streams. In places also, in the lower portion of the Ottawa valley, the distance between the highest terraces on opposite sides of the valley is several miles and the river must have filled the valley from bank to bank. It is probable that the valleys were not originally filled level full by marine deposits but that the surface of the clays sloped towards the central portion of the valleys. The fact, however, that the terraces are cut in the horizontally bedded marine clays shows that large quantities of the clays have been eroded and that the terraces are erosion forms. An important factor in the development of the terraces was, probably, the greatly increased volume of the drainage waters in the Ottawa valley during and for a time after the closing stage of marine submergence. The individual terraces are very nearly horizontal or have too small a gradient down stream to be detected by levelling. The terrace bluffs resemble wave-cut cliffs but their continuity, the general absence of wave-built features at similar levels, and the occurrences of the terraces, in places, in restricted valleys show that they were not entirely formed by wave action. It seems probable, however, that the terraces were partly formed by wave action and partly by stream erosion acting chiefly along the sides of the valleys and widening them in a manner similar to that which may be observed along the south bank of the Ottawa below the city of Ottawa, where the banks are being rapidly cut back by stream erosion, assisted by seepage of water at the ground water level and by constant slipping of the clay banks. The general level of the different terraces may have been determined by different stages of sea-level with respect to the land during the time of progressive uplift of the land, or may also have been determined by barriers at some points in the lower portion of the Ottawa valley which, for a time, held up the waters and whose erosion resulted in a gradual lowering of the river bed. The former seems to be the more probable because of the altitude of the higher terraces and the wide extent of the valleys occupied by the waters.

The general surface of the bedrock of the lowland which occupies the greater part of the area forms part of the St. Lawrence lowland. Over a part of the area the bedrock is covered by a thick mantle of glacial and marine deposits, the greater part being marine clays of Champlain age. The surface of those portions of the area where the marine deposits are thick is generally nearly level and forms an uplifted marine plain. This descriptive term applies more particularly to the eastern part of the area.

CHAPTER III.

GENERAL GEOLOGY.

General Account.

The deposits occupying the surface of a large part of the Ottawa area are superficial deposits which differ from the bedrock or solid rock underlying them in that they are largely unconsolidated, they are different in origin, and are, geologically, vastly younger in age. They belong to the latest of the geological periods, the Quaternary, which is subdivided into Pleistocene and Recent. The soils of the area are almost entirely developed upon these deposits. In this chapter the actual soils are not dealt with and attention is confined to the origin and character of the deposits upon which the soils are developed and which have a controlling influence in determining the agricultural value of the soils.

During Pleistocene or Glacial time, great ice-sheets or continental glaciers spread outward from different gathering grounds in Canada. One of these gathering grounds or centres of ice dispersion was in Labrador peninsula. The ice spread outward from that region and advanced southward across the Ottawa and St. Lawrence valleys into New York state and as far south as New York city. In parts of the Great Lake region and in the Mississippi Valley region, evidence has been found which shows that advances and retreats by the ice-sheets occurred at different times during the ice age. In the Ottawa valley evidence of more than one main invasion has not been found. It is possible that earlier advances of ice-sheets occurred in this region, but, if so, no definite records of such are known to exist.

The ice-sheet, which advanced across the region, incorporated in its lower part much of the loose rock debris, plucked out masses of solid rock, ground down the solid rock over which it passed, and transported vast quantities of this material in the form of boulders, sand, and silt. When the ice melted it left the surface covered with accumulations of this transported material, the glacial drift.

Near the close of the Pleistocene epoch when the Labradorean glacier had melted back as far as the Ottawa valley this area was depressed relatively to sea-level so that, as the glacier retired, the sea water entered by way of the gulf of St. Lawrence and formed what is known as the Champlain sea. The waters of this sea covered the land in some places in the Ottawa valley to a depth of several hundred feet. In these waters large quantities of sand, silt, and clay were deposited. More recent uplift of the land has driven the sea out of this region and has set the streams at work eroding the glacial and marine deposits and transporting them to lower levels. However, comparatively little erosion has been effected, except in the larger stream valleys, because of the comparatively short time which has elapsed since the disappearance of the ice-sheets.

Pleistocene Deposits.

The superficial deposits of the Ottawa area are largely Pleistocene in age. They include glacial, marine, lacustrine, and fluvial deposits. They cover the greater part of the surface, the bedrock being exposed in only a comparatively small part of the area.

The glacial deposits consist of till or boulder clay, chiefly in the form of ground moraine, and fluvioglacial or stratified drift in the forms of kames, and outwash sheets of sand and gravel. The marine deposits consist of stratified sand, silt, and clay laid down on the bottom and along the shores of the Champlain sea, an arm of the Atlantic which extended up the Ottawa and St. Lawrence valleys during the closing stage of the Pleistocene. The marine deposits in places also contain in their body and on their surface boulders deposited through the agency of floating ice. The lacustrine deposits were formed in lakes held up by drift barriers for a time after the disappearance of the marine waters or in water bodies rendered fresh by the shallowness of the receding sea and the inflow of fresh water. The fluvial deposits consist of river gravels and alluvium of the higher stream terraces.

DEPOSITS OF GLACIAL ORIGIN.

Glacial Till of Ground Moraine.

Glacial till or boulder clay, the unstratified deposit of the ice-sheet, occupies the surface of only a small part of the Ottawa area but is extensive over much of the area beneath a covering of marine sediments. It is generally of small thickness and in places is almost entirely absent, the bedrock outcropping with little or no drift covering. In places also the marine deposits rest directly on the bedrock. In the northern part of the area, where the bedrock consists of Pre-Cambrian crystalline rocks, the till is especially thin. It is thickest and more widespread in the southern part of the area where the bedrock consists chiefly of Palaeozoic limestones owing mainly to the fact that the limestones were more easily eroded by the ice-sheet than the crystalline rocks. The till is very unevenly distributed, in places filling depressions in the underlying bedrock, in other places being absent or forming heaps or mounds where no depressions in the bedrock existed. The general effect of the deposition of the till was to lessen the relief and make the surface smoother.

That the character and composition of the till is largely determined by the nature of the bedrock upon which or near which it lies is well shown in the Ottawa district; for, in places distant less than 5 miles from the Pre-Cambrian upland, from which the ice advanced, the till is composed largely of material derived from the underlying or adjacent Palæozoic rocks. It also contains many boulders and smaller fragments of rocks derived from the crystalline rocks but the greater part of the material, especially the finer-grained part, is local in derivation. Hence the till is nearly always highly calcareous in the areas underlain by limestone. In the areas underlain by crystalline rocks and sandstones the till is usually reddish in colour, it is more or less arenaceous, and contains a small proportion of the finer-grained materials. In the areas underlain by Palæozoic limestones the unweathered till is bluish-grey in colour and contains a large proportion of silt and clay. The till of the Ottawa area is usually crowded with angular and subangular stones and boulders set in a matrix of finer-grained material. Hence it is very tenacious and difficult of excavation. The till is without stratification but in places it contains lenticular layers or irregularly shaped masses of stratified sand . l silt. These stratified portions may be of sub-glacial stream origin or, it is more probable that in most cases they represent masses of stratified material ploughed up by the glacier and incorporated while in a frozen condition in the till, for the included masse. usually show evidence of folding and contortion.

Good exposures of the till in sections are found at only a fe places in the Ottawa area (Plate III). The exposures occur along stream valleys and in artificial excavations. A section exposed on the west bank of Rideau river one mile above Hogsback shows a thickness of 10 feet of till underlain by fluvioglacial sands and gravels. In the valley of Greens creek 2 miles southwest of Blackburn post-office, a section shows 18 feet of till resting on bedrock and overlain by marine clay. In the city of Ottawa numerous artificial excavations have exposed the till to varying depths. In excavating for the foundation of the Customs building on Sussex street it was found that the till had a thick ss of at least 50 feet and almost completely filled a bedrock valley. A ballast pit, near the Canadian Northern station in the city of Ottawa, when freshly exposed showed 6 to 10 feet of stony till overlain by marine sand and clay and underlain by fluvioglacial sands which sho wevidence of disturbance apparently caused by overriding of the ice-sheet and which are partially incorporated in the till. Sections exposed in sand pits in Ottawa South on the south side of Rideau river one-quarter mile east of Bank street show a small thickness of till overlying cross-bedded sands and gravels of fluvioglacial origin. The low ridge which occurs in Ottawa South near the canal and extends northwest across the canal is partly composed of till which is highly arenaceous and loose in structure, owing to the inclusion in the till of masses of the underlying fluvioglacial sands and gravels.

The till sheet of the Ottawa area owes its origin almost entirely to deposition as ground moraine from the ice-sheet, that is it was deposited beneath the ice or from the base of the ice during its melting. At the time of deposition of the till sheet the Ottawa area was depressed relatively to sea-level at least 300 feet so that the till of the lower portions of the district was deposited on a land surface which was below sea-level. This is shown by the character of the contact of the till and the overlying marine deposits (Plate III). Sections exposed at various altitudes up to at least 300 feet above sea-level show that no erosion or weathering of the till took place before the deposition of the marine clays. The till contains no marine fossils and is unstratified; hence it cannot be regarded as a marine deposit although deposited below sea-level. The mode of origin of the till as ground moraine explains the absence of stratification and the lack of marine fossils.

Terminal Moraines.

No well developed terminal moraines marking positions of the ice front at time of halt during the general retirement of the ice-sheet have been recognized in the Ottawa area and their recognition is difficult because of the general covering of marine sediments. Part of the ridge extending southeast near Bowesville appears to be of morainic origin, for, in places, its surface is characterized by irregular knolls and undrained basins; but, in general, the surface of the ridge is smoothed off by marine deposition and erosion.

Fluvioglacial Sands and Gravels.

Stratified sands and gravels of fluvioglacial origin are of local and irregular occurrence in the Ottawa area and rarely outcrop at the surface, for they are generally buried beneath a covering of marine deposits. In places also they are overlain by till and are exposed only in sections.

In general character the fluvioglacial deposits are more sandy than gravelly but in places they contain numerous large boulders and occasionally masses of till; they are generally markedly cross-bedded and show abundant evidence of minor folding and faulting due to the melting of included ice-blocks and consequent settling or to overriding of the ice-sheet.

Sections exposing fluvioglacial sands and gravels occur along the west side of Gatineau river one-quarter mile above Wright's bridge. The upper portion of the gravels is cemented to a depth of 2 to 4 feet by infiltration and deposition of lime carbonate derived from the overlying marine clay. Gravels of similar origin are exposed in a gravel pit at

Britannia. At this locality also the gravels are partly cemented. Cementation occurs only where the gravels are overlain by lime-bearing deposits which form the source of the cementing material. They are well exposed in the ballast pit of the Canadian Northern railway three-fourths of a mile east of Bowesville where a thickness of 10 to 15 feet are exposed, overlain by 1 to 4 feet of marine sands and gravels (Plate IV). In the sections exposed in this pit the material shows a marked variation in character, in places being almost entirely sand, usually unoxidized and grey in colour, markedly cross-bedded and in places folded and faulted (Plate V). In other places coarse gravel and boulders irregularly stratified form the larger part. At one place a mass of till 10 feet in diameter is included in the gravels. At the western edge of the pit, till overlaps the deposits. Throughout the greater part of the deposit the sands and gravels are crumpled, folded, and faulted on a small scale, the throw of the faults being usually only a few inches. In places lenticular masses of evenly bedded sand and silt are included in the sands. They are in most cases abruptly terminated and appear to be distinct from the main mass. Marine fossils occur in the overlying gravels which occupy the surface but not in the underlying deposits of fluvioglacial origin. The contact is well defined and forms an even surface apparently marking a wave-cut plain. The marine deposits are not disturbed by folding or faulting. At two places, one being near the western end of the pit and the other on the south side near the eastern end, lens-shaped masses of laminated sand and silt, holding marine fossils of arctic species, occupy depressions in the upper portion of the fluvioglacial deposits and are overlain directly by the marine gravels. The lens-shaped masses are crumpled and folded in a manner similar to that of the underlying fluvioglacial deposits. The lack of disturbance of the overlying marine gravels which are apparently beach or terrace deposits shows that the folding and faulting of the underlying deposits took place previous to the deposition of the marine gravels. It may be largely accounted for by assuming that ice blocks were included in the fluvioglacial deposits at the time of their deposition and with the melting of the ice the deposits settled and readjusted themselves. The intense folding of the sands in places, suggests, however, that the deformation was partly caused by overriding by the ice-sheet and this explanaton is supported by the fact that in places till overlies the fluvioglacial deposits. There is no evidence of erosion or weathering of the fluvioglacial deposits having taken place previous to the deposition of the till and no marine deposits are known to be overlain by till in the Ottawa area so that if readvances of the ice occurred, it is probable that they were of minor importance.

The fluvioglacial deposits of the Ottawa area differ somewhat in form and mode of origin, but, because they are in great part buried beneath marine deposits and in some places by till, their form and mode of deposition are not clearly apparent. The irregularly shaped hill east of Gatineau river near Wright's bridge appears to be a kame. The ridge which extends southeastward for several miles from Bowesville and in which the Canadian Northern ballast pit is situated is probably partly morainic in origin and includes outwash sands and gravels associated with the moraine. The fluvioglacial deposits buried beneath the till may be sub-glacial stream deposits, the till covering merely being the ground moraine deposited from the base of the ice during its melting or they may may be kame or outwash deposits formed near the margin of the ice-sheet and subsequently overridden by the ice.

DIRECTION OF ICE MOVEMENTS AND STAGE OF GLACIATION.

There are at least two distinct sets of glacial striæ in the district. One set, which is the more pronounced, trends nearly south; the other, which is the later, trends nearly southeast. This shows, at least, a marked change in direction of movement of the ice-sheet during the closing stage of glaciation.

Stratified sands and gravels of fluvioglacial origin are in places overlain by till and show evidence of disturbance as if overridden by the ice-sheet. Hence, it is possible that a readvance of the ice took place. But no marine or lacustrine deposits are known to be overlain by till and no evidence of weathering or erosion of the deposits overlain by till having taken place prior to the deposition of the till has been found, so that there is little evidence of any lengthy retreat and subsequent readvance of the ice-sheet. The glacial deposits are weathered to only a slight depth and it is probable that they belong to one general stage of glaciation, which is presumably the latest or Wisconsin stage of glaciation. It is possible that the region was invaded by ice-sheets during early stages of Pleistocene glaciation; but, if so, no definite records have been left, so far as is known.

CHAMPLAIN (MARINE) DEPOSITS.

General Features.

The waters of the Champlain sea followed the retreating front of the ice-sheet and covered the lower ground as fast as the ice withdrew, for the region was depressed relatively to sea-level. The depression of the land relatively to sea-level does not entirely account for the flooding by marine waters, for it is probable that for a time the sea also rose on the land owing to the return to the ocean of the water which had been bound up in the ice-sheets.

The sea-bottom deposits of the Champlain sea in the Ottawa area consist of fine sand, silt, and clay. The deposits were not formed over the whole sea bottom but only in favourable localities, portions of the area being covered by little or no marine sediments. The silt and clay were, for the most part, deposited in the deeper portions and in depressions, and the sand in the shallower portions and near shore. The beach deposits of sand and gravel were formed along the shores and mark the ancient shore-lines of the sea at different levels as the land was being uplifted and was emerging from the sea.

The maximum extent of the Champlain sea in the Ottawa area is shown by the distribution of the marine deposits. The highest shore-line, near Kingsmere in the northern part of the area. has an altitude of 688 to 690 feet above sea-level. The small area near Kingsmere lying above this altitude was the only portion of the Ottawa area not covered by the sea during the time of maximum marine submergence.

Beaches.

Raised beaches occur in the Ottawa area at numerous localities and at altitudes ranging from 240 feet to 690 feet above the sea. In most cases the beaches are not strongly developed so that it is difficult to trace individual beaches for any great distance. They are best developed in localities where there was an abundance of drift and which were well exposed to wave action. In these localities the beaches are closely spaced, apparently showing an almost continuous emergence of the land.

The best locality at which the altitude of the highest beach marking the upper limit of marine submergence may be determined is at Kingsmere, 8 miles northwest of Ottawa. This locality is favourable because of the occurrence of a sheet of boulder clay on the southern slope of the "mountain" and because of the good exposure to wave action. In the stream valley leading up to Kingsmere from the east stratified sands and gravels occur overlying marine clay. The upper limit of the stratified sands and gravels is sharply defined and forms a terrace. The altitude of the inner edge of the terrace (as determined by levelling from the first road corner above this locality, the altitude of which is given on the Ottawa map-sheet issued by the Department of Militia and Defence. as 796 feet) was found to be 688 to 690 feet above the sea. The boulder clay slope rises to an altitude of over 200 feet higher, but no evidence of wave action could be found above an altitude of 690 feet. This locality is probably the same as that at which de Geer determined the altitude of the highest shore-line to be 705 feet.[1] The difference is probably due to the fact that the altitude as found by de Geer was a barometric determination, which would readily account for the slight difference.

[1] De Geer, Gerard. "On Pleistocene changes of level in eastern North America," Proc. Nat. Hist. Soc., Boston, vol. XXV, 1892, pp. 454-477. (Map.)

Raised beaches at lower levels occur in the valley leading up to Kingsmere from the east at altitudes of 492, 484, 477, 468, and 461 feet. Beach deposits also occur in this valley and in the valley leading up to Kingsmere from the west at various altitudes between 492 and 690 feet, but they are generally poorly developed because of the steep and rocky character of the slopes; and in general throughout the district the areas lying between altitudes of 500 and 700 feet were unfavourable for the development of shore-line features. A well developed beach, the crest of which has an altitude of 440 feet, occurs on the west side of Chelsea road one-half mile north of Chelsea. This beach is developed in places around the base of the highland area in the northern part of the district and on the relatively high area northwest of Aylmer. It is probably also represented by beach deposits on some of the higher ground in the southern part of the area, which formed islands in the sea at this stage of the marine submergence. The highest beach in the southeastern part of the area occurs one mile southeast of Bowesville and has an altitude of 405 feet. In the southwest part of the area beaches also occur at altitudes of about 400 feet near Fallowfield and near Stittsville. Two miles northwest of Old Stittsville several beaches have altitudes of 400 to 450 feet, the latter being the highest altitude of the beaches in this portion of the area. Individual beaches of this series cannot be traced for any great distance because they are only locally developed and were formed on islands in the sea, so that their altitudes furnish little evidence as to the character of the uplift.

One beach, however, which can be traced for a considerable distance, was found to occur in the valley of Ottawa river above the city of Ottawa. This beach probably marks the outline 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 and in the vicinity of Ottawa strongly marked river terraces and river gravels occur at altitudes nearly corresponding to the altitudes of the beach in the upper part of the basin. The altitudes of this beach, determined at different points[1], shows, approximately, that the differential uplift which affected this area during the life of and after the disappearance of the lake was greatest in a nearly due north direction and that the rate of tilt is about 3 feet per mile over part of the area.

Champlain Clays.

The Champlain or Leda clays, as they were named by J. W. Dawson, underlie approximately two-thirds of the Ottawa area. They have a maximum thickness in places of nearly 200 feet and are best

[1] Johnston, W. A., "Late Pleistocene oscillations of sea-level in the Ottawa valley," Geol. Surv., Can., Mus. Bull. No. 24, 1916, p. 7

developed in the stream valleys and lowest parts of the area. They do not, however, occupy all the depressions in the area but are somewhat irregularly distributed, being absent in some of the depressions owing partly to non-deposition and partly to stream erosion subsequent to their deposition. They are well developed in Gatineau River valley north of the city of Ottawa, where they have a thickness of over 100 feet, and in Ottawa River valley below the city of Ottawa. Well borings in Ottawa River valley below the city of Ottawa show the clays to have a maximum thickness of at least 170 feet. In the valley of Greens creek where it crosses the Montreal road the clays are 125 feet thick. The clays are also extensive in the eastern part of the area and underlie the Mer Bleue peat bog and adjacent areas to a considerable depth. A well boring near Ramsayville showed the clay to have a thickness of 186 feet The central portion of the city of Ottawa is also underlain by marine clay occupying a basin in which the clay has a maximum thickness of nearly 100 feet. This basin-shaped area extends southward along Bank street from Albert street to the Glebe, westward to Bronson avenue, and northeastward to Rideau river, including a large part of Ottawa East. The northeastern part of the city, known as Sandy Hill, is underlaid largely by marine clay, the surface of which rises considerably above the area lying to the east, showing that the clays were originally more extensive but have been removed by stream erosion. They were originally more extensive also in the southern part of the city in the valley of Rideau river for they occur on the sides of the valley and have considerable thickness at altitudes of 60 to 70 feet above the valley bottom. They also extend south for several miles along the valley of the Rideau and have a maximum thickness near Rideau junction of nearly 100 feet. Two miles south of Rideau junction the marine clays in the Rideau valley are confined to a narrow strip along the river, but south of Black rapids they again become extensive and spread out for several miles on both sides of the valley. In the southeastern part of the area the clays are extensive in the valleys of Carp and Jock rivers, where well borings show the clays to have a thickness in places of at least 100 feet. In the northwestern part of the area a considerable deposit occurs in the valley extending eastward from Breckenridge. This deposit is remarkable for its thickness. Stream valleys have been cut down through the clays to a depth of 100 feet and have not exposed the base of the clays, and a thickness of 220 feet of clay is said to have been passed through in drilling for water on P. Hogan's farm 2½ miles northeast of Breckenridge. Numerous small areas of marine clay, occupying depressions or forming erosional remnants of a more extensive sheet also occur at different altitudes throughout the area. The thick deposits are confined to the lower ground and deepest depressions. Some of the valleys, however, as for instance the Constance Lake valley and the upper part of Ottawa River valley, appear to have received little sediment.

The Champlain clays are exposed in numerous sections in the Ottawa area, at various altitudes from 130 feet, in the lowest part of the Ottawa valley, up to 605 feet above sea-level, the highest locality at which they are known to occur being in the stream valley leading up to Kingsmere from the east. Well borings show that they extend to a depth of 130 feet below the level of the lower part of the Ottawa river, so that they have a total vertical range of about 600 feet. The great mass of the clay, however, lies below an altitude of 400 feet. The clay occupies a few depressions in the hilly northern part of the area at altitudes ranging from 400 feet to 500 feet. Above 500 feet the deposits are small and are confined to the narrow stream valleys.

The surface of the clays is nearly level or gently sloping but, in places, as in Gatineau valley and northeast of Breckenridge, they are deeply trenched by streams. In the vicinity of Ottawa and in the eastern portion of the area the clays show marked evidence of stream erosion and terracing so that the original surface of deposition is in part destroyed. The occurence of flat-topped ridges of horizontally bedded marine clay separated by valleys, as in the southern part of the city of Ottawa and in the vicinity of Mer Bleue peat bog, shows clearly that the ridges as now existing originally formed part of a more extensive plain, and that a considerable part of the clay has been removed by erosion and transported to lower levels. The original surface of deposition is, however, preserved in parts of the area or at least has been only slightly modified by processes of erosion. This surface is particularly well preserved around the base of the Laurentian hills where the clay abuts closely against the base of the steep rocky slopes and extends outward, being only slightly trenched by stream erosion. The general surface of the clay where uneroded is not level, but slopes towards the valleys or central parts of the depressions in which the clays were deposited and in the case of Gatineau valley slopes up-stream. Hence, it is probable that, although a large amount of clay has been removed from the lower portions of the Ottawa and tributary valleys, as is shown by the strong terracing of the clays, the original surface did not form a level plain across the valleys but dipped down into them, conforming somewhat to the original depressions.

In physical character the clays are markedly different in their upper and lower portions. The lower part is a sandy and silty clay often well laminated, especially towards the base, but becoming more massive and indistinctly bedded in the upper part. It occurs practically at all altitudes from 130 feet up to 605 feet. In the lower parts of the Ottawa valley, where the lowest exposures are found, it is generally finer-grained and contains less silt and sand. In its upper portion the lower clay passes upward into sand. This occurs most markedly at altitudes from 200 up to 350 feet. The lowest locality observed at which this occurs is in the valley of Greens creek at the road crossing 2 miles east of Willowdale. A section exposed on the west side of the creek shows at the base 18 feet of till resting on bedrock. The till is overlain by 6 feet of laminated silty clay which passes upward into horizontally bedded sand and fine gravel 7 feet thick, overlain by 11 feet of stratified clay which in the lower 3 feet is interstratified with sandy layers, but in the upper part is uniformly fine-grained. A section exposed on the west side of Rideau river one-quarter mile above the Canadian Northern Railway bridge shows 20 feet of sand and silt overlying the lower silty clay and overlain by the upper clay. Similar relations are shown in sections exposed in the sand pits on the east bank of Rideau river one mile south of Rideau junction, at Black rapids on Rideau river, at the Peerless brickyard south of Rideau river near Ottawa, and along the railway three-fourths of a mile north of Chelsea station. The sand which overlies the lower silty clay and is overlain by the upper clay is generally evenly bedded. In places it contains fine gravel and is ripple-marked. In the lower part of the Ottawa valley near Ottawa the sand is generally thin or absent, and the lower silty clay is overlain directly by the upper clay. Glaciated stones and boulders occur abundantly in the lower clays and the beds are in places crumpled and contorted as if by the grounding of icebergs. This is well seen in sections exposed along the shore of lake Deschênes at the foot of Graham bay, where contorted beds are overlain by undisturbed beds. From the foregoing observations it may be concluded that deposition was continuous throughout the series. In places also the upper beds contain small fragments of the underlying clay apparently formed by floating ice masses grounding on and churning up the clays, portions of which were taken into suspension in the water and rapidly re-deposited. At Black rapids on Rideau river a series of folded and faulted beds also occurs and apparently owes its deformation to similar causes. Crumpled clays are also well exposed in the bed of the brook leading up to Kingsmere from the east (Plate VI). In this case, however, it is probable that the beds were deformed by movement induced by the pressure of the overlying deposits of sand and gravel, for they occur in a restricted valley and on a fairly steep slope. The lower silty and sandy clays form the greater part of the marine sediments and there can be little doubt that they were derived from the waters of the melting ice-sheet which could not have been far distant when the clays were deposited.

The upper clay overlies the lower sandy and silty clay at practically all altitudes from the lowest part of the Ottawa valley up to at least 425 feet. It is generally only 6 to 10 feet thick but in places has a maximum thickness of 20 feet or more. The greatest thickness observed is in the valley of Greens creek where it is at least 20 feet thick and possibly more. It also has considerable thickness in parts of the Gatineau valley. The upper clay differs markedly in physical character from the lower clay. It is an exceedingly fine-grained, plastic clay generally interlaminated with sandy layers in its lower portion near the contact with the underlying sandy or silty beds, but nearly free from sand in its upper portion. The stratification is not usually apparent except on close examination because of the fineness of grain and nearly uniform size of the particles composing the clay. Boulders occur occasionally in and on the surface of the clays as if dropped from floating ice, but the upper clays are not known to be crumpled or disturbed except where landslides have occurred.

The colour of the marine clays is for the most part bluish grey changing to brownish red in the upper weathered portion. In places the lower parts of the clays containing abundant organic matter are nearly black when wet. In places also reddish bands ½ inch to 4 or 5 inches thick occur alternating with grey bands, giving a distinct appearance of colour banding. The red bands occur most abundantly near the base of the upper fine-grained clays and in places extend through a vertical interval of several feet but are not extensively developed. They are well exposed in sections along the east side of Gatineau river near the Canadian Pacific Railway bridge. The red bands are composed of exceptionally fine-grained material, the greater part being composed of particles less than 0·003 mm. in diameter. The general bluish grey colour of the marine clays is similar to that of the unweathered till and is probably due to the fact that the material was largely derived by the grinding action of the glaciers on fresh rocks and was deposited as clay without having been oxidized.[1] The dark coloration mentioned above appears to be due to the presence of the black iron sulphide formed through the agency of the organic matter included in the clay. The red bands are composed largely of weathered material. Their occurrence and interbanding with grey beds may, possibly, be owing to erosion by stream and wave action of different kinds of rocks and superficial deposits, in part weathered, which were intermittently exposed during the time of retreat of the ice and submergence and emergence of the land.

Champlain Sands.

The Champlain marine sands or Saxicava sands, as they were named

[1] Merrill, G. P., "Rocks, rock-weathering, and soils," p. 323.

by J. W. Dawson, are widely but not uniformly spread over the Ottawa area. Where they do occur they usually overlie or rather form the upper portion of the marine clay, for they belong to the same general period of deposition and differ in origin from the marine clay in that they are shallow water and near shore deposits whereas the clay was deposited in somewhat deeper water. They belong chiefly to the time of emergence of the land and were deposited in the shallow waters near the shores as the sea gradually receded, being derived very largely by wave and current erosion acting along the shores and on the shallow bottom. The sands also include a small amount of delta, alluvial, and lacustrine deposits. Because of the difficulty, however, of distinguishing in the field the sands of different origin they have in the mapping been all grouped together.

The marine or Champlain sands are somewhat irregular in their distribution and are usually of no great thickness, varying from a few inches to a few feet, but in exceptional cases being as much as 40 feet thick. They are thickest and most widespread in areas where hills and ridges of glacial drift formed the shores and supplied an abundance of material easily erodible by the waves and currents. This is well shown in the areas adjacent to the ridge, composed largely of glacial drift, which extends southeastward through Bowesville and westward across Ottawa river towards Bells Corners. Along the sides of this ridge the sands are well developed and in places have considerable thickness. Sections exposed in the sand pits along Rideau river one mile south of Rideau junction show in places 40 feet of marine sand overlying marine clay (Plate VII). The sands are horizontally bedded in the lower portion, but the upper 20 to 30 feet is diagonally bedded, indicating near shore deposition. The exceptional thickness of the marine sands at this locality is evidently owing to the fact that an abundance of material was available for erosion by wave and current action and that a fairly steep under-water slope existed upon which the sands were deposited in the form of a built terrace. Marine sands forming a thin covering over the marine clay are extensive in the eastern portion of the area but over large parts of the area the marine clay appears at the surface with little or no covering of sand. This is particularly the case in the northern part of the area where, in places, the clay occurs almost up to the base of the rocky upland area, the absence of the sand being apparently due to general paucity of drift on the rocky upland areas so that little material was available for erosion by wave and current action and the sea did not stand at the high levels long enough to permit of much erosion of the bedrock. The marine sands also in places overlie the glacial deposits and in other places bedrock. In most cases they form merely a thin veneer. In general they were derived by erosion, chiefly by wave action on the glacial deposits, and, in smaller part, by erosion of the marine clays. They e formed in shallow water and their distribution was largely controlled the presence of hills and ridges of drift which were only partly submerged at the time of deposition of the sands.

The marine sands vary in character from very fine sand to coarse sand and gravel and are usually somewhat oxidized and yellow in colour. They are finest and are usually horizontally bedded in the nearly level areas where they overlie the marine clay. The near shore deposits are coarser in character and are diagonally bedded or cross-bedded.

Delta sands and gravels are only slightly developed in the Ottawa area. They were formed as sub-aqueous delta deposits and occur in small amount in some of the stream valleys in the rocky upland in the northern part of the area. In Gatineau valley, east of the river one-half mile above Wright's bridge and also one mile below the bridge there is a deposit of sand which is probably a remnant of a delta formed in the valley by the Gatineau river at a late stage during the marine submergence. Subsequent to its deposition the greater part of the deposit has been removed by stream erosion.

Alluvial sand, formed as a flood-plain deposit on some of the higher stream terraces, occurs in places but is shallow and occupies small areas. It occurs in places along Rideau river as at Rideau junction where alluvium containing freshwater fossil shells occurs at a height of 20 feet above the river. River sands, probably formed as bars, occur along Ottawa river below the city of Ottawa. Sands which appear to have been formed in this way at a time when the river flowed at a higher level occur near East Templeton, and it is possible that some of the sands along Rideau river in the vicinity of Ottawa and at Beechwood cemetery are river sands, but their mode of origin is not clearly apparent.

Lacustrine sands, formed after the disappearance of the marine waters or during the closing stages of the marine submergence when the waters had become fresh, probably also occur; for no marine fossils are known to occur in place in the sands at altitudes below about 240 feet and well-marked river terraces along the Ottawa river, at about this altitude, show that the waters in the Ottawa valley had become somewhat restricted. A lake still existed, however, in the upper part of the Ottawa River valley so that it is probable that the sands in this basin below an altitude of about 240 feet are lacustrine in origin. The altitude of 240 feet applies to the central part of the area. It becomes greater towards the north and less towards the south because of the differential uplift.

The delta, alluvial, and lacustrine sands have, in the mapping, been included in the marine deposits because of their relatively small amount and distribution and because of the difficulty of distinguishing them from the truly marine deposits.

ORGANIC REMAINS OF CHAMPLAIN DEPOSITS.

Large collections of fossils from the marine clays in the Ottawa region have been made at different times by various members of the Geological Survey and by other geologists and lists of the fossils have appeared in different publications. The most complete list is that by H. M. Ami, given in the appendix to the "Report on the geology and natural resources of the area included in the map of the city of Ottawa and vicinity," by R. W. Ells. The best known locality at which these fossils have been found is along the south shore of the Ottawa between Besserers wharf and the mouth of Green's creek a few miles down the river from the city of Ottawa. The clay contains numerous calcareous concretionary nodules from which a great variety of organic remains have been obtained. The concretions are washed from the clays by the river at high stages of water and may be collected in large numbers along the shore when the water is low. The organic remains found in the concretions include fossil fish of the genera *Cottus* and *Mallotus*, fossil shells of several species of mollusca, the bones of seals, the feathers of birds, the remains of plants, leaves, etc., a freshwater shell, and bones of a chipmunk. The occurrence of marine fossils in the clays at several other localities was also described by Ells and Ami in the above-mentioned report. During the progress of the present investigation marine fossils were found in the clays at a number of different localities. They have all, with possibly two exceptions, been previously reported as occurring in the Ottawa area so that little can be added to the already published lists of fossils and their distribution. The following notes of the occurrences and distribution of marine fossils of molluscan species are given, however, chiefly because of the significance which the fossils and their mode of occurrence have upon the questions of climatic conditions and oscillations of sea-level during the time of deposition of marine sediments, questions which do not seem to have received adequate consideration.

The marine clays exposed in sections in the lowest parts of the Ottawa River valley, at altitudes from 130 to 140 feet, contain, in places, as along the east side of Gatineau river at the Canadian Pacific Railway bridge and in the clay pits at Leamy lake fossil shells, of *Portlandia arctica* Gray (=*Leda glacialis*), *Saxicava rugosa* Lin., and *Nucula tenuis* Mont. They occur in the lower silty clay and at the base of the upper clay, but not abundantly.

A section exposed in the bed of a creek at the Canadian Northern Railway bridge one-half mile west of Orleans station shows 6 feet of the lower silty clay overlain by 10 feet of the upper clay. In the lower portion of the section at altitudes from 175 to 180 feet, *Portlandia arctica* occurs abundantly. *Macoma calcarea* Chemn., *Saxicava rugosa*, and *Natica affinis* Gmel., also occur fairly abundantly.

On the east side of Greens creek at the road crossing 2 miles east of Willowdale, a few feet of the lower silty clays, overlain by 10 to 15 feet of the upper clay, are exposed. The silty clay contains large numbers of fossil shells of *Portlandia arctica*, *Macoma calcarea*, and *Saxicava rugosa* at an altitude of about 200 feet. A few small poorly preserved forms of *Portlandia arctica* and *Saxicava rugosa* occur in the lower 2 to 3 feet of the upper clay but the greater part of the upper clay appears to be barren of fossils.

A section exposed in a ditch cutting along the flat just south of Somerset Street bridge over the railway in the western part of the city of Ottawa showed 3 feet of the lower silty clay containing abundant remains of mollusca of the species *Portlandia arctica*, *Saxicava rugosa* var. *arctica*, *Macoma calcarea*, *Macoma balthica*, *Neptunea despecta* Lin., and *Natica affinis*. *Portlandia arctica* occurs in large numbers and is by far the most abundant species. *Macoma balthica* occurs as a small thin form and is not abundant. The fossils occur at an altitude of about 190 feet. In sections exposed along the railway at this locality 6 to 10 feet of the upper clay occurs overlying the silty clay but no fossils were found in it.

Sections exposed in the Peerless brickyards south of Rideau river, near Billings Bridge, and in the Ottawa brickyard on the west side of the river near Hogsback, at altitudes from 200 to 250 feet, show abundant remains of *Portlandia arctica* in the lower silty and sandy clays but no fossils in the upper clay.

One of the best sections of the marine deposits exposed in the district is at the sand pits on the east bank of Rideau river three-fourths of a mile south of Rideau junction and about 6 miles south of the city of Ottawa. In one of the sand pits the following series of beds is exposed:

Section along Rideau River.

		Feet
1.	Diagonally and cross-bedded sand with some fine gravel and an occasional boulder. The sands contain a great abundance of fossil shells of the species *Mytilus edulis* Lin., *Macoma balthica* and *Saxicava rugosa*, the two former being the most abundant. *Balani* are also abundant and are frequently found attached to pebbles or to other shells. *Mytilus edulis* occurs at the base as well as in the middle portion of the sands and in places its remains form the larger part of a bed, many of the shells being in the attitude of growth. In places, also, the shells of *Macoma balthica* form similar beds or parts of beds and where exposed by erosion or by excavation show as glistening white beds extending for 30 feet or more along the bedding planes	28
2.	Horizontally bedded sand holding *Saxicava rugosa*	4
3.	Horizontally bedded clay with sand partings. In the lower portion the sandy layers are thicker than the clay layers. In the upper part the sandy layers are thin and the beds are mostly composed of stiff clay. The beds hold *Saxicava rugosa* in abundance but no other fossils could be found	10
4.	Stratified sand generally horizontally bedded but in places ripple-marked and containing numerous thin layers of silt and small rounded, apparently waterworn masses of silt and clay. The beds hold remains of *Portlandia arctica*, *Saxicava rugosa*, *Cylichna alba* Brown, and fragments of *Balani*	22

5.	Beds concealed	8
6.	Laminated silty clay holding scattered stones and boulders. In the upper 2 feet the beds consist of alternate sand and silt layers. The beds hold *Portlandia arctica*	12
7.	Concealed to level of water in the river	10
	Total	94

The highest part of the section has an altitude of 340 feet.

On the east side of Rideau river at Black rapids a section shows about 20 feet of stratified sands and silts which are in places folded and thrust faulted. At the northern end of the section the disturbed beds of sand and silt are underlain by undisturbed beds of laminated silty clay. At the southern end of the section above the dam the sands are overlain by the upper clay. The sands and lower silty clay contain considerable numbers of fossil shells of *Portlandia arctica*, *Saxicava rugosa* var. *arctica*, *Macoma calcarea*, *Macoma balthica*, and *Astarte compressa* Mont. They occur at altitudes from 250 to 275 feet.

Sections exposed in the Canadian Northern ballast pit three-fourths of a mile east of Bowesville show at two places a small thickness of stratified sand and silt occupying depressions in the surface of glacial and fluvioglacial deposits and overlain by marine littoral or terrace sands and gravels. The stratified sand and silt deposits are crumpled and contorted and are truncated at the top by a marine plane of erosion. They contain numerous fossil shells of *Portlandia arctica*, *Macoma calcarea*, and *Saxicava rugosa*. They occur at altitudes from about 365 to 375 feet.

The highest locality in the Ottawa area at which marine fossils are known to occur in the clay is in the stream valley leading up to Kingsmere from the east. The lower silty clays are exposed in sections at various altitudes along the bed of the creek and are in places crumpled and contorted, t[illegible]mation being probably the result of movement induced by the p[illegible] the overlying sand and gravel deposits. The silty clays contain [illegible] shells of *Portlandia arctica*, *Saxicava rugosa*, *Macoma calcarea*, and small forms of *Macoma balthica*. At one place in sandy layers included in the crumpled beds well preserved forms of *Mytilus edulis* were also found. The fossils occur at altitudes from 150 to 510 feet. The silty laminated clays also occur in the same valley up to an altitude of 605 feet, but in the upper portion they are poorly exposed and no fossils were found in them above an altitude of 510 feet. There can be little doubt, however, that they are all marine.

Fossil shells of marine species also occur in the beach deposits at numerous localities and at various altitudes. In some cases, however, the beach deposits are barren of fossils. The highest locality at which they have been found is one-half mile north of Old Chelsea at an altitude of 470 feet, the most abundant form being *Macoma balthica*. They also occur at nearly the same altitude 2 miles north of Queens park.

The shallow-water sand deposits are generally unfossiliferous over the greater part of the area. This is especially the case at altitudes below 275 feet. The general absence of fossil marine shells in these deposits at the lower altitudes may be owing to the influx of fresh water and constriction of the water bodies as the land emerged from the sea. This is borne out by the occurrence of freshwater shells in the alluvium of the higher terraces of the Rideau at Rideau junction at an altitude of 265 to 270 feet. In places, as at this locality, fossil marine shells are intermingled with fossil freshwater shells but there is no evidence that the marine and freshwater fauna lived in the same waters. The marine shells were probably derived by erosion of the marine clays and became included in the freshwater deposits, for this process may be seen going on at the present time along Rideau river. The occurrence of marl and freshwater shells, as at Mackay lake and along the ridge in Ottawa East south of the canal, at altitudes considerably above the level of the present drainage, shows that these deposits in some cases date back to the closing stage of the marine submergence or were formed after the withdrawal of the marine waters and before the present streams had eroded their channels to the present general level.

CLIMATIC CONDITIONS AND OSCILLATIONS OF SEA-LEVEL.

The fossil marine shells of molluscan species which occur in the Champlain clays of the Ottawa district are largely confined to the lower clays. The commonest and most characteristic fossil shell found in the lower clay is *Portlandia* (*Yoldia*) *arctica* Gray = (*Leda glacialis*), from the abundant o[illegible]ence of which in the clay the name "Leda clay" was given by J. W. Dawson. The molluscan fauna of the lower clays in the Ottawa area also includes *Nucula tenuis* Mont., *Macoma calcarea* Chemn., *Saxicava rugosa* var. *arctica*, *Natica affinis* Gmel., *Neptunea despecta* Lin., *Cylichna alba* Brown, and *Astarte compressa* Mont. These species of mollusca are all in European waters, high Arctic.[1] They are nearly all, however, known to be living in the colder parts of the gulf of St. Lawrence. A notable exception is *Portlandia arctica* Gray, which is not known to occur south of the strait of Belle Isle.[2] *Portlandia arctica* "now only lives in sea water at a temperature below 0 degrees Centigrade and thrives in the muddy waters discharged at the mouth of glacier streams."[3] The silty lower clays holding *Portlandia arctica* and other fossil shells of Arctic species occur in the vicinity of Ottawa at altitudes from 130 feet in the lowest portion of the Ottawa valley up to at least 510 feet above

[1] Brögger, W. C., "Om de Senglaciale og Post-glaciale Nivaforandringer i Kristianiafeltet," Norges Geologiska Undersøgelse No. 31, 1901, p. 681.

[2] Whiteaves, J. F., "Catalogue of the marine invertebra of eastern Canada," Geol. Surv., Can., 1901, p. 127.

[3] Wright, W. B., "The Quaternary Ice Age," p. 327.

sea-level, the highest locality, so far as known, being at the above-mentioned locality near Kingsmere. The fauna occurs in the lower clays most abundantly at altitudes from 175 feet up to 275 feet above sea-level.

The upper clays are generally nearly barren of fossil shells. This is especially the case in their upper portion. In the sandy layers interbedded with clay layers near the base of the upper clays, *Macoma Balthica* Lin. sometimes occurs in considerable numbers. *Saxicava rugosa* also occurs and, rarely, small forms of *Portlandia*. In general, though, the abundant and characteristic fauna of Arctic species found in the lower clays is absent in the upper clays.

The calcareous concretions from which a considerable number of the remains of plants and animals have been obtained occur in the upper as well as in the lower clays. They occur in sections exposed along Ottawa, Gatineau, and Rideau valleys and in their tributary valleys, but are not known to occur in the clays exposed in excavations as in the brickyards away from the stream valleys. They occur most abundantly in the lower portion of the Ottawa valley between Greens creek and Besserers wharf and along Greens creek, from which localities the greater number of the fossil-bearing concretions have been obtained. At these localities the concretions occur most abundantly in the upper portion of the lower silty clays and near the contact with the upper clay. They also occur, but less abundantly, in the upper clay. Where seen in place in the clays the concretions lie with their longer axis in the direction of the planes of bedding. The beds show no evidence of bulging or unevenness around the concretions which appear merely to interrupt the continuity of the bedding. It is generally held that calcareous clay concretions, such as those found in the marine clay, are formed only in the zone of cementation, above the general permanent level of the ground water, and this appears to be borne out by the mode of occurrence of the concretions in this area. Hence it is probable that the concretions were formed after the complete withdrawal of the marine waters and largely during the time since the establishment of the present drainage. The marked oscillations of ground water level in the vicinity of the streams, especially in the lower portion of the Ottawa river owing to the rise and fall of the river, would greatly favour concretionary action and would explain the apparent absence of the concretions in the clays at some distance from the river courses where the oscillations of ground water level would not be pronounced. There is little doubt that most of the concretions found along the shores of the rivers were originally in place in the clays, because considerable numbers may actually be seen in place in the undisturbed clays. It is possible, however, that some of the concretions may have been formed in clays disturbed by land slips and that they include organic remains of recent age, which became buried in the clay by reason of the land slips. Thus the occurrence of a fresh-water shell found in one of the concretions as already noted seems to bear this out. The occurrence of the bones of a chipmunk, feathers of birds, and plant remains as implying an abundant vegetation and climatic conditions nearly similar to the present is of doubtful significance. In any case this conclusion as to climatic conditions could apply only to the time of deposition of the upper clay, for the abundant occurrence of fossil shells of Arctic species in the lower clays shows that Arctic conditions of temperature prevailed at the time of deposition of the lower clays.

As the typical and common species of the lower clays have been found to live abundantly in high Arctic seas only at depths of from about 10 to 30 metres,[1] and as these clays in the vicinity of Ottawa occur at altitudes of from 130 feet up to at least 510 feet and occur abundantly at altitudes from 175 feet up to at least 275 feet above the sea, hence it is evident that the sea must have stood at a considerably lower level with respect to the land when the lower clays holding shells of Arctic species were deposited in the lowest part of the Ottawa valley than when those at high altitudes were deposited. The clays at low altitudes could not have been deposited during the time of emergence of the land, for they are overlain by the upper clay, and the occurrence of abundant remains of *Macoma balthica* in the littoral deposits in the district at altitudes of 470 feet and lower, and of *Mytilus edulis* Lin. at an altitude of at least 325 feet above the sea, and also, at one locality, at an altitude of 450 feet, shows that the climate was not high Arctic during the time of emergence of the land as *Mytilus edulis* on high Arctic shores is not a littoral shell and *Macoma balthica* is more characteristically boreal than Arctic.[2] The occurrence of the clays at high altitudes far up the Ottawa and Gatineau valleys also shows that the ice-sheet had retreated a considerable distance before emergence of the land had taken place to any great extent. Both the physical character of the clays and the character and mode of occurrence of the molluscan fauna, therefore, seem to show that the sea must have risen on the land as the ice-sheet withdrew.

This is exactly what has been shown by Brögger to have taken place in southern Norway. Brögger has held that the oscillation of sea-level was due to a depression of the land. Wright,[3] however, has pointed out that it is more probable that the sea rose on the land owing to the return to the ocean of the water which had been bound up in the ice-sheets, for the depression of the sea-level was "an absolutely necessary

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[1] Brögger, W. C., Ibid. p. 681.
[2] Brögger, W. C., Ibid, p. 693.
[3] Wright, W. B., "The Quaternary ice age."

result of glaciation" as has been shown by the investigations of Penck, Woodworth, and Daly.

The rise of the sea on the land which, apparently, took place in the Ottawa valley was preceded by uplift which affected the Great Lakes region; for the Ottawa valley must have been, in part at least, occupied by the ice-sheet during the existence of lakes Iroquois and Algonquin and at least a small amount of uplift affected the region at the foot of lake Ontario during the life of lake Iroquois.[1] Uplift also affected the northern portion of the Great Lakes region and probably included the upper Ottawa valley near Mattawa during the existence of lake Algonquin and while the ice-sheet still occupied the upper Ottawa valley.[2] No evidence is known which would suggest that depression of the land subsequently affected the northern part of the Great Lakes region or the upper St. Lawrence valley near the foot of lake Ontario. It seems improbable that depression of the land took place in the Ottawa valley during the time of the retreat of the ice-sheet from this region; for the results of investigations by numerous geologists of the raised beaches of the Great Lakes region have shown that differential uplift took place almost continuously as the ice withdrew, but probably proceeded from south to north, so that the region well outside the borders of the retreating ice-sheet was affected by uplift before the more northerly regions were affected. The evidence so far as known suggests that the rise of sea-level which, apparently, took place in the Ottawa valley was due to a return to the sea of the waters which had been bound up in the ice-sheet and was not due to depression of the land.

The fact that the initial rise of sea-level was apparently due to a return to the sea of the waters which had been bound up in the ice-sheets has an important bearing on the question of the applicability of the theory of isostacy to the late Pleistocene changes of level of land and sea and serves to establish the theory on a firmer basis. This theory ascribes the differential depression and uplift recorded by the raised or tilted shore-lines, found around the borders of the regions occupied by the Pleistocene ice-sheets, to depression of the earth's crust beneath the load of the ice-sheets and its subsequent recovery when the ice had melted away. The evidence found in the Ottawa valley strongly supports this view; for if, as seems probable, the initial rise of sea-level was not due to depression of the land but to the return to the sea of water which had been bound up in the ice-sheets, the objection to supposing that depression of the land took place during the time of retreat of the glaciers is removed. The fact, also, that the direction of maximum uplift, as shown by the trend of the isobases or lines of equal elevation of the raised beaches,

[1] Coleman, A. P., "The Iroquois beach in Ontario," Bull. Geol. Soc. Am., vol. XV, 1903, pp. 347-368.

[2] Taylor, F. B., Monograph LIII, U. S. Geol. Surv.

changes from about 20 degrees east of north in the Great Lakes region to nearly due north in the Ottawa valley, indicating a maximum amount of uplift in the region occupied by the great mass of the ice-sheet, further supports this view.

The low stage of sea-level followed by a rising stage in the Ottawa and St. Lawrence valleys during the time of withdrawal of the ice-sheets may also explain the continuance of the Trent Valley outlet channel of lake Algonquin down to the level of lake Ontario and far below the level of marine submergence in the Ontario basin.[1]

SOURCE OF THE CHAMPLAIN CLAYS.

A remarkable and puzzling feature of the Champlain clays in the Ottawa region is their great extent and thickness. In bulk they probably far exceed all the other superficial deposits and the question naturally arises whence and how were they derived. It is clear that they were not derived from stream and wave erosion of the bedrock in the valleys and along the ancient shores, for very slight erosion of the bedrock has taken place in post-Glacial time, as is shown by the frequent occurrence of striæ in the beds of the streams and by the very slight evidence of wave erosion of the rocky shores; nor was the material largely derived from erosion of the glacial deposits, for the glacial deposits, especially on the upland areas, are remarkably thin and only small amounts of bouldery deposits occur, such as would be left by any extensive erosion of the glacial drift. It has been already pointed out that the lower portion of the marine deposits consists of sandy and silty clay which is, in places, folded and contorted as if by the grounding of ice-floes or icebergs and contains glaciated stones and boulders, so that there can be little doubt that these deposits were derived from the waters of the melting ice-sheet which could not have been far distant at the time of their deposition. The lower clays form the greater part of the marine deposits but the upper clays are also widespread and have, in places, considerable thickness. They differ somewhat in origin from the lower clays for they are finer grained, contain fewer stones or boulders, and are undisturbed except where affected by landslides. They were in part derived by stream and wave erosion of land surfaces; for the evidence of the beaches and terraces shows that at least a part of the clay was derived by wave erosion of the glacial deposits and of the previously deposited marine clays. The occurrence of thick deposits of the clays opposite the mouth of Gatineau river and extending far up the valley shows that part of the clay was transported by this stream. Probably the distribution and

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[1] Gilbert, G. K., "The Algonquin river," (Abstract) Am. Geol., vol. XVIII, p. 23.
Johnston, W. A., "The Trent Valley outlet of lake Algonquin and the deformation of the Algonquin water-plane in Lake Simcoe district, Ontario," Geol. Surv., Can., Mus. Bull. 23, 1916.

deposition of the upper clay over the greater part of the area was due chiefly to the fact that during part of the period of marine submergence the whole drainage of the upper Great Lakes was by way of the Nipissing pass into the Ottawa valley.[1] Large quantities of fine sediment were, probably, transported by the great river and deposited in deeper parts of the submerged portion of the Ottawa valley. The thick deposits of marine clay occupying the depression northeast of Breckenridge evidently owe their deposition in part at least to this river for they occur in a depression which is not connected with the Gatineau valley or any other large valley coming from the north. Their position indicated that they were caught in a depression along the side of the main valley channel of the Ottawa which was largely kept free from sediment by currents. The upper clay probably owes its fineness of grain and uniform character to thorough sorting owing to transportation over considerable distances, so that only the finest materials remained in suspension and were finally deposited where current action ceased in the waters of the marine estuary. The upper clays are generally free from stones or boulders. In places, boulders do occur, however, and appear to be more numerous on the surface of the clays than within the clays. Their more frequent occurrence on the surface of the clays may be explained by supposing that as emergence of the land progressed the waters of the marine estuary became shallower and current action in the great river which occupied the Ottawa valley extended farther eastward; so that boulders, rafted by ice-floes, were transported and deposited in the upper portion or on the surface of the clays, to be later exposed as complete emergence of the land finally took place.

RIVER GRAVELS.

River gravels occur at several places along the Ottawa valley. They are most abundant in the vicinity of the city of Ottawa and occur at altitudes considerably above the present drainage channels. In places they rest upon the marine clays and contain fragmentary marine fossils derived from erosion of the marine clays. A deposit of this character occurs in the city of Ottawa on Holland avenue at the junction with the Britannia Street car line at an altitude of about 230 feet. The gravels rest upon marine clay and contain marine fossils. They are not beach deposits because they occur in a protected position where wave action must have been ineffective and they are not fluvioglacial deposits because they contain marine fossils and overlie the marine clays. Hence they are regarded as river deposits and this is confirmed by their lenticular bar-shaped form extending down stream. Similar deposits also occur in the southern part of the city at altitudes from 200 to 230 feet above the sea.

[1] Taylor, F. B., Monograph LIII, U.S. Geol. Surv.

The largest deposit and the most remarkable because of the coarseness of much of the material (Plate VIII) occurs in the city of Hull. This deposit was described by R. Chalmers[1] who suggested that the gravels owe their origin to river and river-ice action during the period of emergence of the land. These seems to be little doubt that this is the correct explanation of their mode of origin.

It is possible that the river gravels, at least in part, should be classed as Recent deposits, but the fact that they occur in places at considerable heights above the present drainage channels seems to show that they for the most part belong to the latest stage of the Pleistocene.

Recent Deposits.

ALLUVIUM.

Alluvial or flood-plain deposits of the present streams occur along Ottawa river and along its tributary streams. The deposits are most abundant in the lower portion of the Ottawa valley where there is a marked rise and fall in the river. They occur chiefly on the north side of the river owing to the fact that the river is actively eroding the south bank. The islands in the river downstream from the mouth of the Gatineau are composed largely of alluvium. They were probably at first formed as bars and were gradually built up by accretions of flood-plain deposits. In places along the north side of the river, as at Gatineau point, a low natural levee has been built along the bank of the river.

The alluvial deposits consist largely of very fine sand containing considerable organic material and are underlain in places by gravels. The sands are generally yellowish or reddish in colour and are well leached and oxidized so that they contain little calcareous material. In places the beds have a thickness of 10 to 15 feet but in general the thickness is only 6 to 10 feet. The bedding is generally poorly defined but is in places made apparent by layers of organic material or by alternations of coarser and finer material. The general absence of distinct bedding is, no doubt, owing to the fact that the successive layers were exposed to processes of weathering during periods of low water, following stages of high water when deposition took place, so that the original bedding was largely destroyed.

DUNE SAND AND BEACH SAND.

Deposits of wind-blown sand occur on the east side of Rideau river between Rideau junction and Black rapids and on the west side of the river near Merivale and extend westward from the latter locality

[1] Chalmers, R., "Report on the surface geology and auriferous deposits of southeastern Quebec," Geol. Surv., Can., Ann. Rept., vol. X, 1897, pp. 61-62J.

for several miles to the vicinity of Bells Corners. The deposits east of the river have in part at least been derived by wind erosion and transportation from the marine sands exposed in sections along the east side of the river. On the west side of the river the dune sand, in places, overlies sands and gravels of fluvioglacial origin from which it was in part derived. Owing to the prevailing westerly winds the sands have tended to move eastward and are gradually encroaching upon and overlapping the older deposits in that direction. Smaller dune areas also occur in the southeastern part of the district and are usually associated with and adjacent to exposures of marine sands or sands and gravels of fluvioglacial origin.

Beach sand occupies small areas in places along the shore of lake Deschênes.

PEAT.

Deposits of peat consisting of partly decomposed organic material occupy numerous small areas and a few comparatively large areas in the district. The largest, which occurs in the eastern part of the area, is known as the Mer Bleue bog. This bog, which contains the largest supply of fuel peat in the district, has been described by E. Nystrom and A. Anrep in Bulletin No. 1 of the publications of the Mines Branch, Department of Mines, Canada. Several comparatively large peat bogs also occur in the southeastern part of the area but in these bogs the peat is generally of small thickness.

MARL.

Marl consisting of nearly pure carbonate of lime with a varying admixture of other materials occurs at several localities in the Ottawa district. The best known locality is at Mackay (or Hemlock) lake near Rockcliffe where a deposit about 5 feet in thickness occurs at the south end of the lake. The deposit was formerly more extensive but has been largely removed. It is referred to in the Geological Survey report for 1845-46, on page 96. In the Annual Report, vol VII, 1894, p. 23R, the results of a chemical analysis of the marl are given. The largest deposit known to occur in the area underlies a part of the small swamp or bog lying just east of Gloucester station. The marl has a depth, in places, of at least 3 feet and is overlain by 1 to 3 feet of peat. It is exposed for about one-quarter of a mile in a ditch alongside the road which traverses the bog in a north and south direction, and probably underlies a considerable part of the bog. Small deposits of marl occur at other places in the area but are of slight importance.

A list of fossil shells found in the marl deposits at Hemlock lake is given by H. M. Ami in the appendix to the report by R. W. Ells, part G, Annual Report, vol. XII, 1899.

The marl contains numerous well preserved fossil shells and also fragments of shells but they do not form a large part of the deposits, which consist largely of fine impalpable powder and fine to rather coarse granular material which is apparently not composed of comminuted shell fragments. It is probable that much of the calcium carbonate owes its origin, as has been shown by C. A. Davis,[1] to concentration and precipitation by the agency of chara and other related algæ.

[1] Davis, C. A., "A contribution to the natural history of marl," Jour. of Geol., Sept.-Oct., 1900, pp. 485-503, and Sept.-Oct., 1901, pp. 491-506.

CHAPTER IV.

ECONOMIC GEOLOGY.

Soils.

GENERAL STATEMENT.

The soils of the Ottawa area are practically all drift soils, that is they are derived from superficial deposits of Pleistocene and Recent ages. These deposits, the general character and mode of origin of which have been discussed in the preceding chapter, are sometimes referred to as soils; but the term is more correctly applied to the actual cultivated layer or uppermost stratum of earth which supports plant life. The soil, or agricultural soil as it may be termed, differs from the deposits upon which it is developed in that it has been affected by processes of weathering, by the gradual accumulation in this stratum of animal and vegetable matter, and has been acted upon by life in some form, so that it is productive. The soil may be considered as including the surface soil, or soil proper and the subsoil; the surface soil consists of the uppermost portion a few inches in thickness, which is generally distinguished from the subsoil by a darker colour. The subsoil contains less organic matter and has been acted upon by organic agencies to a less extent than the surface soil. It passes down without any sharp change into the substrata which may consist either of unconsolidated or solid rocks.

On the map which accompanies this report the distribution of the various soils is shown by different colours. The colours also represent the various surface formations upon which the soils are developed. The descriptive names of the soils, e.g., sandy loam, refer to the surface soil and are based on the texture of the soils as shown by mechanical analyses, following the classification of soil material as adopted by the United States Bureau of Soils. Only the most characteristic soils of the district are shown on the map and the boundaries are approximate. The samples of surface soil mechanically analysed were taken to an average depth of 6 inches and the subsoil samples to a depth of 3 feet. In the following descriptions of the soils the surface soil is considered to extend to an average depth of 6 inches and the subsoil from 6 inches to 3 feet.

The following table shows the classification of soil material into different classes with their descriptive names:

CLASSIFICATION OF SOIL MATERIAL.

Soils Containing Less Than 20 per cent Silt and Clay.

Coarse sand	Over 25% fine gravel and coarse sand and less than 50% of any other grade of sand.
Sand	Over 25% fine gravel, coarse and medium sand, and less than 50% fine sand.

Fine sand	Over 50% fine sand, or less than 25% fine gravel, coarse and medium sand.
Very fine sand	Over 50% very fine sand.

Soils Containing 20 to 50 per cent Silt and Clay.

Sandy loam	Over 25% fine gravel, coarse and medium sand.
Fine sandy loam	Over 50% fine sand, or less than 25% fine gravel, coarse and medium sand.
Sandy clay	Less than 20% silt.

Soils Containing Over 50% Silt and Clay.

Loam	Less than 20% clay, and less than 50% silt.
Silt loam	Less than 20% clay, and over 50% silt.
Clay loam	Between 20 and 30% clay and less than 50% silt.
Silty clay loam	Between 20 and 30% clay and over 50% silt.
Clay	Over 30% clay.

The sizes of the particles of the different grades adopted and used in the mechanical analysis work are as follows:

Grade	*Diameter in millimetres.*
Fine gravel	2 to 1
Coarse sand	1 to 0·5
Sand	0·5 to 0·25
Fine sand	0·25 to 0·1
Very fine sand	0·1 to 0·05
Silt	0·05 to 0·005
Clay	0·005 to 0·0

GENERAL CHARACTER OF THE SOILS.

The soils of the district have been derived from glacial and marine deposits which are, for the most part, calcareous in character; hence the soils as a whole are somewhat calcareous, especially in the subsoil portions. The till soils are, for the most part, highly calcareous but small areas on the Pre-Cambrian upland contain little lime. The marine clay and clay loam soils, which are the most important and widespread soils, contain from 1 to 3 per cent of lime in their subsoil portions. The surface soil is usually sufficiently leached to eliminate most of the carbonate material but the small amount which it does contain together with the calcareous character of the subsoil renders the soil somewhat calcareous but not markedly so.

In general, the soils of the district have the light to medium dark colours of the soils of most timbered regions and lack the deep black colour characteristic of the prairie soils. The muck and peat soils are brown to black in colour, the dark shade being more pronounced in the muck soils in which the organic matter is more decomposed. The alluvial soils are generally dark coloured owing to the presence of abundant organic material. The æolian, river gravel, beach, and fluvioglacial soils are generally light-coloured, indicating a low organic-matter content. The marine fine sand soil is in most places light to medium dark-coloured, being low in organic matter except in places where the content of organic matter has been increased by proper methods of farm practice. The marine and glacial soils, especially in the case of the marine clay loam and clay soils, are darker coloured, ranging in colour from greyish-brown to dark brown and in places where they have a high content of organic matter they are nearly black.

The "lightest" soils of the district are the æolian, river gravel, and beach soils. They occupy small areas and, on account of the relief of the surface and open porous character of much of the material, tend to be excessively drained and are easily affected by drouth in dry seasons. The marine fine sand is also a light soil and has a loose porous structure, but on account of its nearly level or gently sloping surface and finer texture, is not so easily affected by drouth. The "heaviest" soils of the area are the marine clay and clay loam soils. The soils intermediate between the light and heavy soils are the marine fine sandy loam soil and the glacial soils, of which the most important is the gravelly fine sandy loam. These soils are also of considerable extent.

The swamp, peat, and muck soils occupy areas of considerable size and consist of organic matter in varying stages of decomposition, with which is incorporated only a small amount of mineral matter.

The alluvial soils occupy the flood-plains of the present streams and are best developed along the lower portions of the Ottawa and Gatineau rivers.

DISTRIBUTION OF SOILS.

The total area included in the Ottawa map-area is nearly 420 square miles of which 35 square miles is occupied by water. Five square miles is occupied by the cities of Ottawa and Hull in which the soils have not been mapped, leaving 380 square miles. Of this area 43 square miles have been mapped as bedrock outcrop. The portion mapped as bedrock outcrop includes small areas of agricultural soil but these areas are too small to show on the map. Over the greater part the soil covering the bedrock is very thin and in many places the bare rock outcrops. Much of the area is timbered and as a whole the areas mapped as bedrock outcrop are better adapted for cultivation of forest growth than for agricultural purposes. The following table gives the areal distribution of the different soils of the area exclusive of those portions occupied by water, the cities of Ottawa and Hull, and the bedrock outcrops.

	Square miles.
Swamp soils	
Muck and peat	22¼
Æolian soils	
Dune sand	3¼
Alluvial soils	
Fine sand	6
River gravel soils	
Stony sand	¾

	Square miles.
Beach soils	
Gravelly coarse sand	2½
Marine soils	
Fine sand	44¾
Fine sandy loam	63¾
Clay loam and clay	105
Glacial till soils	
Shale loam	35½
Stony loam	8½
Gravelly fine sandy loam	39½
Fluvioglacial sand and gravel soils	
Gravelly sandy loam	5½
Total area	337

DESCRIPTION OF SOILS.

Swamp Soils.

Muck and Peat. The muck and peat soils consist largely of organic material in various stages of decomposition, and vary in depth from 1 to 15 feet or more. The muck differs from the peat in that it contains a greater amount of mineral soil and the organic material which comprises a considerable part of it is more decomposed. The peat contains comparatively little mineral soil and the organic matter is only partly decomposed. The formation and preservation of the peat is owing to the presence of the ground water near the surface. Drainage, by lowering the water level, brings about atmospheric oxidation and decomposition of the peat and tends to produce a mucky soil. In areas covered by 1 to 3 feet of peaty material it has been found that after drainage and cultivation the peat largely disappears; for the bulk of the peat is greatly reduced by oxidation and when mixed with the undersoil forms a rich mucky soil. In the Ottawa district the muck areas are small and in the mapping have not been distinguished from the peat areas. Small areas in the vicinity of Ottawa, which have been cultivated, and narrow strips around the larger bogs are mucky in character. Peat forms the surface soil in the greater portion of the swampy areas. Along Carp Stream valley, the surface soil is mucky in character owing to the inclusion in the peat of mineral soil by overflow of the stream.

Peat, with included areas of muck, is distributed in areas of varying size throughout the district. The largest area is that occupied by the Mer Bleue peat bog in the eastern part of the area. Other comparatively large areas occur in the southeastern part near South Gloucester and Greely.

The surface of the peat marshes is for the most part nearly level and the natural drainage is very deficient. Some of the small areas occupy natural depressions which have no visible outlet but for the most part the bogs occupy areas which are so nearly level that the natural drainage is deficient and swampy conditions prevail. In places small areas of peat occur, as near Black rapids, on relatively steep slopes near the base of a hill where springs issue. In nearly all cases the bogs have at least a slight slope so that artificial drainage is possible.

The peat of the Mer Bleue bog, the largest of the peat areas, is underlain for the most part by marine clay or clay loam. The marine clay also forms the subsoil in Carp River valley. The peaty areas in the southeastern part of the district are underlain chiefly by fine sand. In places also as in the bog near Gloucester station the peat is underlain by marl.

The peat has been largely formed by the gradual accumulation of vegetable matter in swamps and shallow ponds and hence contains only a small amount of mineral soil. On this account it is deficient in some of the mineral elements necessary for the growth of plant life, potassium being the element in which it is likely to be most deficient. The peat contains a large amount of nitrogen, one of the most important elements required for the growth of plants, but the nitrogen in peat is largely in a form not available to plants. In order to render the nitrogen available it is necessary to convert the peat, at least in part, into humus. This is partly accomplished by drainage, cultivation, and aeration of the soil. The process is greatly aided by liming to correct the generally acid character of the peat and by applications of manure. Where the peat is thin and has been mixed to some extent by cultivation with the underlying sand or clay, or where the peaty material contains a sufficient amount of mineral matter, a muck soil is produced which is usually highly productive. Where the peat is thick it is of low agricultural value and requires the use of fertilizers to render it productive. It has been found that peat has in places been rendered productive by the application of a thin top dressing of mineral soil or earth. This top dressing is most effective if taken from the surface soil of fields in which leguminous plants have been grown. This surface dressing, however, tends to pass downward into the peat and requires renewal from time to time.

Aeolian Soils.

Dune Sand. The largest areas occupied by dune sand are on the east side of Rideau river near the Hunt club and on the west side extending from the vicinity of Merivale westward for several miles. Other small areas occur in the southeastern part of the district.

The dune sand soils are of little agricultural value chiefly because, if cultivation is attempted, the sand is likely to drift. In places where a forest covering has been maintained the sand does not blow out, but where the trees have been removed and cultivation carried on or where the areas have been pastured too severely, the sod originally formed under natural conditions is destroyed and "blow outs" occur. On account of the prevailing westerly winds the dune sand in the Ottawa area tends to drift towards the east and in places, as in the vicinity of Merivale, is overlapping upon and destroying good agricultural land. It has been found that one of the most effective means of checking the drift of the sand is by mixing small amounts of clay with the surface soil and planting willows to act as a wind break.

Included under dune sand are small areas of beach sand, partly wind blown, along the shores of lake Deschênes. The areas are of very small extent.

Alluvial Soils.

Fine Sand. Alluvial fine sand forms the soil in areas along the lower portions of Ottawa, Gatineau, and Rideau rivers. Small areas also occur on the lowest terraces of some of the tributary streams, but these areas are generally too small to be shown on the map.

The surface soil usually consists of reddish-brown, fine sand which is well leached and oxidized but contains in most places considerable organic material. The subsoil for the most part consists of fine sand, but, in places, the marine clay forms the subsoil. The subsoil is somewhat lighter in colour than the surface soil. In places the subsoil as well as the surface soil contains considerable organic material.

The areas have all been subject to overflow by the streams during stages of high water. During recent years the areas along Ottawa and Gatineau rivers have not been subjected to floods so often as in former years owing to the more efficient control of the upper waters of these streams.

The following table gives results, in percentages, of mechanical analyses of typical samples of the soil and subsoil of the alluvial fine sand:

Mechanical Analyses of Alluvial Fine Sand.

Soil	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Surface	0·0	0·3	0·9	39·7	48·9	9·8	0·2
Subsoil	0·0	0·1	0·3	18·7	64·2	16·4	0·3

River Gravel Soils.

Stony Sand. The surface soil consists of reddish-brown or yellowish sand containing stones and occasional boulders. The subsoil consists of yellowish sand with stones and boulders. In places the soil is very stony and contains such a small amount of fine material that it is of little agricultural value. In places the soil is gravelly rather than stony and contains a higher percentage of fine material.

The largest area occupied by the river gravel soils is in the vicinity of the city of Hull. Other small areas occur along Ottawa and Rideau rivers in the vicinity of Ottawa. The total area is small, being only about three-fourths of a square mile.

The surface of the areas occupied by this soil is usually in the form of low ridges. Because of the relief of the surface and the character of the material forming the soil, the natural drainage is excessive and the soil is easily affected by drouth.

Beach Soils.

Gravelly, Coarse Sand. The surface soil of the beach soils consists for the most part of reddish-brown, coarse sand containing a greater or less proportion of gravel. The subsoil consists of lighter-coloured, coarse sand with gravel and in places a large proportion of coarse gravel or boulders. The soil in most places contains a low percentage of organic material.

The beach soils occupy small areas scattered throughout the district, the total area being about 2½ square miles. The surface is in the form of low and relatively long, narrow ridges. Because of the ridged surface and loose porous character of the material composing the soil, the natural drainage is usually excessive and the soil is easily affected by drouth in dry seasons.

Marine Soils.

Fine Sand. The surface soil of the marine fine sand soil consists for the most part of reddish-brown or brown, fine sand containing in places a small amount of gravel but generally nearly free from stones or boulders. The subsoil consists of yellowish, fine sand or sandy loam generally free from stones or boulders. In places the surface soil consists of coarse sand or sand, the subsoil in most places being fine sand. The surface soil is well leached and oxidized and contains little or no lime. It is generally low in organic matter except in the poorly drained areas and where the content of organic matter has been maintained and increased by proper methods of farm practice.

The fine sand areas occur throughout the district and are most widespread in the southeastern portion. They have a total area of 44¾ square miles.

The surface for the most part is nearly level or gently sloping. In places in the southeastern part of the district the natural drainage of part of the fine sand areas is poor owing to the nearly level surface, but over the greater part of the areas the surface is naturally drained. Owing to the nearly level surface the soil is not so readily affected by drouth as the beach sand soils.

The following table gives results, in percentages, of mechanical analyses of typical samples of the soil and subsoil of the marine fine sand:

Mechanical Analyses of Marine Fine Sand.

Soil	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Surface	0·8	6·6	13·6	40·3	30·1	6·8	2·0
Subsoil	0·0	0·8	2·7	33·3	55·4	5·0	3·0
Surface	1·8	10·2	35·1	25·8	9·5	15·5	2·0
Subsoil	1·6	10·1	19·5	7·8	29·9	24·0	7·1

Fine Sandy Loam. The surface soil of the marine fine sandy loam consists for the most part of reddish-brown or brown, fine sandy loam generally free from stones or boulders. The subsoil consists of grey to brown clay loam or clay. In places, the surface soil consists of fine sand, sandy loam, or loam which is underlain at a varying depth by clay loam or clay. The depth of the surface sandy material is usually only a few inches but in places is 1 to 1½ feet. It usually becomes progressively finer downwards and merges into the underlying clay loam or clay. The subsoil becomes lighter in colour and finer in texture with depth and grades into a brownish-grey or grey, sticky clay which is very retentive of moisture. The soil is for the most part slightly calcareous, especially in the subsoil portion. The content of organic matter is generally higher and is more easily maintained than in the sandier soils.

The marine fine sandy loam occupies areas of considerable extent throughout the district. The largest areas occur in the southeastern portion. The total area is 63¾ square miles.

The surface is nearly level or gently sloping, but the natural surface drainage is generally adequate. In places, because of the heavy subsoil, the under drainage is somewhat deficient. Owing to the nearly level surface and fine-grained character of the soil, especially in the subsoil portion, the soil is not readily affected by drouth. The somewhat sandy and friable nature of the surface soil renders the soil easily worked, and this together with its other properties makes it one of the most important soils in the district.

The following table gives results, in percentages, of mechanical analyses of typical samples of the soil and subsoil of the marine fine sandy loam:

Mechanical Analyses of Marine Fine Sandy Loam.

Soil	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Surface	2·6	3·9	7·1	30·5	19·1	27·0	6·8
Subsoil	0·3	1·2	2·3	5·9	3·0	37·0	50·3

Clay Loam and Clay. The surface soil of the marine clay loam and clay consists of greyish-brown to dark brown clay loam or clay generally free from stones or boulders. The subsoil consists of grey to brown clay which becomes lighter in colour and finer in texture in the lower portion. The results of mechanical analyses of several samples of the surface soil show that it usually contains from 28 to 35 per cent of clay with a large percentage of silt. Hence the soil varies between a clay loam and a clay the distinction between which cannot readily be detected in the field. In places the surface soil contains as high as 45 per cent of clay. These areas are confined chiefly to the lower terraces along Ottawa river. In general the surface soil is not an especially heavy clay soil and usually contains a sufficient amount of silt and fine sand to render it somewhat friable when dry, but it is sticky when wet. The subsoil contains a higher percentage of clay than the surface soil and is very sticky when wet and highly retentive of moisture. The subsoil is remarkably uniform in its fine-grained character and in the small amount of material coarser than silt or clay which it contains. The soil is slightly calcareous, especially in the subsoil portion which usually contains from 1 to 3 per cent of lime, the surface soil containing somewhat less.

The marine clay loam and clay are the most extensive soils in the district. Large areas occur along Gatineau and Ottawa rivers, in the northwest part near Breckenridge, and in the southern part along Rideau river. Smaller areas also occur throughout the district. The total area is 105 square miles.

The surface is nearly level or gently sloping, except where trenched by stream valleys. In places the general even surface is interrupted by terraces. The surface for the most part has a slight slope and the natural surface drainage is adequate, but, in places, owing to the very slight surface slopes and absence of stream valleys, the surface drainage is poor. Owing to the slight surface slopes and fine-grained and only slightly pervious character of these soils, especially in the subsoil portions, the under drainage is generally somewhat deficient.

The marine clay loam and clay soils are the most important in the district. They are naturally more highly productive than the lighter soils but are more difficult to work and can be worked with best results only within limited periods of time. If worked when too wet the soil tends to puddle or run together forming clods. If the soil is worked when too dry, clods tend to form by baking. Hence the clay loam and clay soils can only be worked to best advantage when the soil is neither too wet nor too dry. The physical condition and working qualities of the heavy soils are greatly improved by liming and by increasing the organic matter content, which tend to promote granulation of the soil, and by under drainage.

The following table gives results, in percentages, of mechanical analyses of typical samples of the soil and subsoil of the marine clay loam and clay.

Mechanical Analyses of Marine Clay Loam and Clay.

Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Surface soil.....	1·7	2·0	2·0	5·4	16·4	43·7	28·7
Subsoil..........	0·4	0·6	1·2	5·8	12·8	44·0	35·0
Surface soil.......	1·8	4·1	3·8	3·4	8·5	37·0	41·4
Subsoil....	0·8	3·1	3·5	3·1	8·8	36·7	44·4

Glacial Till Soils.

Shale Loam. The surface soil of the areas mapped as shale loam consists, for the most part, of brown or dark brown loam containing in places small amounts of stones and boulders, and is underlain, at varying depths, by partly disintegrated shale or limestone. In places the depth of soil over the bedrock is only a few inches and usually does not exceed 2 feet. In the areas underlain by limestone, the bedrock is usually somewhat disintegrated and fragments of the rock are more or less mixed with the soil which is thus partly composed of disintegrated portions of the bedrock and partly of drift materials. In the areas underlain by shale, small fragments of the shale, in places, form a large part of the soil. Where the soil is of sufficient thickness and the underlying rock is somewhat decomposed the soil is usually highly productive. In small areas east of the city of Ottawa the surface soil is heavier and is underlain by a stiff waxy clay formed by the disintegration of the underlying shale. The subsoil is only slightly pervious to water and requires artificial drainage to make the soil productive. In small areas also sandstone or sandy shale underlie the surface soils. In these areas the soil is of little value. As a whole the soils are affected by the nearness to the surface of the bedrock and tend to be droughty in dry seasons. They are most productive where underlain by disintegrated shale or limestone.

The total area occupied by shale loam is 35¾ square miles.

Stony Loam. The surface soil of the stony loam consists for the most part of brown loam containing considerable quantities of stones and boulders underlain by stony loam or bedrock. The areas are usually too stony to be of value for agricultural purposes except for grazing, and are best adapted for the cultivation of forest growth. Small areas in the vicinity of the city of Ottawa from which the greater part of the stones and boulders have been removed have been brought under cultivation but the greater part of the areas forms "waste land."

The total area occupied by the stony loam is 5½ square miles.

Gravelly Fine Sandy Loam. The surface soil of the gravelly fine sandy loam of the glacial till consists for the most part of greyish-brown to dark brown, fine, sandy loam containing varying amounts of gravel, stones, and boulders but usually not in sufficient amount to seriously interfere with agriculture. The subsoil consists of grey to greyish-brown, compact, fine, sandy loam containing stones and boulders in varying amounts. In places the surface soil is nearly free from stones and approaches in general character the marine clay loam soil but is generally more friable and contains less clay. The till soils throughout the area, except in the northern portion, in the upland area usually contain large quantities of limestone and are the most highly calcareous soils of the district. In places a thin covering of marine sand occupies the surface and the surface soil is sand or sandy loam.

The areas occupied by the gravelly fine sandy loam of the glacial till occur scattered throughout the greater part of the district. The total area is 39½ square miles.

The surface for the most part is slightly rolling or sloping. In places low ridges or irregularly-shaped hills occur, but the relief is generally low. Over the greater part of the areas the surface is naturally drained and artificial drainage is not required except rarely where small basin-shaped depressions occur.

The following table gives results, in percentages, of mechanical analyses of typical samples of the soil and subsoil of the gravelly fine sandy loam of the glacial till.

Mechanical Analyses of Gravelly Fine Sandy Loam.

Soil	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Surface..........	1·8	2·4	3·3	27·0	29·9	24·2	11·3
Subsoil..........	0·6	1·8	2·5	21·0	36·8	24·6	12·5

Fluvioglacial Sand and Gravel Soils.

Gravelly Sandy Loam. The surface soil of the fluvioglacial sand and gravel soils consists, for the most part, of yellowish to reddish-brown sandy loam containing a considerable proportion of fine to coarse gravel with some boulders. The subsoil consists of yellowish or grey sandy loam containing varying amounts of gravel and boulders. In places the surface has a thin covering of marine sand and the soil varies from sand to sandy loam. In places also the subsoil is variable but is usually somewhat finer and more compact than the surface soil. The surface soil is well oxidized and leached and contains little or no lime but the subsoil is usually calcareous. The soil is, for the most part, low in organic matter, the maintenance of which is difficult on account of the loose open structure of the soil.

The gravelly sandy loam areas are small and are confined largely to the southeastern part of the district. They have a total area of 5½ square miles.

The surface for the most part is sloping or uneven and is naturally well-drained. Owing to the relief and open porous character of much of the material the soil, in places, tends to be excessively drained and is easily affected by drouth. Where the subsoil is more compact and consists of finer material the soil is not so readily affected by drouth.

Brick and Tile Clays.

The marine clays of the Ottawa district are used for the manufacture, by the soft mud process, of common red brick. They have also been used in the manufacture of Portland cement at the works of the Canada Cement Company near Hull, Quebec. Bricks are manufactured at several brickyards in the vicinity of Ottawa and Hull. Two brickyards are located near Hull, one along the Chelsea road north of Hull and the other north of the Aylmer road near Br view. Three are located near Ottawa, one south of Rideau river ne Billings Bridge, and two close together on the west side of Rideau anal near Hogsback. The clay deposit and method of manufacture of the brick at the brickyard on the Chelsea road have been described by J. Keele in the "Preliminary report on the clay and shale deposits of the province of Quebec," Memoir 64, Geol. Surv., Can., Ottawa, page 53. The clay deposits and method of manufacture of the brick at the brickyards near Ottawa have been described by M. B. Baker in the Report of the Bureau of Mines, 1906, vol. XV, part II, "Clay and the clay industry of Ontario," pp. 60-61

Deposits of marine clay which can be utilized for the manufacture of common brick and field drain tile are of widespread occurrence in the Ottawa district. Their distribution is shown on the map which accompanies this report. Their general character is very similar in most of the sections exposed. The upper portion, usually to a depth of 5 to 10 feet, consists of a uniformly fine-grained, plastic clay, the top 1 to 3 feet being somewhat oxidized. In places the upper clay is overlain by a greater or less thickness of sand. The upper clay is underlain by 2 to 10 feet and in places by a greater thickness of sandy clay or sand and silt which passes downwards into blue silty clay usually of considerable thickness. The three clays are referred to by the brickmakers as the strong, the mild, and the blue. The upper "strong" clay is too uniformly fine-grained and plastic to be utilized alone for the manufacture of brick and a mixture of the three clays is commonly used or the upper clay is mixed with sand. The marine clays burn to a red brick. They are impure and readily fusible, so that no higher grade of structural wares than common brick or field drain tile can be made from them.

Numerous localities at which the clays are available for the manufacture of brick and tile occur in the Ottawa district. The following is a report by J. Keele of this department on a typical sample of the upper clay from one locality at the foot of Graham bay. At this locality 5 to 10 feet of the upper strong clay is exposed and is underlain by the lower silty clay.

"*Lab. No. 387.* Grey clay from section at Graham bay, ¼ mile east of mouth of Stillwater creek and 1½ miles southwest of Boat Club wharf at Britannia. This material requires 30 per cent water to bring it to the best working consistency, and in this condition is very plastic and smooth, inclined to be pasty, but otherwise has good working qualities. This clay must be dried slowly after moulding to prevent it from cracking. The shrinkage in drying is excessive, being about 10 per cent, but the addition of sand would reduce this, and also help in drying. When burned to cone 010 the clay has a good red colour and hard body, with an absorption of 15 per cent. If burned to cone 06 a better red colour and harder body is obtained, but the shrinkage is increased. If burned to still higher temperature the shrinkage becomes excessive and the material overfired and probably softened. This clay is suitable for the manufacture of common building brick or field drain tile. In practice, it will be necessary to add from 20 to 30 per cent sand. The commercial limits of burning vary between cone 010 and 07 (1742 to 1850 degrees F)."

Sands and Gravels.

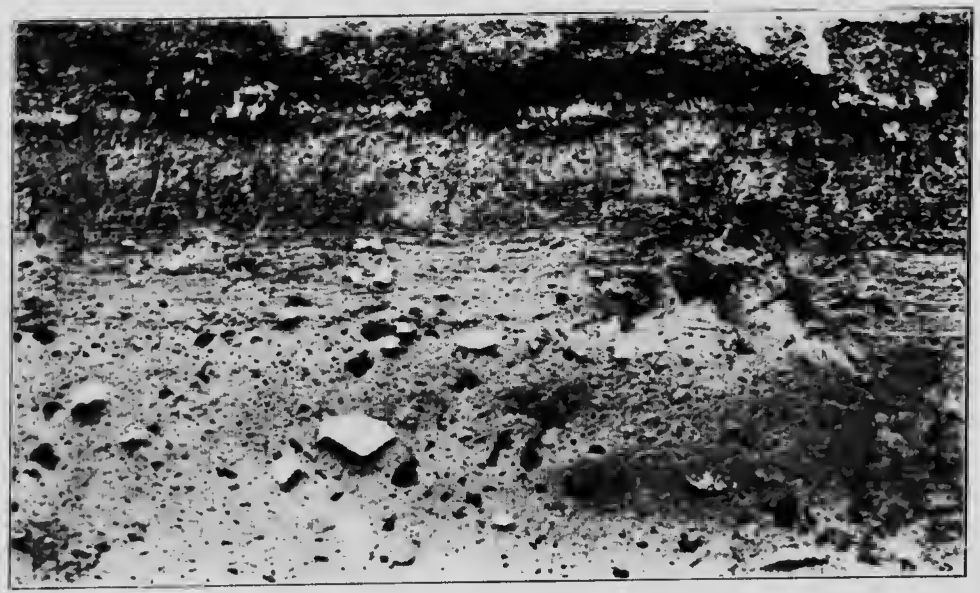
Sands and gravels used for ballast and for various structural purposes occur in the river gravel and alluvial deposits along Ottawa river and in the beach, marine sand, and fluvioglacial deposits at various places throughout the district. The largest ballast pit in the district is that worked by the Canadian Northern railway near Bowesville. At this locality the upper 1 to 4 feet of the deposit is composed of marine sands and gravel, the gravel being mostly coarse and containing in places large boulders. The marine gravels are underlain by sands and gravels of fluvioglacial origin which are extremely variable in character. The greater part of the deposit consists of fine to coarse sand. In places irregularly shaped lenses of gravel occur and, occasionally, masses of boulder [illegible] clay, and boulders. In places, also, coarse to fine gravel [illegible] considerable part of the deposit but the gravel deposits are irregularly distributed. Material of this general character, overlain by a gr[illegible] thickness of marine sands and gravels appears to form the greater part of the ridge extending southeastward from near Bowesvi[illegible]r large deposit of gravels of similar origin are known to occur [illegible]ssibly, in the case of the irregularly-shaped [illegible] Gatineau river near Wright's bridge, which, [illegible] a few small test pits, appear to be composed largely [illegible]. A large deposit of river gravels composed chiefly of very coarse gravel occurs in the city of Hull, and numerous small deposits of various origin occur throughout the district.

Sands used for various structural purposes are obtained chiefly from the marine sands which are found in large quantity, and are easy of access, along the east bank of Rideau river between Rideau junction and Black rapids. These sands are yellowish or yellowish-grey in colour and in places contain numerous fossil shells. Sands are also obtained, as at the sand pits south of Rideau river one-fourth mile east of Bank street, Ottawa, and at various localities in the district, from the fluvioglacial sands which are in places overlain by a small thickness of boulder clay. These sands are somewhat variable in character, varying from coarse to fine, and are usually grey in colour. Sand is also obtained from the alluvial sand deposits on the islands and sand bars of the lower portion of Ottawa river. These sands are more uniformly fine-grained than the sands of the other deposits.

PLATE II

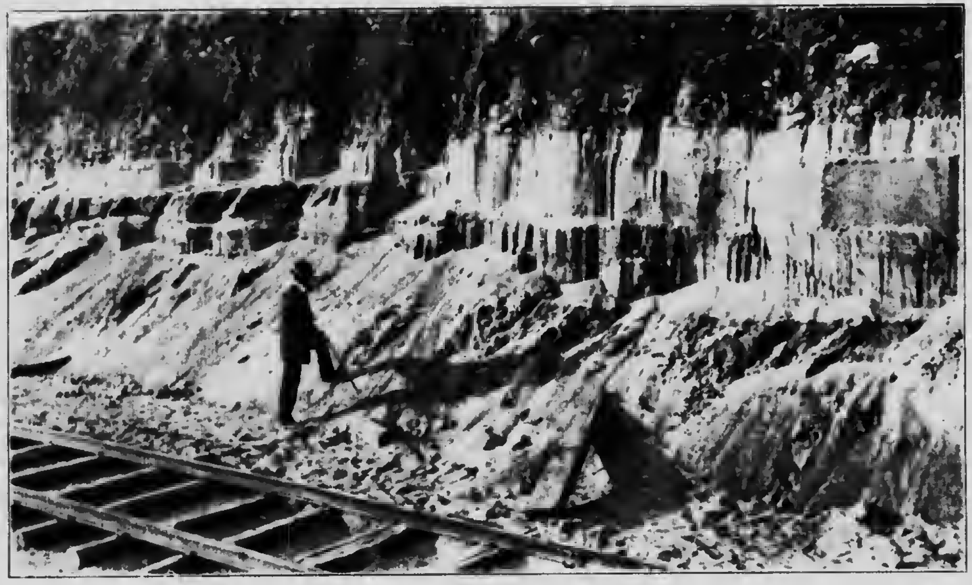
Rounded face of escarpment, excavation for new Customs building, Sussex street, Ottawa.

PLATE III.



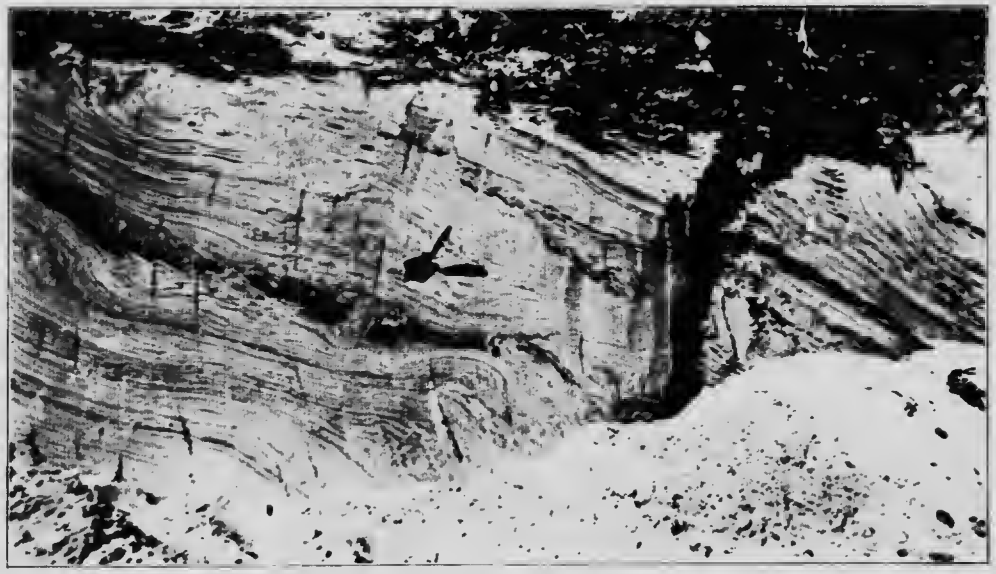
Contact of till and overlying laminated marine silty clay, Albert and Kent streets, Ottawa.

PLATE IV.



Fluvioglacial sands and gravels overlain by marine gravels, Canadian Northern ballast pit near Bowesville, Ont.

PLATE V.



Minutely folded sands of fluvioglacial origin, Canadian Northern ballast pit near Bowesville, Ont.

PLATE VI.

Crumpled and contorted Champlain (marine) silts, bed of Chelsea brook, 1 mile east of Kingsmere, Que.

Section of 40 feet of Champlain (marine) sands, sand pit on east bank of Rideau river three-quarters mile south of Rideau junction.

PLATE VIII.

Coarse river gravels, Hull, Que.

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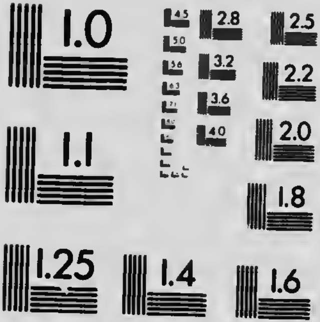
MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



SOILS

LEGEND

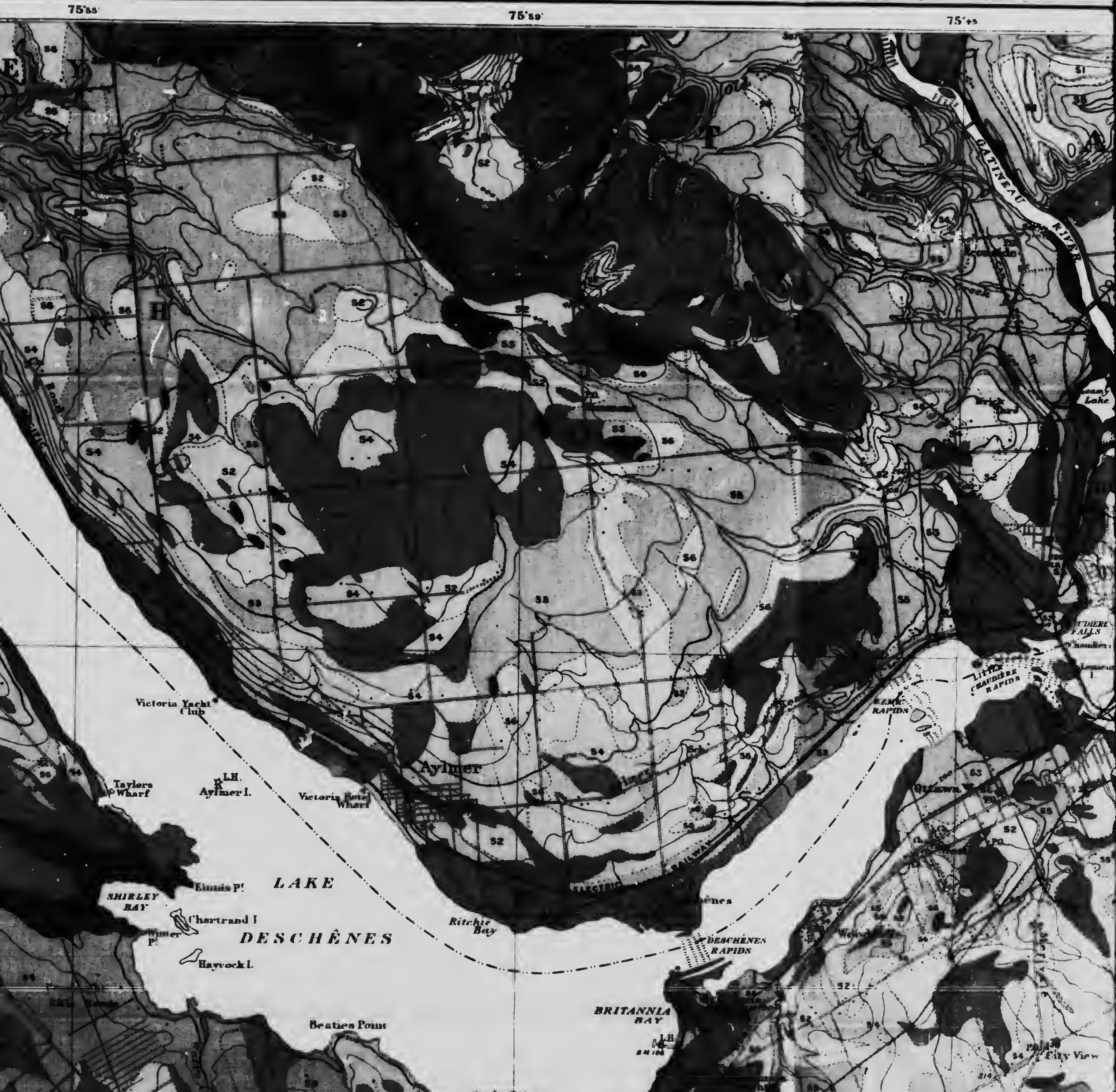
Period		Unconsolidated Rocks *upon which the soils are developed.*	Soils
QUATERNARY	RECENT	Muck and peat *swamp deposits*	**Muck and peat** *Chiefly organic material. One foot or more in thickness.*
		Dune sand and beach sand *Chiefly wind blown deposits.*	S11 **Dune sand and beach sand** *Chiefly fine to coarse sand of little agricultural value*
		Alluvial sand and silt *Flood plain deposits of present streams*	**Fine sand** *Underlain by fine sand.*
		River gravels	**Stony sand** *Underlain by stony sand*
	PLEISTOCENE	Beach sand and gravel *Littoral deposits of Champlain Sea, includes some fresh water deposits*	**Gravelly coarse sand** *Underlain by gravelly coarse sand.*
		Marine sand, silt, and clay *Stratified delta, terrace, and sea bed deposits of Champlain Sea, includes some lacustrine and alluvial deposits.*	**Fine sand** *Underlain by fine sand or sandy loam.*
			S6 **Fine sandy loam** *Underlain by clay loam or clay.*
			S5 **Clay loam or clay** *Underlain by clay*
			S4 **Shale loam** *Underlain by partly disintegrated shale or limestone.*
		Glacial till and boulder clay *Unstratified deposits chiefly in the form of ground moraine of Labradorean Glacier; Wisconsin stage of glaciation, includes a small amount of marine and lacustrine deposits and disintegrated bedrock*	S3 **Stony loam** *Underlain by stony loam or bed rock.*

Canada
Department of Mines

ÉVIGNY ACTING ...

GEOLOGICAL SURVEY

Issued 1917

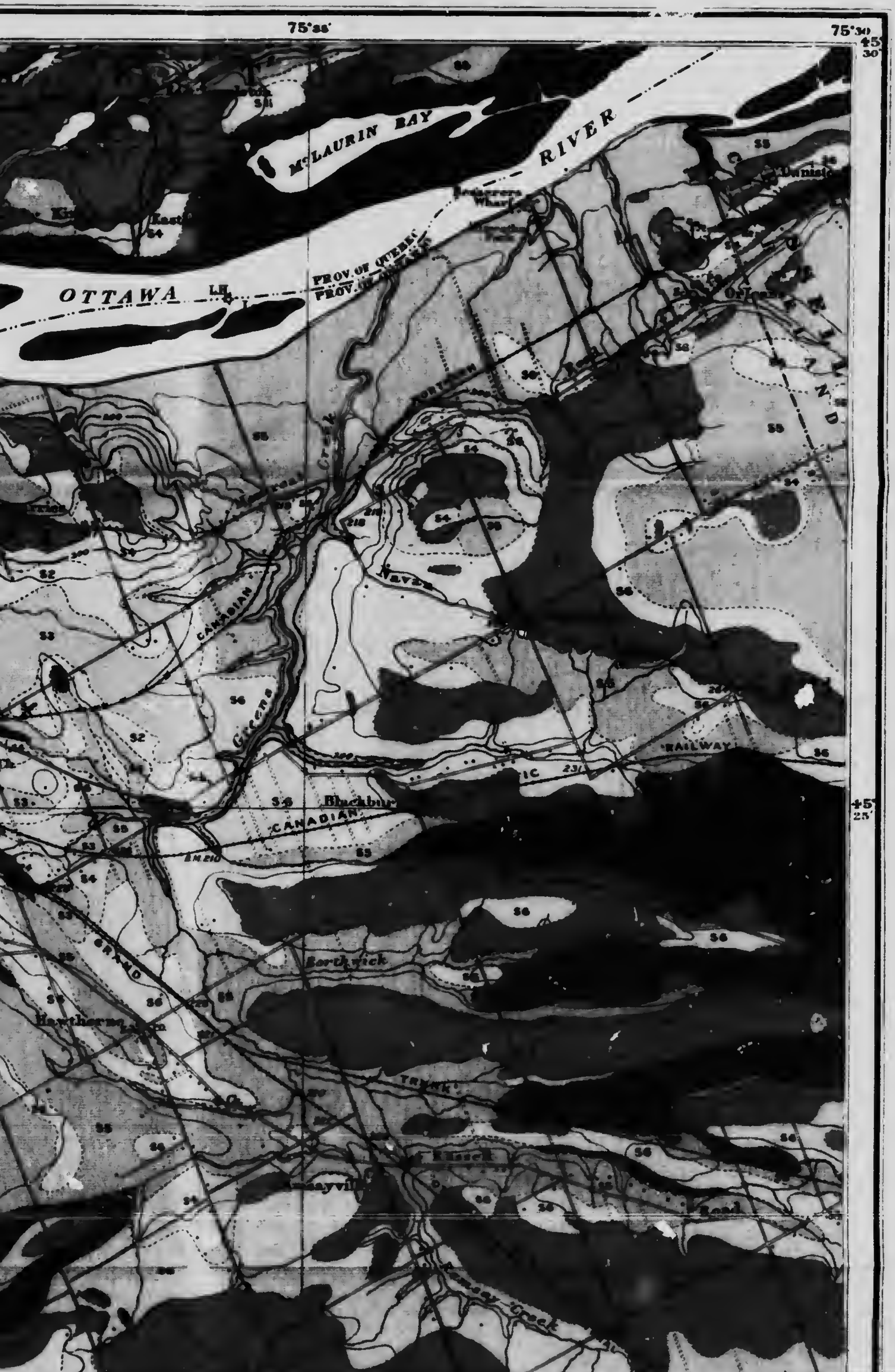


Canada
Department of Mines

A. S[illegible], Acting Minister; [illegible], Deputy Minister

GEOLOGICAL SURVEY

Issued 1917



LEGEND

Culture

Streets, roads and buildings

Roads along township boundaries

Railways

Bridges

+ Ch.
Churches

• Sch
Schools

• P.O.
Post Offices

Cemeteries

Quarries

Wharves

Dams

Locks

Ferries

L.H.

PLEISTOCENE

S5 — **Clay loam or clay**
Underlain by clay

S4 — **Shale loam**
Underlain by partly disintegrated shale or limestone.

Glacial till and boulder clay
Unstratified deposits chiefly in the form of ground moraine of Labradorean Glacier; Wisconsin stage of glaciation includes a small amount of marine and lacustrine deposits and disintegrated bedrock

S3 — **Stony loam**
Underlain by stony loam or bed rock.

S2 — **Gravelly fine sandy loam**
Underlain by gravelly fine sandy loam.

Fluvio glacial sand silt and gravel
Stratified sub glacial and marginal outwash deposits of Labradorean Glacier; Wisconsin stage of glaciation; includes some sandy till and marine sand

S1 — **Gravelly sandy loam**
Underlain by gravelly sandy loam

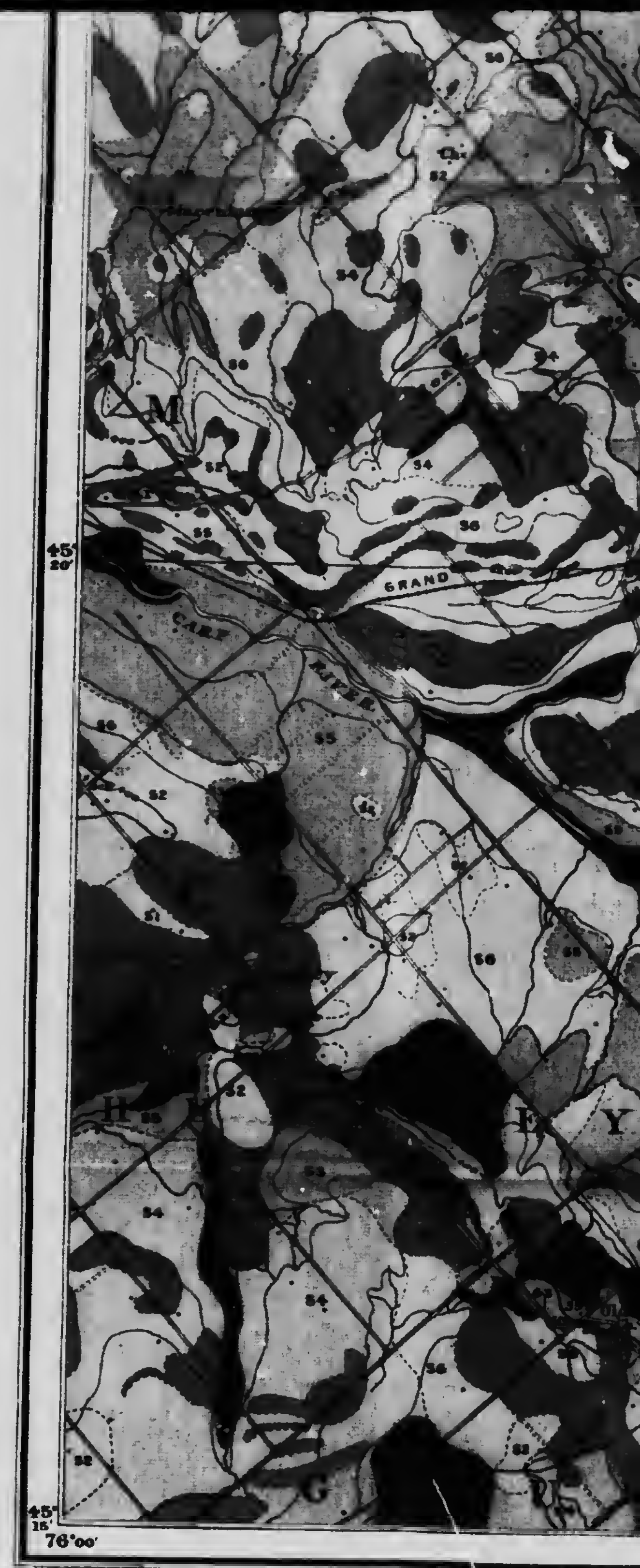
Bedrock outcrop
Little or no soil covering.
(Areas of low agricultural value; better adapted to forest cultivation.)

Symbols

Geological boundary

Glacial striae

Note: Clay for making bricks occurs in marine clays, gravel for road material, ballast, and concrete in river gravels, beach deposits, and fluvio glacial deposits, sand for making sand lime bricks and for structural purposes in marine sand, beach deposits, and fluvio glacial deposits, peat for fuel in peat bogs.



C.O. Senécal, *Geographer and Chief Draughtsman.*
A. Braidwood, *Draughtsman.*

To accompany Memoir by W.A. Johnston.

OTTAWA

CARLETON AND OTTAWA COU

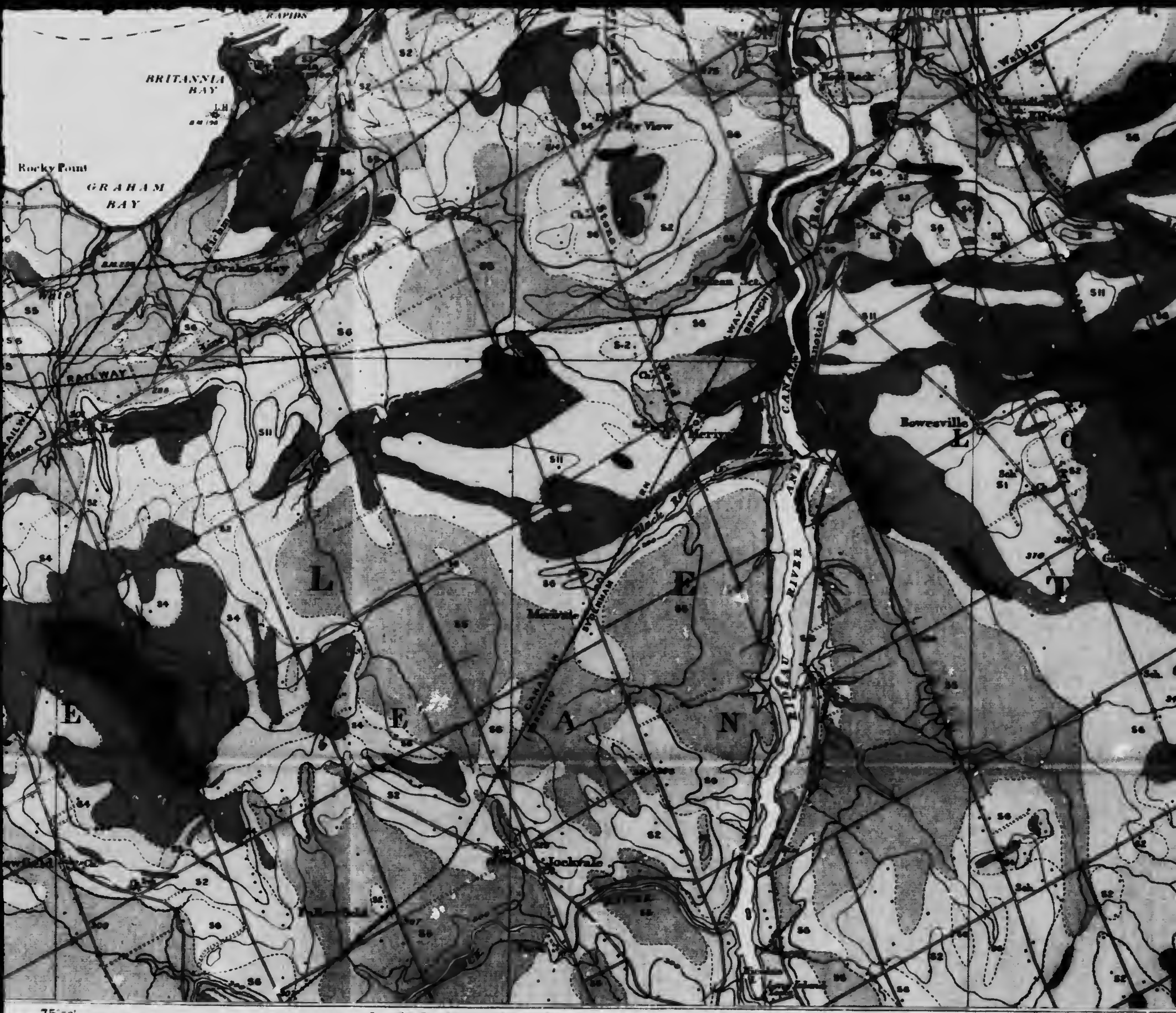
ONTARIO AND QUEBEC

Scale

Miles

Kilometres

1 MILE TO 1 INCH



OTTAWA

CARLETON AND OTTAWA COUNTIES

ONTARIO AND QUEBEC

Scale $\frac{1}{63,360}$

Miles

Kilometres

1 MILE TO 1 INCH

Based on a map published by the Department of Militia and Defence.

Publication Nº 1662

GEOLOGY

W.A. JOHNSTON 1915