Cahiers de géographie du Québec

Raised Shorelines and Drainage Evolution in the Montréal Lowland

Joyce Brown MacPherson

Volume 11, Number 23, 1967

URI: https://id.erudit.org/iderudit/020731ar
DOI: https://doi.org/10.7202/020731ar

See table of contents

Publisher(s)

Département de géographie de l'Université Laval

ISSN

0007-9766 (print)
1708-8968 (digital)

Explore this journal

Cite this article

MacPherson, J. B. (1967). Raised Shorelines and Drainage Evolution in the Montréal Lowland. *Cahiers de géographie du Québec*, *11*(23), 343–360. https://doi.org/10.7202/020731ar

Article abstract

La rive la plus élevée de la mer Champlain, qui a envahi les Basses-Terres du Saint-Laurent après la dernière glaciation, a été identifiée à une altitude de 750 pieds au nord de Montréal, et de 525 pieds au sud. Une rive plus récente parcourt toute la région à une altitude uniforme de 100 pieds. Les rivages intermédiaires résultent de pulsations variables de la mer, mais leur répartition et leur nature même rendent difficile la corrélation du niveau des eaux par des méthodes statistiques. Cependant, la preuve est maintenant établie qu'il est possible de localiser les niveaux intermédiaires par l'analyse du pollen. L'accumulation de sédiments renfermant du pollen est plus ancienne dans les secteurs les plus élevés, évacués les premiers par les eaux, et les échantillons positifs tirés de tourbières choisies permettent d'établir les différentes altitudes des surfaces séparant ces tourbières qui se sont développées dans les zones anciennes et plus récentes recelant du pollen. La surface séparant les tourbières datant de la zone IV de pollen (récente) de celle de la zone V (plus ancienne) a été remaniée et se situe à 230 pieds d'altitude au nord de Montréal et à 170 pieds au sud. La déclivité nord-sud de cette surface est de 1.25 pied au mille, ce qui correspond à une rive bien déterminée à une altitude équivalente. Dans la basse vallée de l'Outaouais. Une preuve plus poussée de la validité de la méthode est fournie par la nature horizontale de la surface séparant les tourbières datant des zones de pollen n° III et IV, à la même altitude que la ligne de rivage de 100 pieds. Un rivage inférieur, par exemple à une altitude de 50 pieds, ne peut être daté selon cette méthode.

Les noms de *Rigaud, Montréal* et *Saint-Barthélémi,* sont proposés pour nommer les rives s'élevant respectivement à 200, 150 et 50 pieds d'altitude. Au stade « Rigaud », les eaux envahissaient les vallées de l'Outaouais, du Saint-Laurent et du Richelieu. Au stade « Montréal », le lac Saint-François, section du Saint-Laurent, a été séparé du corps principal de la mer de Champlain, tandis que le lac Champlain, le lac des Deux-Montagnes et le lac Saint-Louis se sont successivement séparés durant le stade transitoire « Montréal - Saint-Barthélémi ».

RAISED SHORELINES AND DRAINAGE EVOLUTION IN THE MONTRÉAL LOWLAND

by

Joyce BROWN MACPHERSON, M.Sc., Ph.D.

Memorial University

From its passage across the Frontenac axis to the effective head of tide at Trois-Rivières, the Saint Lawrence River traverses an interior lowland developed on Paleozoic sedimentary strata. The bounding highlands, the Laurentides on the north and the Appalachians to the southeast, converge downstream, giving the lowland its triangular outline.

During the final stages of the Pleistocene the lowland was inundated by the Champlain Sea when the ice front withdrew from the south side of the Saint Lawrence valley near Québec City (Gadd, 1964). The sea stood at its maximum across the lowland about 11,400 years ago (Preston, Person and Deevey, 1955; Gadd, 1964). Since then, the lowland has re-emerged as the result of isostatic recovery and a new drainage pattern has developed on the veneer of glacial, marine and other superficial deposits. Thus, although the broad outlines of the lowland were shaped before the invasion by Pleistocene ice, the Saint Lawrence River and its tributaries form in detail one of the most youthful of the world's drainage systems.

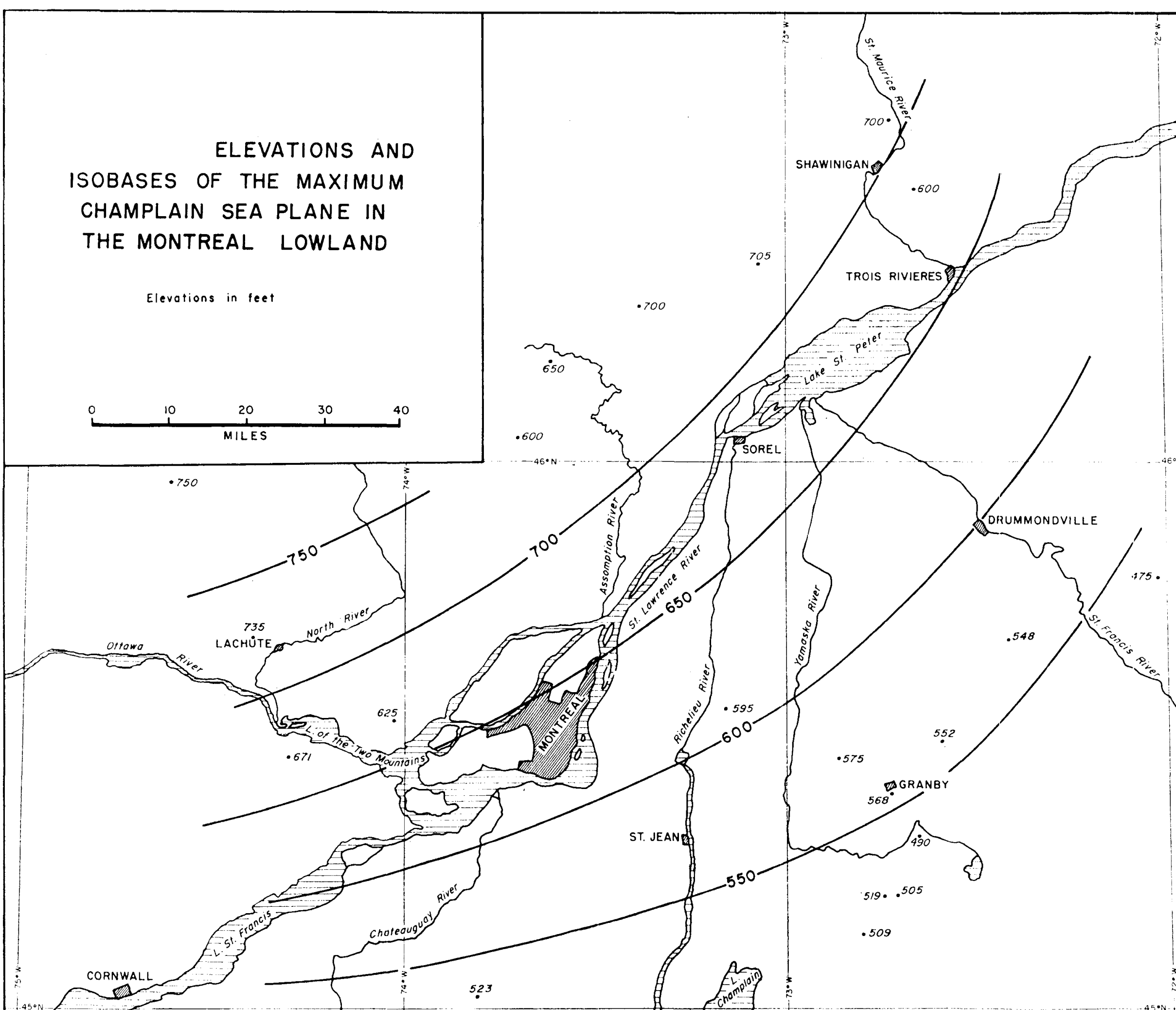
The marine maximum

There is abundant and widespread evidence of shoreline processes at the margin of the retreating sea. Sandy slopes, such as delta fronts, are frequently ribbed with beaches at vertical intervals of only a few feet, while in an adjacent area of clay a single bluff may extend through the whole of the corresponding range of elevation, the earlier, higher shorelines having been destroyed by the later. Areas of till have been subject to the removal of fines by wave action, and the residual boulder concentrate may be spread down a slope, thrown into beach ridges, or crudely terraced. However, isostatic recovery immediately following the Champlain Sea maximum appears to have been so rapid (of the order of 20 feet per century) and the early shoreline features are so discontinuous that correlation into successive stages is not feasible. During the later part of the emergence, on the other hand, the rate of isostatic recovery was much reduced, and shoreline processes, working upon the more complete cover of marine sediments nearer the centre of the lowland, produced more continuous features. Physiographic and palynological evidence enables these later shoreline features to be correlated into significant stages, and for each stage a discussion of the evolving drainage pattern is possible.

When the Champlain Sea stood at its maximum the whole of the floor of the lowland was submerged. It is important, nevertheless, to consider the present form of the upper marine plane, for its differential uplift establishes the maximum degree of tilting which may be invoked in the correlation of lower shorelines. Numerous factors make recognition of the marine limit difficult. The first is the difficulty of locating the water marks. During the early stage of rapid emergence only faint shorelines were registered on the slopes of scoured or shattered bedrock or bouldery till. These slopes are today, moreover, generally forested. Even on Mount Royal there is no generally accepted elevation of the marine limit. The second difficulty concerns the differentiation between marine shorelines and those of earlier, higher proglacial lakes. The absence of marine molluscs is an insufficient criterion for judging a shoreline to be of lacustrine origin, for the littoral environment near the upper limit of the sea was unfavourable for their growth. In addition, shells which may have been deposited in certain non-calcareous beach deposits may have been leached away.

Elevations of the marine limit are shown on the map, Figure 1, which is based largely upon the work of Goldthwait (1911, 1913, 1914, 1933), and have

Figure 1 Elevations and isobases of the maximum Champlain Sea plane in the Montréal lowland.



also been tabulated (Table 1). The map differs in detail from that previously published by the author (Brown, 1962); further elevations in the Shield area have been plotted following the work of Parry (1963) and from other observations. The isobases on the upper marine plane swing round parallel with the edge of the Shield, indicating a dome-like uplift. The differential uplift along the approximately north-south direction of maximum tilt through Montréal is of the order of 3 feet per mile, becoming somewhat greater near the edge of the Shield.

Later stages of the emergence

In an unpublished summary of his work on the Saint Lawrence Lowlands, Goldthwait (1933) discussed three stages of the retreat of the Champlain Sea, at 210 feet, 110 feet and 50 feet above present sea level. His 210-foot stage is topographically continuous only in the lower Ottawa valley (Brown, 1962) and in the Terrebonne sand plain north of Montréal, where bluffs bordering abandoned estuarine channels lie at elevations of between 200 and 220 feet. Since the shoreline is conspicuous on the slopes of Rigaud Mountain, the names « Rigaud shoreline » and « Rigaud stage » are proposed.

Goldthwait's 110-foot stage was named « Lake Montréal » by Mackay (1949); the present writer proposes a modification to the « Montréal stage ». The

Table 1 Elevations of the Champlain Sea maximum

Location	*Elevation (feet)*	*Feature*	*Source*
Northern margin of the lowland			
Kingsmere	690	Terrace	Johnston, 1916
Arundel	750	Delta	Parry, 1963
Dalesville	735	Delta	Wilson, 1924
Rawdon	600	Delta	R. Béland, 1960
Sainte-Béatrice	650	Delta	Parry and Macpherson, 1964
Saint-Gabriel	700	Delta	Elson, 1962
Prémont	705	Terrace	Macpherson
Saint-Maurice valley	700	Highest mapped marine clay	J. Béland, 1961
Mount Carmel	600	Delta	Osborne, 1950
Southern margin of lowland			
Covey Hill	523	Beach	Goldthwait, 1911
Dunham	509	Beach	Goldthwait, 1914
Sweetsburg	505	Delta	Goldthwait, 1914
Cowansville	519	Beach	Chapman, 1937
West Shefford	490	Beach ridge	Goldthwait, 1911
Grandby	568	—	Goldthwait, 1933
South Roxton Station	552	Beach	Goldthwait, 1914
Danby	548	Beach ridge	Goldthwait, 1911
Danville	475	Unmodified topography	Gadd, 1964
Hills within lowland			
Rigaud Mountain	671	Beach ridge	Johnston, 1916
Oka Mountain	625	Beach	Romaine, 1951
Mount Royal	617	Marine shells	Stansfield, 1915
	568	Beach	Goldthwait, 1913
Mount Saint-Hilaire	595	Beach	Macpherson
Yamaska Mountain	575	Terrace	Goldthwait, 1911

shoreline may be traced downstream with few breaks from the lower Ottawa valley (Brown, 1962) and the Richelieu valley to Lake Saint-Pierre (Figure 2). The 50-foot shoreline is most conspicuous on either side of Lake Saint-Pierre, but occurs as far upstream as the Lachine Rapids (Figure 3). It is suggested that the shoreline be named after the village of Saint-Barthélémi, where it is particularly well developed.

Both the Montréal and the Saint-Barthélémi shorelines appear to be untilted and it must be concluded that by the time they were formed measureable differential uplift had ceased. Tilting was still active at the time of the formation of the Rigaud shoreline, however, for its northward slope in the lower Ottawa valley is at the rate of about 1.5 feet per mile. As it is unlikely that the deformation of the Rigaud waterplane is uniform across the lowland, it is hazardous to correlate it with shoreline features elsewhere on the basis of elevation.

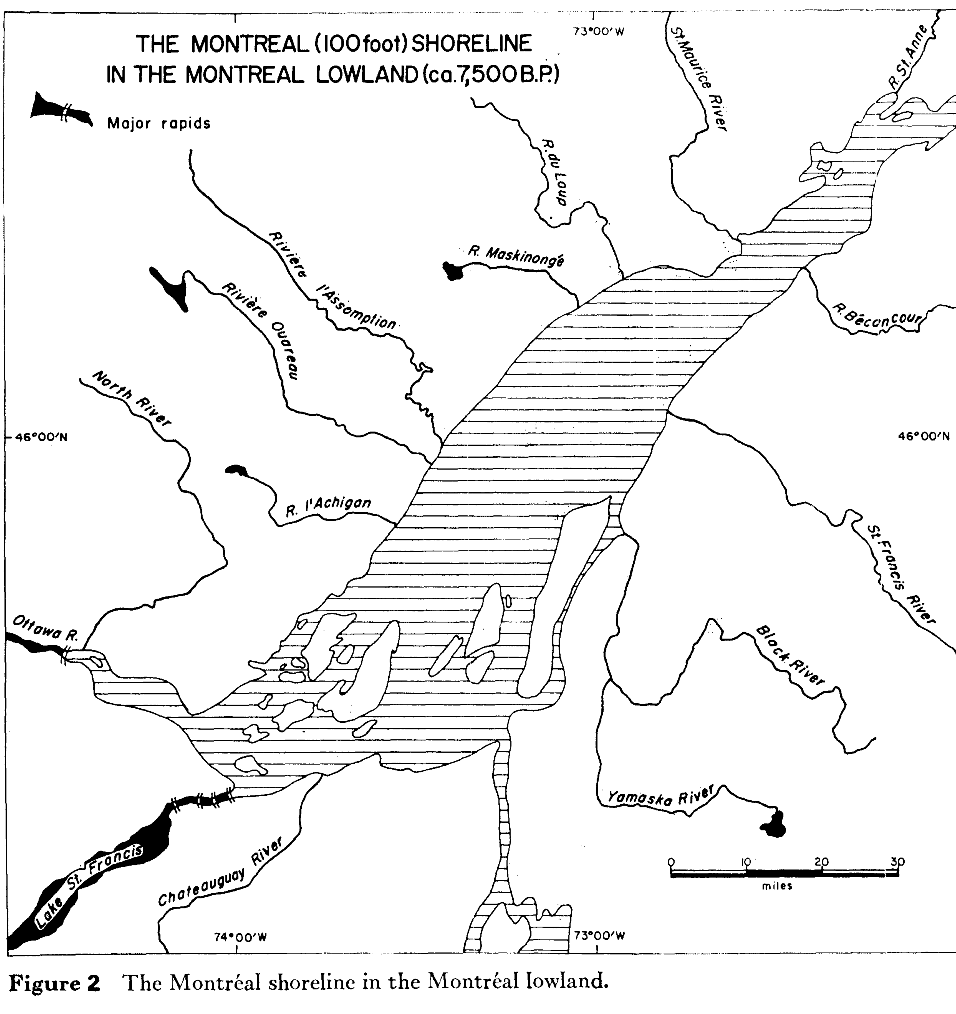


Figure 2 The Montréal shoreline in the Montréal lowland.

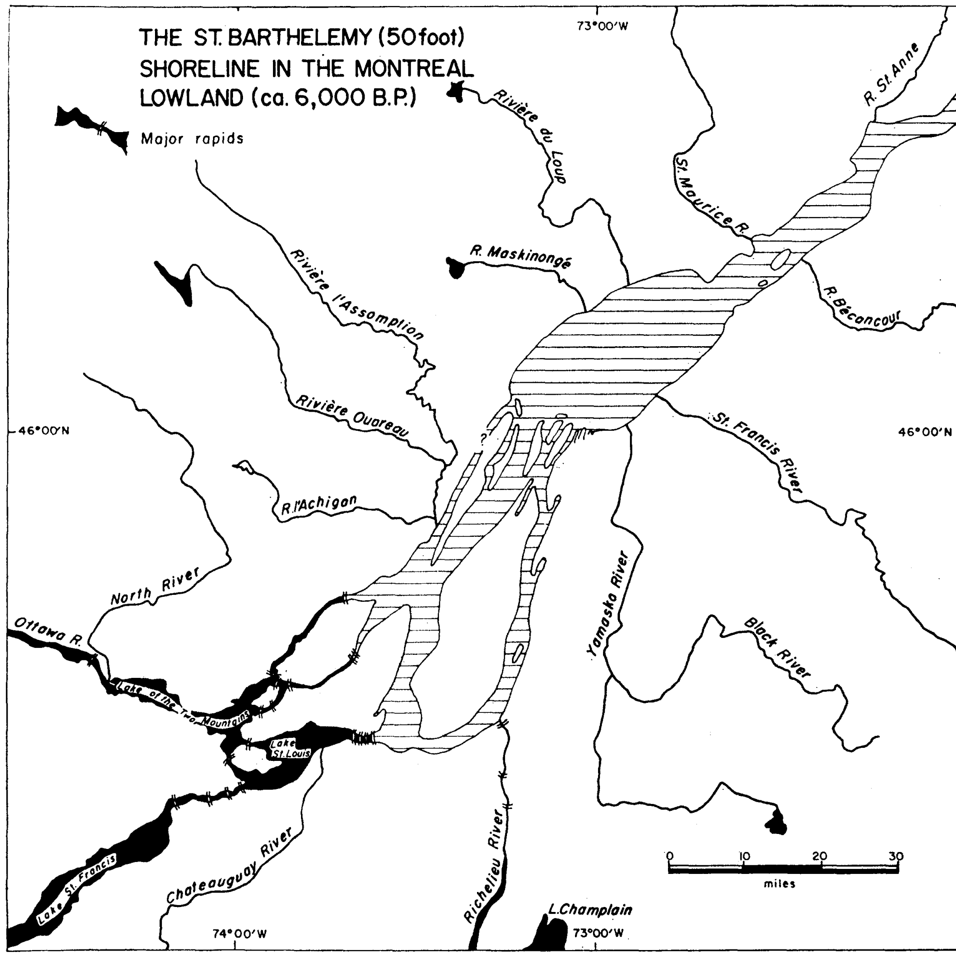


Figure 3 The Saint-Barthélémi shoreline in the Montréal lowland.

Palynological evidence, however, provides a solution to the problem of correlation. The accumulation of pollen-bearing sediments at the site of a bog could not occur until it had emerged from the sea. The construction of a pollen profile, therefore, in providing an estimate of the relative age of the bog, also dates the emergence of the site relative to others.

The standard pollen sequence for the St. Lawrence Lowland proposed by Terasmae (1959) has been adopted in this work (Table 2). Contrary to customary usage he numbers the pollen zones from the surface down. The earliest pollen zone known in the lowland, zone VI, is characterised by a high count of non-arboreal pollen. The following zone V shows the count of spruce (*Picea*) pollen at a maximum. Zones IV and III are identified by their high counts of jack pine (*Pinus banksiana*) and white pine (*Pinus Strobus*) pollen. In zone II the propor-

Table 2 Pollen zones after Terasmae, 1959

Probable age (Years B. P.)	*Pollen zones*	
	I	Decline of hemlock and pine ; increase of spruce.
2,000		
	II	High beech, hemlock ; decline of pine ; slight increase of spruce, fir and birch.
5,000		
	III	High white pine, mixed hardwood ; low spruce, fir, hemlock, beech.
7,500		
	IV	High jack pine, fir ; low birch, mixed hardwood. Decline of spruce.
8,500		
	V	Spruce maximum.
9,500		
	VI	Low spruce ; high pine, birch, alder.
10,000		

tion of hemlock (*Tsuga*) pollen reaches a maximum, and in zone I hemlock and pine pollen decrease while spruce and non-arboreal pollen increase.

A number of pollen profiles were obtained by the writer and were related to the standard sequence. It was evident that a crude altitudinal zoning of bogs of different ages existed. Figure 4 is a diagrammatic cross profile illustrating this relationship in the lower Ottawa valley. The Saint-Canut bog, at an elevation of 250 feet at the crest of a till ridge, began to develop during pollen zone V. The Beech Ridge and Cut-over bogs in abandoned drainage channels at lower elevations began to form in pollen zone IV, while the Pointe-Fortune bog at the base of the 100-foot bluff did not begin to develop until pollen zone III. The diagram also illustrates the possibility of delay in the development of a bog. Peat accumulation in the Saint-Eugène bog began late in pollen zone IV or early in pollen zone III, later in the lower Cut-over bog. The site of the Saint-Eugène bog is sandy ; delay in bog development in such sites is common.

In an attempt to extend the altitudinal zoning across the lowland the work of other authors was incorporated (Auer, 1930 ; Potzger, 1953 ; Courtemanche, 1956 ; Terasmae, 1960) and, where necessary, related to the standard pollen sequence. For ease of analysis the sites considered were grouped by area : the Ottawa, Richelieu, Saint-François and Saint-Maurice valleys. For each area the elevations and ages of the bogs were plotted in a way which enables the altitudinal limits of the pollen zones to be determined (Figure 5). In some cases the inorganic sediment underlying the peat or organic lacustrine sediment had been analysed for pollen, and in a few instances this pollen assemblage was from an earlier zone than that of the organic deposit. In such cases the pollen zone of the inorganic sediment is given first, with the zone of the organic sediment

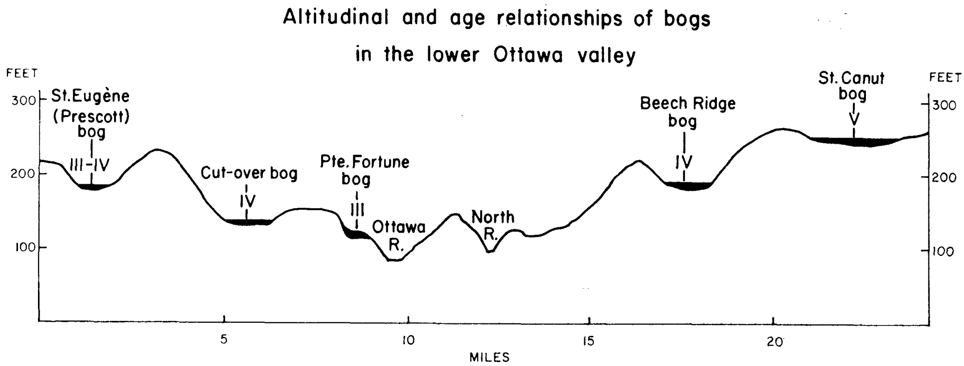


Figure 4 Altitudinal and age relationships of bogs in the lower Ottawa valley.

in parentheses. Within each area it is the elevation of the lowest bog dating from a particular pollen zone which is the first criterion of the altitudinal limit between that zone and the later zone at a lower elevation. The more exact placing of the zone limit is based on evaluation of the pollen profiles to determine at what stage in a pollen zone pollen-bearing sediment began to accumulate. The highest elevation of a bog dating from a given pollen zone is of little significance, because of the delayed development of certain bogs.

In the Ottawa valley the lower limit of pollen zone V is placed at 230 feet, just below the elevation of bog A, the Saint-Canut bog. The pollen profile of this bog indicates that organic sediment began to accumulate late in pollen zone V, and no bog dating from this pollen zone lies at a lower elevation. By the time that land at lower elevations had emerged the vegetation had changed, and the basal sediments of the lower bogs incorporate pollen assemblages of zones IV or III. Similar reasoning places the boundary between pollen zones V and IV at elevations of 170 feet in the Richelieu valley, 220 feet in the area of the Saint-François valley and 210 feet in the Saint-Maurice valley area.

Isobases on the deformed boundary surface between pollen zones V and IV have been drawn (Figure 6). The general form of the surface is similar to that of the Champlain Sea maximum, although the degree of tilting is less, being only 1.25 feet per mile in a northward direction through Montréal, compared with the tilt of 3 feet per mile of the marine maximum. This suggests that it might be possible to consider the pollen boundary surface as a deformed water plane. Supporting evidence is found by a comparison with the Rigaud water plane in the lower Ottawa valley. The Rigaud plane lies some 10 feet lower than the pollen boundary surface and with a tilt of the same order of magnitude (1.5 feet per mile) (Figure 7).

When the boundary surface between pollen zones IV and III is considered the evidence becomes even stronger. The lower limit of pollen zone IV in the Ottawa valley is placed a little above the Pointe-Fortune bog, at 115 feet above sea level (Figure 5). In the distant Saint-Maurice valley the boundary may be defined with similar precision, at an elevation of a little less than 100 feet. A boundary drawn at a similar elevation in the Richelieu and Saint-François

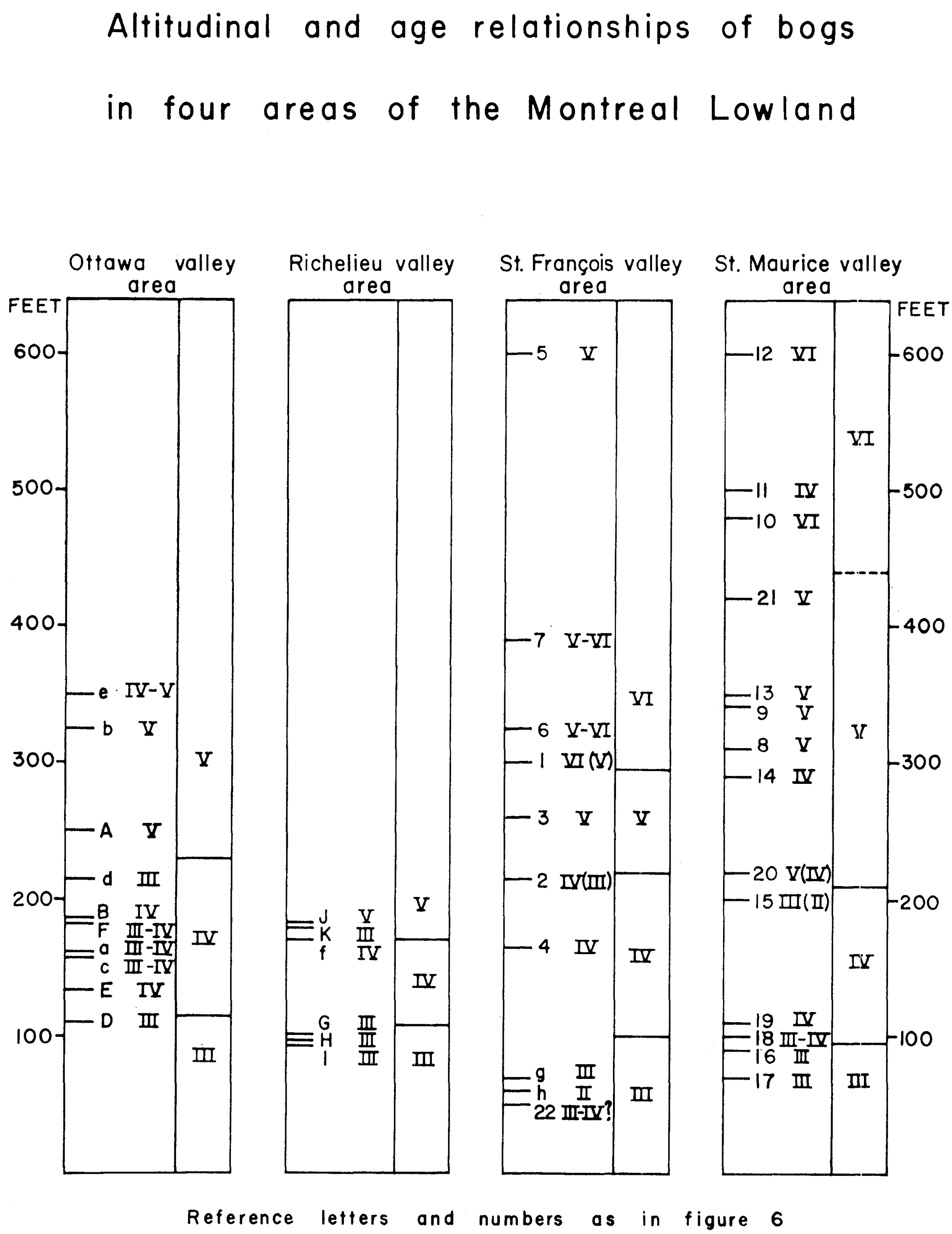


Figure 5 Altitudinal and age relationships of bogs in four areas of the Montréal lowland.

valleys is in accord with the palynological evidence. The boundary thus drawn corresponds closely with the Montréal water plane, which, from a consideration of Table 2, may be assigned a tentative date of 7,500 B. P. It appears likely, therefore, that the V-IV pollen boundary surface also corresponds with a water

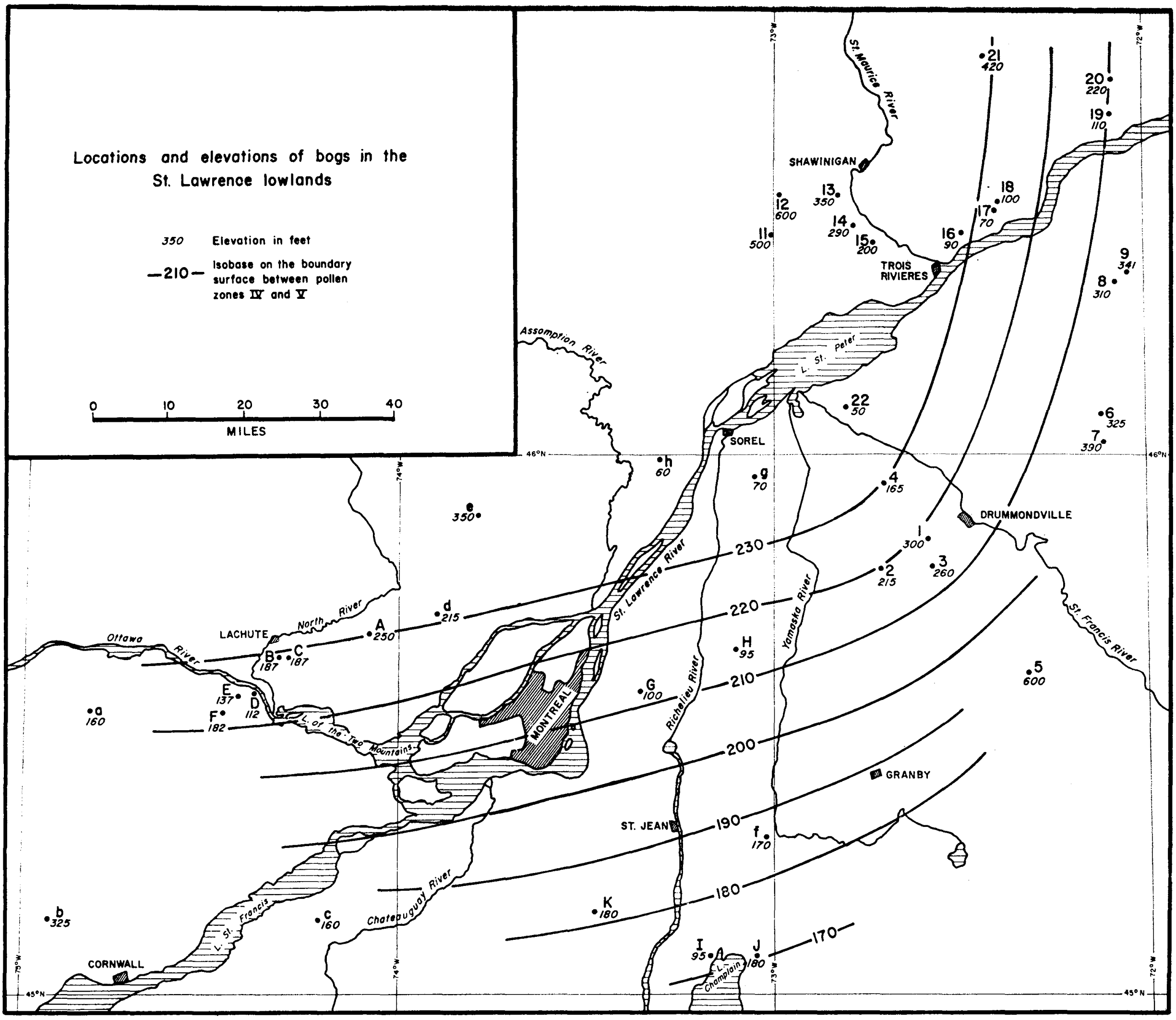


Figure 6 Locations and elevations of bogs in the Montréal lowland, with isobases on the V-IV pollen boundary surface.

plane, and the implication of a close correspondence, if not an exact correlation, with the Rigaud water plane is inescapable.

On this basis, therefore, the Rigaud plane has been projected beyond the Ottawa valley throughout the lowland (Figure 8). The extrapolated Rigaud shoreline coincides in elevation with a number of measured water marks in widely separated localities. It may be that these water marks were in fact produced at the Rigaud shoreline, but there is frequently a suite of closely-spaced shoreline features at about the required elevation, and it is not surprising that one member of the suite should coincide in elevation with the hypothetical water plane.

Why is the Rigaud shoreline so conspicuous only in the lower Ottawa valley and the adjacent Terrebonne sand plain? From a consideration of radiocarbon dates and of the dates given for the pollen zones by Terasmae (1960) it appears that the Rigaud shoreline, dating from approximately 8,500 B.P., was cut when proglacial Lake Barlow-Ojibway discharged through the Ottawa valley

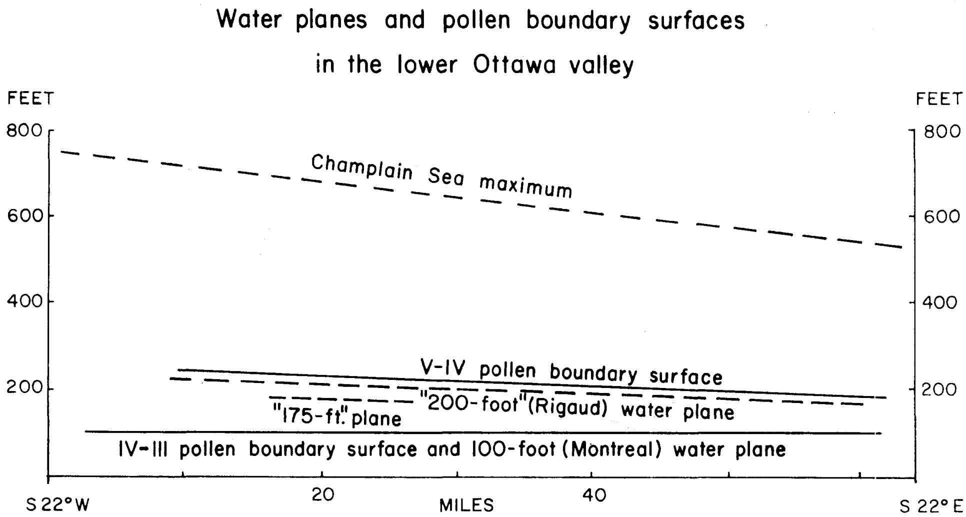


Figure 7 Water planes and pollen boundary surfaces in the lower Ottawa valley.

(Macpherson, 1966). The floors of the channels through which the current swept were soon to be raised above sea level and their bounding bluffs preserved. The erosive effects of the current would have been less strong if the area had not previously received thick deposits of sediment carried into the sea by rivers charged with glacial melt-water. The current was dissipated in the more open parts of the Rigaud water body, so that shoreline features were less pronounced, even where there were unconsolidated deposits of a depth comparable to those of the lower Ottawa valley.

The Rigaud shoreline and the related drainage pattern

At the Rigaud stage the head of the estuary lay in the Ottawa valley west of the area of study (Figure 8). Branching estuarine channels were being cut in the unconsolidated deposits of the lower Ottawa valley and the Terrebonne sand plain, while broad embayments occupied the basins of Lake Saint-François and Lake Champlain. At the eastern margin of the lowland the shoreline lay close to Logan's Line, while to the north the heads of the Assomption and Saint-Maurice embayments had emerged. The present elevation of the shoreline in the Saint-Maurice embayment is doubtful, as the palynological evidence was inadequate to establish the elevation of the V-IV pollen boundary surface. The water body decreased in width toward the narrows at Québec City.

In those parts of the lowland that had emerged at the Rigaud stage the drainage pattern was little different from that of today. On the Ottawa – Saint Lawrence interfluve, west of Rigaud Mountain, a number of short streams had developed, their courses controlled by outcrops of till and by the slope of the surface of marine sediments. In a zone flanking the Adirondacks and lying west of the Richelieu valley there were again a number of small independent streams,

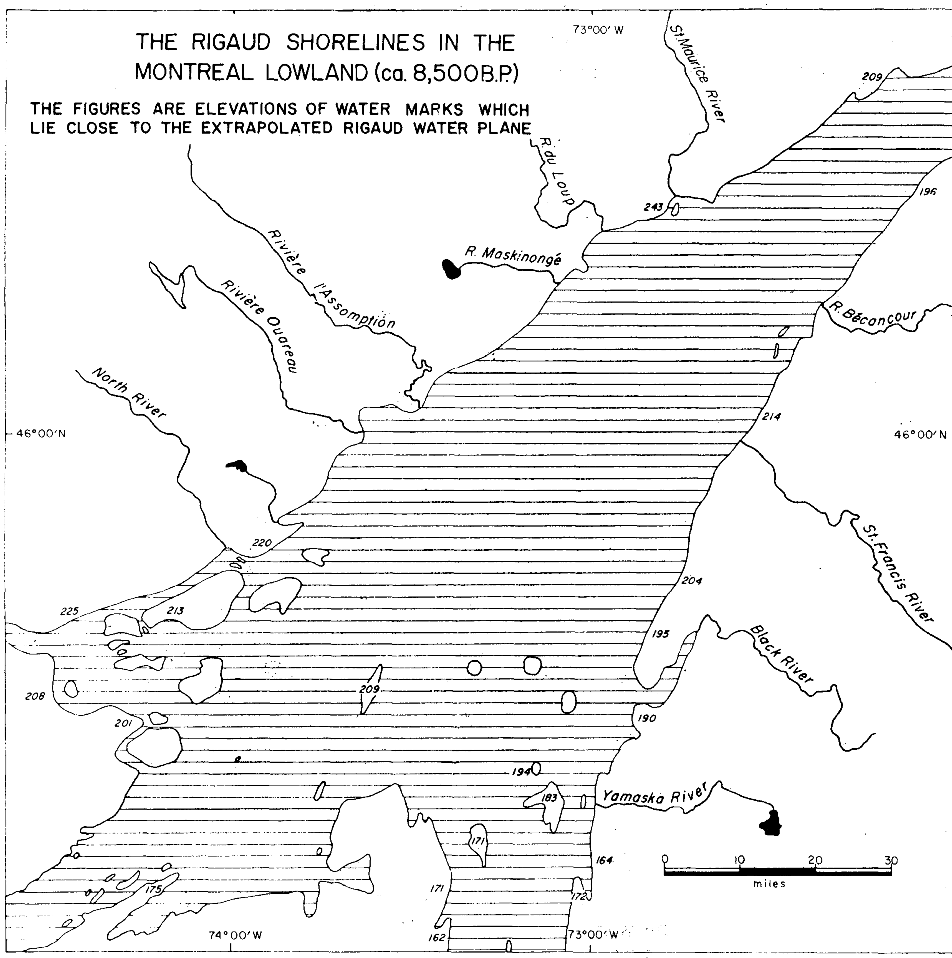


Figure 8 The Rigaud shoreline in the Montréal lowland.

the courses of which were determined by outcrops of bedrock and of till and glacial gravel. Despite the deep penetration by the Champlain Sea at its maximum into the Appalachian valleys, the shoreline at the Rigaud stage was little indented, the only major embayment being the valley of the Black River. The outer streams had filled the floors of their valleys with deltaic deposits at higher stages of the Champlain Sea, and were by this time entrenching their courses into the deltaic sediments in response to the falling sea level.

On the northern side of the lowland a few streams drained from the crest of the Lachute – Saint-Jérôme morainic ridge in the lower Ottawa valley. In the Assomption embayment the Rivière l'Assomption and the streams which are now its tributaries were becoming entrenched within raised deltas, and the main stream, in particular, was continuing to extend its delta by the redeposition of material. The courses of minor streams in this area were influenced by low bedrock knobs projecting through the marine sediments. The Saint Maurice River was actively extending its lower delta and at least one distributary channel was operative west of the present course of the river.

The Montréal shoreline and the related drainage pattern

The retreat of the shoreline to about 110 feet above present sea level initiated the upper phase of the Montréal stage of the Champlain Sea ; the shoreline of the lower phase lies some 10 to 15 feet lower, and it is convenient to refer to the Montréal stage as a whole as the 100-foot stage.

During the Rigaud – Montréal interval considerable areas of the lowland had emerged and had become subject to sub-aerial processes. The head of the estuary at the Montréal stage had withdrawn down the Ottawa valley to near the foot of the Carillon Rapids (Figure 2). The volume of water carried by the Ottawa River was now much reduced compared with the Rigaud stage, but was still greater than that of the Saint Lawrence River. The Montréal archipelago comprised many islands, and the shoreline is distinct only where cut in marine deposits. North of the archipelago the shoreline wound between the promontories and islands of the area of till which lies between the Rivière des Mille-Îles and the Grand-Coteau. The water washed the foot of the Grand-Coteau at its eastern end, near the town of Terrebonne, The shoreline may be traced northeastward, with some gaps, mainly as a bluff cut in marine sediments, until it is lost in the salient of Shield rocks between the Saint-Maurice and Sainte-Anne embayments.

South of the Montréal archipelago the 100-foot shoreline is usually marked by an erosional bluff. In the vicinity of the Caughnawaga Indian Reserve, however, it lay in an area of till, where its outline was irregular and its traces are few. Here an eastward-trending channel discharged some of the drainage of the Châteauguay River. The water mark of the Montréal stage may be traced along the Laprairie – Chambly bluff and into the Richelieu valley. Here, because of inconclusive evidence for and against tilting of the Montréal water plane, it is impossible to locate the head of the marine embayment with any precision. If the plane has been affected only by simple vertical uplift and remains untilted, and if erosion at the head of the Saint-Jean Rapids has not been more than a few feet, the Montréal water body was continuous with that in the basin of Lake Champlain. Its extent within the basin was little greater than that of the present lake, the surface of which is held at an elevation of 96 feet by the sill at the head of the Saint-Jean Rapids. If, on the other hand, the Montréal water plane had been tilted, it must pass beneath the surface of the lake and may, as Chapman (1937) suggested, intersect the lake floor in a submerged delta at Port Henry.

North of the point where the Richelieu embayment opened into the main Montréal water body the shoreline may be traced at the margins of straits between emerging islands. The strait which was to develop into the lower Richelieu valley lay between Mounts Saint-Bruno and Saint-Hilaire ; north of the two Monteregian hills former swells on the sea floor had emerged to define the course of the strait seaward. The swell extending north from Mount Saint-Hilaire served also to define a strait which later developed into the Hurons – Salvail channel. A bluff-bounded channel divided Mount Saint-Bruno from its attendant belt of marine sediments, which now forms the island terrace of Verchères Wood. The crest of the bedrock-cored Boucherville till ridge lay as an island between Mount Saint-Bruno and the present line of the Saint Lawrence River.

To the northeast, south and east of Lake Saint-Pierre, the shoreline lay in areas of deltaic and littoral accumulation and only rarely is it defined by an erosional bluff. It merges with the present Saint Lawrence bluff near Deschaillons. In this northeastern part of the area of study the width of the Montréal water body, as of the earlier Rigaud water body, was much narrower than it was upstream in the vicinity of Montréal. It is suggested that the shoals which were later to emerge as the island terraces of the Lanoraie delta developed as a tidal delta upstream of the narrows in the Montréal water body.

Although the Champlain Sea was still extensive between Montréal and Trois-Rivières at the Montréal stage, considerable areas of the lowland had emerged during the previous 1,000 years. This period of time, the probable duration of pollen zone IV, corresponds approximately with the Rigaud – Montréal interval. During this time the drainage patterns of the lower Ottawa valley and the Terrebonne sand plain had assumed almost their present forms. In these areas the stream courses were directed principally by abandoned estuarine channels. These in their turn had been controlled in the lower Ottawa valley by the trend of outcrops of till and bedrock, and in the Terrebonne sand plain by the forms of shoal deposits of estuarine sand.

The major event in the Saint Lawrence valley during the Rigaud – Montréal interval was the separation of Lake Saint-François from the main estuary by the emergence of a bedrock sill near Valleyfield. There is some evidence that the lake was originally more extensive than it is now, its area having been reduced by downcutting at the sill. The emergence of the sill probably occurred shortly after the Rigaud stage, at a time when a well-defined shoreline at an elevation of about 175 feet was being registered in the lower Ottawa valley. The massive till ridge south of Lake Saint-François extended its function as the Saint Lawrence Châteauguay interfluve, so that at the Montréal stage the latter stream had an independent drainage basin, entering the estuary to the east of the mouth of the Saint Lawrence River.

In the upper Richelieu valley only the floor of a narrow channel, probably marine but possibly lacustrine, remained submerged at the Montréal stage. The land surface which had emerged during the Rigaud – Montréal interval was of very similar character to that which had emerged by the Rigaud stage, and similar factors, principally the forms of till and gravel ridges, were operating to control the developing drainage pattern. South of the Laprairie – Chambly bluff, however, a clay plain had emerged and was developing a dendritic drainage pattern with streams which were becoming incised in response to the falling base-level; this area was similar to that above the Montréal bluff to the east of Rigaud Mountain.

The Rigaud – Montréal interval saw the development of the lowland course of the Yamaska River to the first of the elbows below Saint-Hyacinthe, where it entered the estuary. Much of this section of the river's course lies in a depression between the Saint-Dominique fault-slice and a sea-floor swell extending north from Rougemont. Today this barely perceptible ridge forms the interfluve between the Yamaska River and its tributary, the Salvail River, the valley of which was then still a marine strait. Little of the drainage of the interfluve entered the Yamaska River, which received, however, numerous tributaries from the slope of the fault-slice.

The Saint-François, Nicolet and Bécancour rivers, a series of northwest-flowing streams, continued to extend their deltas, into which they subsequently became incised. New generations of tributaries developed as more land was exposed, rising in some instances in belts of beach sand and gravel, and draining the depressions between the deltas of the major streams.

The main streams of the Assomption embayment at the northern margin of the lowland, the Rivière l'Assomption itself, and its present-day tributaries, the rivers Ouareau and l'Achigan, still had separate mouths at the Montréal stage. The sand of the Assomption delta extended to the shoreline. A few small sandy islands lay off-shore, the flanking deposits of the Lanoraie delta, most of which was still submerged and had yet to exert its influence upon the drainage pattern.

In the western part of the Saint-Maurice embayment the rivers continued to extend their courses and incise their beds during the Rigaud – Montréal interval; failures of the weak banks of marine clay were common. The present mouth of the Saint-Maurice River had become dominant by the Montréal stage. The decreasing radius of successive meander scars on either side of the main channel bears witness to the decreasing volume of water carried by the river during the preceding 1,000 years. Despite the abandonment of the main western distributary channel deltaic accumulation still continued at its mouth; here the small Rivière aux Sables deposited material gathered in its course along the former channel floor. East of the Saint-Maurice delta a low ridge of marine and littoral deposits prevented the Champlain River from flowing directly to the estuary, much as the course of the Yamaska River was controlled by the low ridge extending north from Rougemont. In its northeasterly course the Champlain River gathered the drainage of numerous streams rising on the southern slopes of the Saint-Narcisse moraine. The Batiscan and Sainte-Anne rivers, to the northeast, flowed into embayments of the Montréal water body and their courses had been but little extended during the Rigaud – Montréal interval.

The Saint-Barthélémi shoreline and the related drainage pattern

The 50-foot bluff is a conspicuous feature on either side of Lake Saint-Pierre, although, as Goldthwait (1933) pointed out, the bluff foot has locally been cut down to lower elevations. The head of the estuary at the Saint-Barthélémi stage lay at the foot of the Lachine Rapids, but there was little open water between that point and the head of Lake Saint-Pierre (Figure 3). Instead, the upper portion of the estuary consisted of interconnecting channels, of which that which was to evolve into the Saint Lawrence River was the broadest.

An estuarine channel extended eastward from the foot of the Lachine Rapids to the Richelieu valley at Chambly Basin, where the Richelieu River reached sea level at the foot of a flight of rapids. The channel continued northward along the line of the lower Richelieu valley, with embayments and branch channels where it crossed the emerging Lanoraie delta, to merge with the main estuary in the Lake Saint-Pierre basin.

Embayments northwest of the main, or Saint Lawrence, channel occupied the lower parts of the valleys of the rivers Saint-Pierre, des Prairies and des Mille-Îles. The Rivière l'Assomption entered a branch channel through the Lanoraie delta. It cannot be determined whether this channel was still open to the northeast at the Saint-Barthélémi stage, as it was a short time previously, or whether the Rivière l'Assomption flowed into a residual embayment occupying the southern end of the channel.

During the Montréal – Saint-Barthélémi interval the Lake of the Two Mountains was separated from the estuary and the rapids on either side of Île Perrot and at the heads of the rivers des Mille-Îles and des Prairies were initiated. The local base level for the lower Ottawa valley thus became that of the present level of the lake, 73 feet above sea level. The emergence of the sills which confine the lake was shortly followed, or possibly preceded, by the emergence of the head of the Lachine Rapids and by the consequent separation of Lake Saint-Louis. The Châteauguay River is the largest right-bank tributary to enter the Lake Saint-Louis section of the Saint Lawrence River. By the time of the separation of the lake the channel by which some of its water had crossed the Caughnawaga Indian Reserve at the Montréal stage had been abandoned, and the western channel was established as the mouth of the river ; here a delta had begun to develop.

If the sill at the head of the Saint-Jean Rapids in the Richelieu valley had not emerged by the Montréal stage, it did so shortly thereafter, separating Lake Champlain from the estuary. The present elevation of the lake surface is 96 feet ; thus the local base level in the upper Richelieu valley is relatively high. However, few significant tributaries enter the upper Richelieu River, which is in fact an arm of Lake Champlain.

To the east of the lower Richelieu valley the main changes which occurred during the Montréal – Saint-Barthélémi interval were the emergence of the floor of the Hurons – Salvail channel and the seaward extension of the Yamaska River. On the Richelieu – Saint Lawrence interfluve emerging estuarine channels provided routes for drainage of local origin. In the lowermost section of the Richelieu valley the island terraces of the Lanoraie delta had emerged, and minor streams had developed on the floors of some of the intervening channels.

It was the northern portion of the Lanoraie delta, however, which was exerting a more conspicuous influence upon the drainage pattern by the Saint-Barthélémi stage. The course of the Rivière l'Assomption below the Montréal shoreline was determined by channels across the delta, but the river flowed in a generally southerly direction, not, as might have been expected, toward the northeast. A channel into which the river flowed at an intermediate stage appears to have been choked by the river's own deposits ; with continuing emergence the river found no course open but that to the south. In its southward course the river collected the drainage of the other major streams of the Assomption embayment, so the drainage of the greater part of the embayment was discharged through a single mouth. This was in contrast to the independent streams of the Saint-Maurice embayment. These, like those entering the other side of Lake Saint-Pierre, underwent no striking developments during the Montréal – Saint-Barthélémi interval, which was marked only by further extension of the stream courses and incision of the stream beds.

The final stages of the emergence

During the period of several thousand years that has elapsed since the Saint-Barthélémi shoreline was cut the Champlain Sea has been finally excluded from the Montréal lowland. Today marine influence is felt only in the tidal reach of the Saint Lawrence River below Lake Saint-Pierre.

As the land emerged the head of the estuary retreated downstream and the rivers extended their courses in a pattern which was implicit in the pattern of estuarine channels at the Saint-Barthélémi stage. The first significant event was the severance of the connection between the Saint Lawrence and Richelieu valleys when the floor of the Laprairie-Chambly depression was raised above sea level. The next was the separation of the Laprairie Basin from the estuary.

Gradually, as fluvial conditions extended seaward, the Saint Lawrence, Richelieu and l'Assomption rivers came to occupy their present courses within the broader channels of the Saint-Barthélémi stage. As the shoreline withdrew from the 50-foot bluffs around Lake Saint-Pierre the deltas of the larger streams, including the Saint Lawrence River, were extended into the lake and a new generation of minor streams, rising at the former shoreline, flowed toward the lake across the « low terrace sands ».

Goldthwait (1933) stated that bedrock occurs in the bed of the Saint Lawrence River at Trois-Rivières, below Lake Saint-Pierre. Further emergence of this bedrock sill will complete the separation of Lake Saint-Pierre from the head of the estuary, to extend the process which has been successively repeated in the past, a process which Goldthwait aptly described as follows :

> « Emergence of the lowland was not accompanied by a simple withdrawal of the sea from the far western corners of the lowland eastward to the estuary at Québec, and the steady extension of the Saint Lawrence and Ottawa rivers in that direction. Broad basin-like portions of the lowland, detached from the marine waters one by one, became fresh-water lakes, through which the river pursued its new course. Rock thresholds, first to emerge as the sealevel drew down, developed rapids where the water from one basin spilled over into the next. Some of these basins and thresholds are still prominent features of the rivers » (Goldthwait, 1933).

ACKNOWLEDGEMENTS

This paper is an expansion of one presented to the 20th International Geographical Congress, London, 1964. The work which it records was done under the supervision of the Department of Geography, McGill University. The writer acknowledges the advice given by members of that department, especially Professor J. Brian Bird, and by Dr. Jean Terasmae of the Geological Survey of Canada, without whose assistance with the palynological aspects the work would have been impossible.

RÉSUMÉ

La rive la plus élevée de la mer Champlain, qui a envahi les Basses-Terres du Saint-Laurent après la dernière glaciation, a été identifiée à une altitude de 750 pieds au nord de Montréal, et de 525 pieds au sud. Une rive plus récente parcourt toute la région à une altitude uniforme de 100 pieds. Les rivages intermédiaires résultent de pulsations variables de la mer, mais leur répartition et leur nature même rendent difficile la corrélation du niveau des eaux par des méthodes statistiques. Cependant, la preuve est maintenant établie qu'il est possible de localiser les niveaux intermédiaires par l'analyse du pollen. L'accumulation de sédiments renfermant du pollen est plus ancienne dans les secteurs les plus élevés, évacués les premiers par les eaux, et les échantillons positifs tirés de tourbières choisies permettent d'établir les différentes altitudes des surfaces séparant ces tourbières qui se sont développées dans les zones anciennes et plus récentes recelant du pollen. La surface séparant les tourbières datant de la zone IV de pollen (récente) de celle de la zone V (plus ancienne) a été remaniée et se situe à 230 pieds d'altitude au nord de Montréal et à 170 pieds au sud. La déclivité nord-sud de cette surface est de 1.25 pied au mille, ce qui correspond à une rive bien déterminée à une altitude équivalente. Dans la basse vallée de l'Outaouais. Une preuve plus poussée de la validité de la méthode est fournie par la nature horizontale de la surface séparant les tourbières datant des zones de pollen n° III et IV, à la même altitude que la ligne de rivage de 100 pieds. Un rivage inférieur, par exemple à une altitude de 50 pieds, ne peut être daté selon cette méthode.

Les noms de Rigaud, Montréal *et* Saint-Barthélémi, *sont proposés pour nommer les rives s'élevant respectivement à 200, 150 et 50 pieds d'altitude. Au stade « Rigaud », les eaux envahissaient les vallées de l'Outaouais, du Saint-Laurent et du Richelieu. Au stade « Montréal », le lac Saint-François, section du Saint-Laurent, a été séparé du corps principal de la mer de Champlain, tandis que le lac Champlain, le lac des Deux-Montagnes et le lac Saint-Louis se sont successivement séparés durant le stade transitoire « Montréal – Saint-Barthélémi ».*

REFERENCES

AUER, V., *Peat bogs in Southeastern Canada*, Geol. Surv., Can., Mem. 162, 1930.

BÉLAND, J., *Shawinigan area, St. Maurice, Champlain and Laviolette Counties*, Dept. Natural Resources, Québec, Geol. Rept. 97, 1961.

BÉLAND, R., *Rawdon area*, Dept. Mines, Québec., Geol. Rept. 92, 1960.

BROWN, J. C., *The drainage pattern of the lower Ottawa Valley*, in *Can. Geog.*, 6, 1962, pp. 22-31.

CHAPMAN, D. H., *Late-glacial and post-glacial history of the Champlain valley*, in *Am. Jour. Science*, 234, 1937, pp. 89-124.

ELSON, J. A., *Pleistocene geology of the St. Lawrence lowland*, in *New England Intercollegiate Geological Conference.* Guide Book for 54th annual meeting, Montréal, ed. T. H. Clark, 1962, pp. 15-24, pp. 61-66.

GADD, N. R., *Moraines in the Appalachian region of Québec*, in *Geol. Soc. Am. Bull.*, 75, 1964, pp 1249-1254.

GOLDTHWAIT, J. W., *Raised beaches of Southern Québec*, Geol. Surv., Can., Summ. Rept. for 1910, 1911, pp. 220-233.

GOLDTHWAIT, J. W., *The upper marine limit at Montréal ; the upper marine limit at Covey Hill and vicinity*, *Int. Geol. Congr.*, 12th Session, Guide-Book No. 3, 1913, pp. 119-126.

GOLDTHWAIT, J. W., *Marine shorelines in Southeastern Québec*, Geol. Surv. Can., Summ. Rept. for 1912, 1914, pp. 357-359.

GOLDTHWAIT, J. W., *The St. Lawrence Lowland*, Unpub. MS., Geol. Surv. Can., 1933.

JOHNSTON, W. A., *Late Pleistocene oscillations of sea-level in the Ottawa valley*, Dept. Mines, Canada. Mus. Bull. 24, 1916.

MACKAY, J. R., *Physiography of the lower Ottawa valley*, in *Rev. Can. de Géog.*, 3, 1949, pp. 53-96.

MACPHERSON, J., *The post-Champlain evolution of the drainage pattern of the Montréal lowland*, Unpub. Ph. D. thesis, Dept. Geography, McGill University, 1966.

OSBORNE, F. F., *Ventifacts at Mont-Carmel, Québec*, in *Trans. Roy. Soc. Can.*, 14, ser. III, sec. IV, 1950, pp. 41-49.

PARRY, J. T., *The Laurentians : a study in geomorphological development*, Unpub. Ph. D. thesis, Dept. Geography, McGill University, 1963.

PARRY, J. T., and MACPHERSON, J. C., *The Saint-Faustin – Saint-Narcisse moraine and the Champlain Sea*, in *Rev. Géog. de Montréal*, 18, 1954, pp. 235-248.

POTZGER, J. E., *Nineteen bogs from Southern Québec*, in *Can. Jour. Botany*, vol. 31, 1953, pp 383-401.

POTZGER, J. E., and COURTEMANCHE, A., *A series of bogs across Québec from the St. Lawrence valley to James Bay*, in *Can. Jour. Botany*, vol. 34, 1956, pp. 473-500.

PRESTON, R. S., PERSON, E., and DEEVEY, E. S., *Yale natural radiocarbon measurements, II*, in *Science*, vol. 122, 1955, pp. 954-960.

RITCHOT, G., *La morphologie des environs de Montréal.* Thèse M. A., Montréal, 1959.

RITCHOT, G., *La plate-forme de Montréal, étude et cartographie géomorphologiques.* Thèse 3e cycle, Strasbourg, 1963.

ROMAINE, V., *Physical geography of the Two Mountains area, Québec*, Unpub. MA. thesis, Dept. Geog., McGill University, 1951.

STANSFIELD, J., *The Pleistocene and recent deposits of the Island of Montréal.* Geol. Surv. Can. Mem. 73, 1915.

TERASMAE, J., *Notes on the Champlain Sea episode in the St. Lawrence lowlands, Québec*, in *Science*, vol. 130, 1959, pp. 334-336.

TERASMAE, J. *Contributions to Canadian palynology*, No. 2. Geol. Surv. Can. Bull. 56, 1960.

WILSON, M. E., *Arnprior, Quyon and Maniwaki areas.* Geol. Surv. Can. Mem. 136, 1924.