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MARINE CREVASSE FILLINGS IN THE LOTBINIERE REGION, QUEBEC

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ABSTRACT. Peculiar ridges in an extensive region on the south shore of the St. Lawrence River near Quebec, are the result of the filling of crevasses in drift-burdened and stagnant ice by sands and gravels of a late Pleistocene sea. The presence of such easily eroded features below the marine limit indicates that the ice must have persisted until the sea level had fallen to a low, but as yet undetermined elevation. Topographic maps have features which suggest that a considerable part of the valley on the south side of the St. Lawrence was protected by stagnant ice.

INTRODUCTION

QUEBEC CITY is strategically situated on the route to the interior of North America. The high ridges of the Appalachian region here come against the Laurentian upland to form the eastern vertex of the St. Lawrence lowlands. The entrance to the lowlands is thus through the narrow gap in which the St. Lawrence River now flows and through which sea water invaded the lowlands in late Pleistocene time. The deposits formed during that time are, therefore, of particular interest in working out the history of the region. Considerable work has been done to determine the upper limit of marine submergence (Goldthwait, 1911, 1914), but the Pleistocene deposits of the lowlands at lower elevations have not received much attention.

In driving from Quebec to Montreal by the road on the south side of the river, a geologist cannot help contrasting the topography with that along the highway on the north side of the St. Lawrence. On the north side, terraces with pronounced cusps are prominent, whereas, on the south, such terraces are absent. Furthermore, on the south side, ridges of sand and gravel, which superficially resemble eskers, stand above sand plains at elevations below the upper limit of the late Pleistocene sea. Examination of the ridges shows that they were originally fillings of channels in a stagnant ice sheet that protected the unconsolidated deposits of the surface from watermarking by the shallowing sea.

LOCATION OF CREVASSE FILLINGS

The ridges occur sporadically in a region of about 450 square miles in Lotbinière, Nicolet, Mégantic, and Arthabaska counties, in the area covered by the Lyster, Bécancour, and Portneuf (one mile) sheets of the National Topographic series of the Department of Mines and Resources, Ottawa. Figure 1 shows the outline of the area together with a key to the topographic sheets, which are listed under maps in the "references." The Canadian National Railways, Intercolonial Branch, crosses the region, which in the main is but sparsely settled. Up until recently, a few secondary roads provided access to the area, but the Laurier highway (No. 3) now links Montreal and Quebec *via* the south shore of the St. Lawrence and makes the region easily accessible by motor car.

The borrow pits and road-cuts along the highway expose sections of the sand and gravel deposits. Much of the area is covered by a scrubby second growth of mixed hardwoods and softwoods, so that the smaller topographic features are easily overlooked. However, late in 1949, forest fires swept much of the region, and many of the minor topographic forms are temporarily easily observed.

GEOLOGICAL SETTING

The outcrop of the St. Lawrence and Champlain fault, which forms the boundary between the lowlands of the St. Lawrence and the Appalachian region, crosses the area in a N 55°E

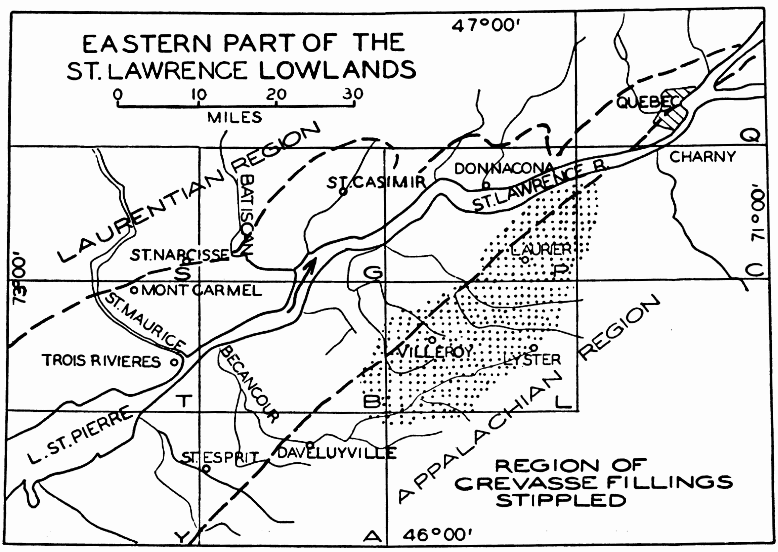

Fig. 1. Location map. The broken lines show the limits of the lowlands.

direction. The overburden is so continuous, particularly in the area covered by the Lyster sheet, that the precise position of the fault cannot be determined by ordinary mapping. The broken and higher ground that might be expected to mark the Appalachian front occurs about ten miles southeast of the boundary fault.

The region is a sand plain whose uniformity is broken only by stream valleys, by some sand dunes, and by the features described in this paper. The surface slopes southwestward at about four feet a mile from the 450-foot to the 350-foot contour; there is, however, on the northwestern side a tendency for the slope to be more toward the nearby channel of the St. Lawrence.

The plain is characterized by well-bedded medium- to coarse-grained sand. The abundance of sub-angular boulders from a Laurentian source in the sand is noteworthy. In some cultivated fields, boulder heaps are as large as those commonly seen in morainic regions. Locally small deposits of alternating beds of fine sand and silt may be seen, and some peat (Ells, 1889) occurs. Till was not observed at the surface, although it was seen where a stream channel had been deepened for an irrigation project. Here blue boulder clay underlies the sand 15 feet below the general surface of the plain.

DESCRIPTION OF CREVASSE FILLINGS

Tracings of parts of the topographic maps of the region are shown in figures 2, 3 and 4 in which the form and relationships of some of the higher ridges are shown. As will be seen from the maps, the ridges have narrow bases and they rise steeply to as much as 75 feet above the surrounding sand plain. Offsets such as those on the ridge 1¾ miles southeast of Villeroy (fig. 2) are common. Despite the continuity of the ridges, they are seen to be made up of elements that have consistent trends, which are inclined to the long axes of some of the ridges. One of the few exposures of bedrock in the region forms the hill near the southeast corner of figure 3. The ridges of sand are shown by the contours, and they are not related to the form of the hill, showing that they were not developed on the present surface.

"Arrowheads" or "wishbones" are a spectacular feature of the ridges. These vary in perfection from the simple type shown in the region, one mile south of Villeroy (fig. 2), to the double type shown on the southwest corner of figure 2. It is noteworthy that in all cases the points of the arrowheads are directed southwest.

In addition to the pronounced features such as are shown on the topographic maps, there are low rounded ridges that at any one locality have two trends which intersect at about 30°. The low ridges are continuations of the higher ridges and may form the prolongations of parts of the arrowheads. The ridges, which are from one to 10 feet high and commonly from 25 to 50 feet wide, are not easily visible in the uncleared land, but on burned-over or cleared land, they may be seen to form a quadrille pattern on the surface. In general, the low ridges are continuous for considerable distances, and they are from 200 to 1000 feet apart, although they are apparently absent in some parts of the region. The trends of the ridges were measured at a number of localities, and statistical examination showed two maxima at N 60°E and N 83°E.

The ridges and the surrounding plain are composed principally of sand in uniform beds from one to four inches thick.

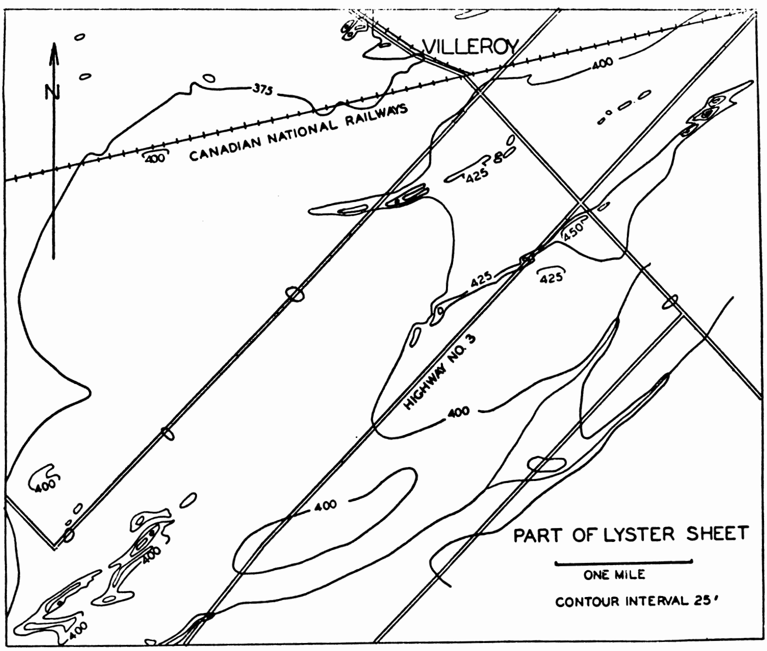

Fig. 2. Part of Lyster topographic sheet showing crevasse filling.

Little cross-bedding is seen. At some localities, fine well-bedded gravel is found.

A pit in one of the ridges, a mile southeast of Villeroy, has been exploited for sand. The uniform bedding on the flanks of the ridge dips 20° away from the axis of the ridge. On the axis of the ridge the bedding is somewhat irregular but tends to be horizontal. In this pit, the coarser gravel appears to occur at lower elevations near the axis of the ridge. Near the entrance to this pit, many fragments of shells broken by the passage of trucks occur. Whole shells were seen in sand near the top of the pit face. They are almost certainly in place for they do not have the scoured appearance of transported shells. The shells, identified for me by Dr. J. W. Laverdière, are *Macoma groenlandica*, *Saxicava rugosa*, and *Mya truncata*, all of which genera are common in the upper (Saxicava) clay and sand along the St. Lawrence valley in Quebec. These shells are certainly marine, and since they are in place, they show that marine water once covered this district.

ORIGIN OF THE RIDGES

At first sight, the higher ridges resemble eskers, as for example, the ridge two miles northeast of Laurier when it is viewed from the train or road. In detail, however, the ridges are unlike eskers in that they are less rounded in cross-section and less smoothly sinuous in plan. Tributaries to eskers are moderately common, but the arrowhead pattern seen on the ridges is not characteristic of eskers. Furthermore, it is a commonplace that the material of eskers is characterized by pronounced and rapid changes in size grades along the length,

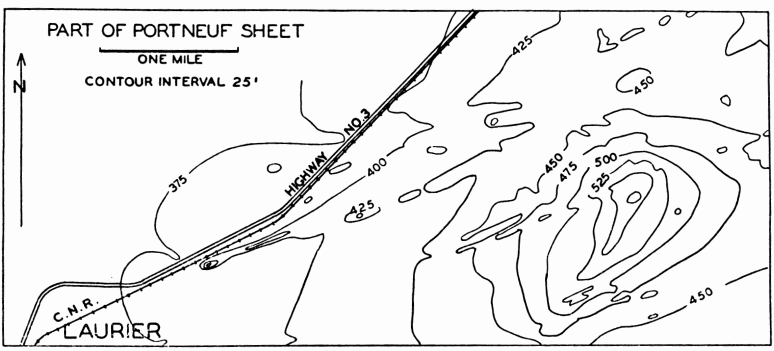

Fig. 3. Part of Portneuf topographic sheet. The hill on the southeast corner of the figure is bedrock. Note that the ridges extend across it.

whereas in these ridges, the material is uniform over considerable distances. Finally, marine shells are not commonly found in eskers.

Despite the fact that the ridges are not eskers, it is certain that ice had a role in their formation. Some material, now vanished, must have acted as retaining walls to protect and allow such ridges to form, and ice is the only substance that will fulfil the requirements. It is inferred that the ridges are in the direction of the channels, whose trends were in part determined by the direction of the crevasses. The arrowheads at the intersection of the ridges are thus the sites of enlarged crevasses, whereas the low ridges were the deposits formed in shallow channels on the ice surface. The larger and more irregular areas of elevated ground, for example 1¾ miles southeast of Villeroy, are probably the sites of depressions on the ice surface.

The even bedding of the sand and the marine fossils show that the sand was deposited from a sea that extended over the top of the ice sheet. Rock debris in or on the ice helped prevent it from being buoyant in the salt water.

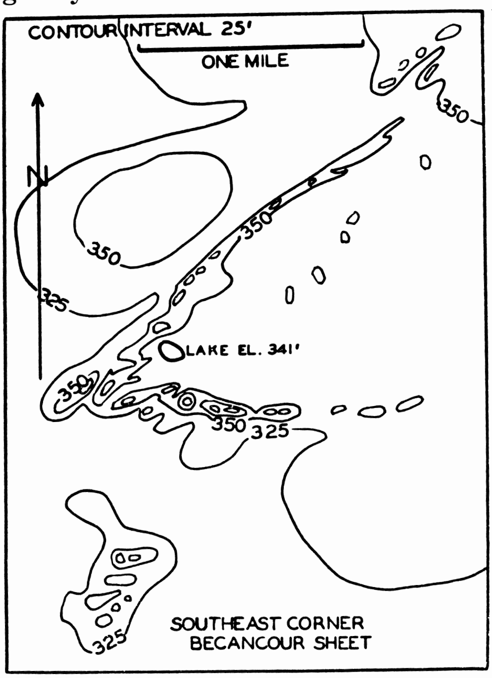

Fig. 4. Complex "arrowhead."

The fineness of the sediments composing the ridges and their exposed position above the plain after the ice melted would certainly allow such features to be obliterated in a few hours by wave movement in a large standing body of water, especially if the considerable fetch of the prevailing westerly winds at this place be considered. Chapman (1937, p. 117) suggests that single storms may have formed terraces in glacial lake Vermont. It is, therefore, probable that the surface of the sea was below the lowest ridge before the ice melted. Undoubtedly, the melting of the stagnant ice was retarded by the cover of glacial debris and marine sand.

The height of the present ridges gives the minimum thickness of the ice. The highest ridge stands 75 feet above the surrounding plain. Therefore, at this locality, there was at least 75 feet of ice. The upper limit of the marine submergence in this district determines the elevation of the surface of the sea in which the fossils lived. Goldthwait (1911, 1912) has determined the marine limit as 591 feet at a locality a mile south of Laurierville, only a few miles south of the features described here. Fossils at 425 feet elevation were the highest observed, and the thickness of ice sheet at this locality at the time sea crossed it was probably of the order of 170 feet. On the other hand, the lowest elevation at which ridges of this type are seen on the topographic maps is 300 feet, which is 290 feet below the marine limit. It is thus improbable that the ice on which the channels were developed was less than 75 feet and more than 300 feet thick as the sea advanced across it.

After much discussion, it has come to be agreed that eskers do not ordinarily form by the filling of channels on the top of ice. Their dissimilarities to certain types of crevasse fillings have been pointed out by Flint (1928). The principal argument against the superglacial origin of eskers is the common observation that streams on the surface of an ice sheet find, in a short distance, access to lower levels either at the bottom of or within the ice. Such an argument has no force in the case of ice submerged in water for the downward movement would be arrested by the pressure exerted by the surrounding water, which in the present case being saline, should be denser than fresh water. It is even possible that a reverse movement could occur, and the salt water would force fresh water upward through crevasses in ice. Such fresh water would be at the temperature of melting ice and should not appreciably enlarge the crevasses.

The sequence of events in the formation of the ridges may be summarized as follows. An ice sheet became stagnant in this part of the valley of the St. Lawrence. Crevasses were etched as the surface was ablated. Superglacial streams that probably drained westward occupied some of the crevasses, and debris released during the ablation accumulated in the crevasses. When the surface of the ice had fallen to about 600 feet elevation, marine water flooded the region, and surface debris was reworked to give a cover of uniformly bedded sediments. The greatest thickness of sediments was in the crevasses and as the ice melted the sediments were let down. The slumping away from the thicker accumulation of sediments produced the present dips of 20° outward.

OCCURRENCES OF FOSSILIFEROUS "ESKERS" AND CREVASSE FILLINGS

In North America, a fossiliferous esker-like form has been described by Trefethen and Harris (1940) from near East Orrington, Maine. Abundant marine shells occur *in situ* in what is considered a crevasse filling. Nichols and Lord (1937) have reported shells in eskers near Weymouth, Massachusetts. They, however, believe that the shells are derived from older sediments for they say: " . . . apparently, as the glacier moved over the inter-glacial Boston Harbor, it picked up mud and sand which contained shells. Later, these shells were either incorporated with the till or were washed out of the ice and into the eskers and outwash deposits." The statement is interesting when it is considered that the till, particularly along the lower St. Lawrence (Dawson, 1893, p. 38) contains marine shells.

Professor Auguste Mailloux, of the Agricultural College at Ste. Anne de la Pocatière, found during the course of his work on soil classification in Quebec, an esker-like form with marine fossils. The locality is 1½ miles southeast of Ste. Philomène, which is 8 miles south of Ville La Salle, a suburb of Montreal. Examination of the Lachine topographic sheets shows that the region has a general elevation of 150 feet. A series of disconnected elongated ridges forms a line ten miles long trending S 20°W. In places, the summit of the ridge is at an elevation greater than 200 feet, and the higher parts of the ridge are as much as a quarter mile wide. The map by Keele and Cole (1922) shows that the region is largely covered by till. Professor Mailloux states that 7 feet below the crest of the ridge, where it has been exploited for gravel, marine shells occur "by the shovelfull." No fossils were found in lower beds. Dr. Yves Desmarais (personal communication) states the ridge has considerable coarse gravel with cobbles.

The origin of the topographic features at such low elevation is not at once clear. The presence of marine shells in an esker at this position is remarkable, for it would have been mantled by the younger marine and freshwater deposits. The trend of the feature towards the mountain at Montreal suggests that it was formed by the meeting of currents in the sea or river, that it is a bar. Ridges with very coarse blocks near Hull, Quebec, have been considered the result of the interaction of sea and river-borne ice blocks in the declining stages of the sea by Chalmers (1898, p. 61), and Johnston (1917, p. 32) has accepted this explanation.

With the data at hand, the possibility that the Ste. Philomène ridge is the filling of the channel cut in stagnant ice cannot be ruled out. Stansfield (1915, p. 22), who examined the unconsolidated deposits at Montreal, suggested that clays and sands at the Glen, which is on the flank of Mount Royal near Westmount station, are ice contact deposits although he does not give his opinion on the position of the ice front at the time.

Crevasse fillings of sand have been described from the Cree Lake region, Saskatchewan, by Sproule (1939), who termed them "ice-crack moraines". The map and air photographs accompanying his paper show them as narrow ridges trending almost at right angles to drumlins and eskers around them and approximately parallel to a terminal moraine. An intersecting pattern of crevasses is preserved in the ridges, and obtuse angle of intersection is bisected by the direction of ice retreat and advance. Not enough data are available to know whether the same is true in Lotbinière.

Sproule emphasizes the sharpness of the features and insists on the absence of a standing body of water. Mawdsley (1936) considered that the washboard moraines of the Chibougamau district, Quebec, formed in the crevasses in an ice sheet near a standing body of fresh water. Norman (1938) showed that the washboard moraines are terminal features. Shaw (1944) described similar features formed against marine water east of James Bay. None of the papers on washboard moraines mentions the filling of crevasses by fine-grained sediments with a standing body of water advancing across the ice.

The many references to eskers as compared with the few descriptions of crevasse fillings suggsets that eskers are developed principally in or below ice and that special conditions are necessary for at least the preservation of crevasse fillings of fine material.

EXTENT OF LOTBINIERE ICE

In order to determine the extent of the former stagnant ice, a careful examination of the topographic maps was made. It failed to show any similar ridges below 300 feet elevation. It is possible, although the ice was loaded with debris, that where thicker, it became buoyant in the sea and calved into the estuary. Currents carried the icebergs out to sea.

The central part of the Aston topographic sheet shows irregularly disposed ridges and knolls that suggest kames. These features were not examined on the ground. They occur near elevation 300 feet and were possibly formed where the ice front was embayed. The narrowness of the bay would probably prevent the terraces forming there, for the best-developed terraces on the north side of the St. Lawrence River show evidence of strong current action.

T. H. Clark, in an unpublished report in the files of the Quebec Department of Mines, has described an esker near Grand St. Esprit, in the northwestern part of the Aston topographic sheet, 20 miles west of the nearest crevasse fillings. He comments that it is the only esker he has observed on the lowlands. Examination of the map shows that the general surface in the district is at altitude 200 feet. The esker, which trends N 20°W, has a typical sinuous pattern. Clark states that the esker is composed of sand and gravel. In view of the exposed position, it is unlikely that the sand would survive in standing water for long, hence the esker was probably formed after the decline of the sea.

Even more telling evidence for the presence of a protecting mantle of ice on the south side of the St. Lawrence is the absence of terraces such as are found on the north side of the river. According to Goldthwait (1932), the 210-foot terrace which marks a halt point in the lowering sea level, is of common occurrence on the north side of the St. Lawrence: nevertheless, no traces of a terrace at this elevation is seen on the south shore between Lac St. Pierre and Quebec. This in itself shows that at least some ice persisted until sea level had fallen to 210 feet, although the ice front may have been locally embayed, but the bays were not so wide as to allow currents to cut terraces. Most of the terraces on the north side of the river show evidence for current trimming. On the other hand, there are many occurrences of an 105-foot terrace on both sides of the river showing that the sea reached the surface of the rock or the till by the time that the surface had fallen to this level.

Northwest of the region with the crevasse fillings, much of the valley of the St. Lawrence is below 105 feet elevation, and hence it is difficult to determine whether the ice sheet ever extended there; however, as will be described in ensuing paragraphs, there is evidence that an ice sheet once rested against a considerable length of the Laurentian escarpment along the north side of the St. Lawrence lowlands.

The best evidence comes from the region where the Batiscan and St. Maurice rivers cross the boundary between the lowlands and the Laurentian region (fig. 1). In this section, the Laurentian escarpment is much lower than is commonly the case, and a triangular area with a base 25 miles east-west and its surface near 400 feet altitude forms an embayment extending about 15 miles into the Laurentian uplands. Part of the southern limit of the embayment is marked by a narrow ridge that stands as much as 75 feet above the ground to the north and extends 5 miles east and west of the village of St. Narcisse, which is near Batiscan River. The ridge is made of coarse gravel with large blocks and shows a cross-bedding that dips steeply northeast, that is, toward the Laurentian region. On the northwest side of the ridge, there is a gradation in a short distance from boulders through cobbles to sand and silt going northwest. The ridge shows so many features in common with the Newington moraine described by Katz and Keith (1918), that there is no doubt that it is also a moraine and was formed when ice stood along the base of the embayment.

Another ridge, Mont Carmel, also on the base of the triangular area of the embayment reaches 620 feet elevation at a locality 6 miles west of the moraine. This ridge, which is about 6 miles long, is composed entirely of gravel and sand which are cross-bedded with steep dips northwest. It is considered to be a delta formed with ice on the south and open water on the north. Another and lower delta of similar character is anchored on the Laurentian escarpment at Charette, which is 12 miles west of the delta just described.

The deltas and moraines provide evidence that the ice once extended along a considerable part of the edge of the Laurentian region, and it is probable that the whole area of the St. Lawrence lowlands in this region was occupied by ice when the Laurentian upland to the north was free from it. It is only reasonable to consider that the moraine and deltas mark the limit of the same ice sheet that stagnated in Lotbinière.

The deltas and the moraine were terraced by the declining sea and this, with the evidence of stagnant ice on the south side of the St. Lawrence, suggests that the sea gained entry to the lowlands along their northern edge.

SOURCE OF THE ICE SHEET

The silts on the northwest side of the moraine near St. Narcisse and the gravels of the delta deposits lie upon massive clays of the Leda type, and in view of the fact that Leda clays are commonly considered deposits of the Champlain sea formed soon after the Laurentide ice retreated across the estuary of the St. Lawrence, the question of the age and source of the Lotbinière ice sheet is raised. Furthermore, the Lotbinière ice is older than the gravels, sands and silts with clay that have been called Saxicava sand. One, therefore, is faced with the problem of an ice sheet present between two marine formations.

Many observers of the superficial deposits in eastern Canada have recorded the presence of two tills or of till overlying marine clay. Most of the references have been collected by Coleman (1927, 1932, 1941), who concluded that Leda clay is interglacial, and that the Saxicava sands, silts and clays are post-glacial. Disregarding the assignment of the Leda clay to an interglacial period, Coleman's conclusion that two marine formations are present and unconformable is probably valid. Such a view was long ago expressed by Dawson (1893.)

The Lotbinière ice then was not simply a relic of the retreating Laurentide ice sheet, that was crossed by the incoming

Champlain sea. The fact that the boulders and pebbles in Lotbinière and in the moraine and delta deposits are from a Laurentian source would support such a contention, but the relationship to the Leda clay invalidates it as does also the fact that there was open water on the lower parts of the Laurentian region, north of the deltas and the St. Narcisse moraine.

The possibility of an ice sheet from the Appalachian region must be considered. Chalmers (1898), who inferred the presence of ice caps in the Appalachian region near Quebec, believed a piedmont glacier formed in the St. Lawrence valley. Clark (1937) and Cooke (1937) have published evidence of the flow of ice northward from the Appalachian region to the St. Lawrence lowlands. However, other workers in the district, notably MacKay, who records striae with two trends in the Beauceville district, believe that the ice in the Appalachian region was part of the Laurentide sheet. MacKay (1921) concluded from striae that the ice moved S 15°E and S 65°E, but he was unable to determine certainly which set of striae is older.

One piece of evidence in the direction of ice retreat and relative age of the striae is described, but not discussed by MacKay (1921, p. 37). Along the Chaudière River in the Beauceville region at a locality where striae of both sets occur, an esker, which trends S 10°E and is 3 miles long, begins at elevation 900 feet on the north and reaches 540 feet on the south end. Although the evidence is not conclusive, the known habit of eskers suggests that the ice was retreating northward. The esker probably belongs to the latest ice sheet in this place, and therefore, the S 15°E striae are probably the younger set. And the direction is the same as that of striae in the Laurentian region.

Chalmers (1898) inferred that the ice cap in the Appalachian region was in existence before the Laurentide ice advanced into the region. The Lotbinière ice was, however, younger than the Laurentide ice and hence could not belong to an ice cap developed on the Appalachian highlands if Chalmers' inferences regarding the age are correct. The principal objection to an Appalachian source of the ice is the presence of the erratics of Laurentian rocks. It is difficult to conceive how the ice transport of Appalachian rocks by an ice sheet originating in the Appalachians could be avoided. The suggestion that the erratics could have been picked up from an older Laurentide till is not helpful for the Lotbinière ice sheet probably advanced across Leda clay. The Leda clay is believed to be thick although few good sections of the Leda clay and Saxicava sand have been measured; however, one measured by Clark (1947) on a landslip scar near St. Esprit, which is 9 miles west of the nearest crevasse filling, is instructive. It is shown as table 1, and is unusual in the presence of *Leda* shells at a locality so close to Quebec. The base of the section is at elevation

TABLE 1

		Ft.	In.	
				Top of cliff.
A	Soil and sand	2	0	Unbanded sand and soil.
	? non-marine	2	0	Banded brown sand.
B	Saxicava sand	13	4	Finely banded clay at top, grading downwards into very fine sandy clay, becoming more sandy towards the base.
		6	9	Poorly stratified sand. Fossils abundant, mostly *Saxicava*. Most of the fossils in slumped material below came from this layer.
			4	Well-bedded sand with abundant fossils, mostly *Saxicava*.
			11	Unbanded sand, no fossils, but with boulders up to 6″ across.
			7	Blue clay, no fossils.
		1	6	Sand, unbanded, no fossils.
C	Leda clay	25	10	Well-banded unctuous clay in layers 1 to 2″ thick with sandy partings. Gray on outer surface, black and fetid ¼″ or more within. *Leda glacialis*, with epidermis, occurs abundantly about 8′ 6″ below the top.
D	Algal and hydroid clay	39	1	Clay in 6″ beds separated by rusty sand partings up to 1″ thick. Black and fetid within. The lower 20′ contain algae and hydroids, but practically no other fossils.
E	Mya clay	2	0	Blue clay, well bedded, with fairly abundant marine fossils, including *Mya truncata*.
				Water level, August, 1945.
		94	4	Total thickness of section.

100 feet. It is significant that no certain till occurs between divisions "C" and "B" of the section, although it is possible that the lower 3 feet of "B" is a modified till, or perhaps this region is the site of embayment in the ice front, such as was suggested for the central part of the Aston sheet, and the till was removed. It is to be noted that the 67 feet of clay in the three lower divisions of the table would be called Leda clay. The break between Leda clay and Saxicava sand is characteristic of the region along the valley of the St. Lawrence, although at many localities boulders are larger and more numerous than in Clark's section. The break probably corresponds in time to the emergent period at Ottawa (Johnston, 1916, 1917; Antevs, 1939.)

The foregoing considerations would rule out both an Appalachian and the main Laurentide ice sheets as the source of the Lotbinière ice. However, the presence of the erratics from the Laurentian region indicates that the ice came from there. Chalmers (1898) and others have plotted glacial striae that are directed upriver in the Laurentian north of Quebec. The striae trend away from the large and high monadnock that lies in *Parc des Laurentides* between Quebec and Lake St. John and are younger than the Laurentide striae. It is inferred that, after the retreat of the Laurentide ice sheet and deposition of the Leda clay, a local ice cap developed on the monadnock, and a tongue of ice from it occupied the northeastern part of the St. Lawrence lowlands before marine water broke in for a second time. The evidence in support of this conclusion will be given in another paper.

CONCLUSION

The ridges of Lotbinière are somewhat modified casts of the channels in stagnant ice that existed when marine water advanced into the region in late Pleistocene time. The ice sheet once occupied the entire width of the St. Lawrence valley and was probably from a Laurentian source which was a local ice cap. Although the best evidence of the former extent of the stagnant ice is given by the crevasse fillings, other features shown on the topographic maps show that the surface was protected by ice until the sea fell below 210 feet but was exposed to wave action by the time the surface was at 105 feet.

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Maps—Canada, National Topographic Series, Scale: 1″ = 1 mile. The letters refer to figure 1.

Aston (A) 1920 revised 1944; Bécancour (B) 1921 reprinted 1938; Chaudière (C) 1916 revised 1944; Grondines (G), 1931; Lyster (L) 1922 revised 1944; Portneuf (P) 1920 revised 1944; Quebec (Q) 1914 revised 1944; Shawinigan (S) 1928 reprinted 1949; Three Rivers (T) 1921 revised 1944; Yamaska (Y) 1922 revised 1937.

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