GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

PAPER 59-8

SURFICIAL GEOLOGY OF THE BÉCANCOUR MAP-AREA, QUEBEC 31 I/8

N. R. Gadd

Price, 50 cents

1960

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Map 42-1959, Surficial Geology, Bécancour, Que... in pocket

SURFICIAL GEOLOGY OF THE BÉCANCOUR MAP-AREA, QUEBEC

INTRODUCTION

LOCATION

The Bécancour map-area is that part of the St. Lawrence Lowlands bounded by latitudes 46° 15' and 46° 30' N and longitudes 72°00' and 72° 30' W. It occupies parts of Champlain, Nicolet, Arthabaska, and Lotbinière counties of the province of Quebec. Map-sheet 31 I/8 of the National Topographic Series, Bécancour Sheet, is the base-map for the geological work described here. The area is accessible from Montreal and Quebec by highway 2 on the north shore, and by highways 3 and 9 on the south shore of St. Lawrence River. The nearest St. Lawrence River port is Trois Rivières.

ACKNOWLEDGEMENTS

Able assistance was given in the field by Garth D. Jackson, Gilles Carrière and Jean-Paul Charette in 1950, by Robert Crouse, Guy Sicard and Pierre Crépeau in 1951, and by Paul F. Karrow, Conrad Bédard and Phillipe Cardinal in 1952. Pollen analyses of organic deposits were made by J. Terasmae of the Geological Survey of Canada.

This report is based on a doctoral thesis presented at the University of Illinois (Gadd, 1955). Professor George W. White, head of the Department of Geology at the University of Illinois, gave valuable guidance in office and field consultations during its preparation.

PHYSIOGRAPHY

Minor topographic features controlled by surface deposits are superposed on a large regional bedrock feature, the elongate trough of the St. Lawrence Lowland. The general profile of the Lowland through the map-area is flat and U-shaped with a central depression excavated in bedrock by a preglacial river, later filled by glacial and marine sediments, and now nearly re-excavated by the St. Lawrence River. The Bécancour map-area stands astride the St. Lawrence River in the central part of the Lowland.

Maximum relief within the map-area is of the order of 350 feet. The local base-level of erosion, the St. Lawrence River, has elevations of 15 to 20 feet within the map-area. Local relief is gener-

ally small, but marked escarpments and sharply incised valleys provide an interesting contrast. The highest point, the crest of a 'Crête de Coq'[1] in the southeast corner of the area, is a little more than 375 feet in elevation.

The highest point north of the St. Lawrence River is a small hill of glacial till between 150 and 175 feet in elevation, west of the village of Vincennes (St. Luc de Vincennes). From this hill a sand plain, marked only by the Champlain Valley and a shallow depression now filled with bog, slopes gently southeastward towards the main line of the Canadian Pacific Railway. There a marked escarpment truncates this gently undulating sand plain. A few dunes, now chiefly stabilized by vegetation, have formed near the crest of the escarpment, but few exceed 10 feet in height. The smooth escarpment, which is nearly 75 feet high, can be seen best from points along highway 2 in the section between the villages of Champlain and Batiscan. North of the escarpment the greatest relief is along the Champlain Valley where the river has incised a valley 50 to 60 feet below the level of the plain.

From the major escarpment at the railway to the St. Lawrence River the descent of about 25 feet is made stepwise in a number of broad flat terraces at small vertical intervals. The height of most of the scarps is accentuated by the occurrence at their crests of low, narrow sand ridges that vary in height up to about 10 feet, but are generally 5 feet high or less.

South of the St. Lawrence River the surface topography is similar to that on the north; it is highest in the southeast, sloping riverward with several more or less planar areas separated by escarpments that parallel the St. Lawrence River. Again the local relief is small, except for that of the Crêtes de Coq (map-unit 7), some parts of which stand 75 feet or more above the surrounding plain.

A triangular area south and east of a line between Ste. Gertrude and Ste. Philomène de Fortierville is characterized by rolling topography. A belt 5 to 7 miles wide across the base of this triangular area consists of smooth, low, subparallel till-cored ridges and low knolls that are part of the Drummondville moraine (Gadd, 1955, p. 28). Local relief in this belt generally does not exceed 25 feet. The small area southeast of the moraine drains to both north and south, but mainly south to the west-flowing section of the Bécancour River, which touches the southeast corner of the area near Blandford (St. Louis de Blandford). A thick wedge of sand deposits flanks the northwestern limit of the morainic belt.

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[1] A well-established local name for the sharp-crested, elongate transverse dune ridges of the area; means coxcomb.

A major compound escarpment is cut in these sands. The scarp is obvious where the Bécancour River crosses the southern limit of the map-area. It extends northeastward through Ste. Gertrude, reaches its maximum 3 miles southeast of Gentilly, and then divides into a number of scarps; the most prominent and continuous one passes through Ste. Sophie de Levrard to Ste. Philomène de Fortierville. About 3 miles southeast of Gentilly, the road between Gentilly and Ste. Marie de Blandford crosses the escarpment and rises approximately 100 feet in a little more than a mile. At this point the main scarp is complex, comprising numerous narrow terraces and minor scarps ranging in height from a few feet to about 50 feet; the minor scarps truncate one another in a very complex pattern of multiple-swing cusps.

Northwest of the major scarp, in a belt about 6 miles wide crossing diagonally across the centre of the area (and in the vertical zone between 150 and 100 feet elevation), terraces are broad, (up to about a mile wide), and are limited by low sandy beach ridges. Terraces are separated by small vertical intervals, and scarps are not always readily visible on the ground, but, being marked by sand ridges, usually can be traced on vertical air photographs as white streaks.

A second major escarpment on the south side of the St. Lawrence forms the south bank of the abandoned channel now occupied by Lake St. Paul (southwest corner of the area). It extends northeastward to Gentilly where it crosses to the north side of highway 3. Two and a half miles farther northeast the scarp becomes the shore-cliff of the St. Lawrence River. Between Lake St. Paul and Gentilly the scarp has a fairly regular height of about 20 feet. At Gentilly it truncates a few low scarps and attains a height of about 30 feet. From there to the northern limit of the map-area, the scarp truncates higher and higher terraces until it reaches a maximum height of nearly 100 feet. This scarp corresponds to the one near the railway on the north shore, the southern being the slip-off slope and the northern, the undercut bank. Between these two scarps are alluvial deposits of recent date.

The channel now occupied by Lake St. Paul, southeast of the village of Bécancour, is a former channel of the St. Lawrence River. The till-covered area between the lake and the St. Lawrence was an island between channels whose currents were strong enough to scour clean and erode the bedrock in some places. Recent meanderings of the main channel of the St. Lawrence River and silting of the east end of the old channel by the Bécancour River have isolated the channel sector and reversed its drainage so that Lake St. Paul now drains westward into the St. Lawrence and not northeastward as it did formerly. Even now, during high flood stages of the St. Lawrence River, some water may flow over into the Bécancour River from Lake St. Paul.

DRAINAGE

ST. LAWRENCE RIVER

In its 160-mile course between Montreal and Quebec city the St. Lawrence River drops from a surface elevation of about 25 feet to sea-level. The limit of measurable tidal influence on the St. Lawrence is probably in the vicinity of Lake St. Pierre (a lake-like expansion upstream from Trois Rivières). From there downstream, tidal influence increases. At Trois Rivières the range of tides (i.e. the average difference between successive highs and lows due to tidal influence, regardless of river stage) is 1 foot; at Champlain it is 2.75 feet, and at Batiscan, 3.5 feet (Jones, 1952, p. 22). Thus in the Bécancour area the level of the St. Lawrence River is under a small but measurable tidal influence. Low-stage tidal flats occur particularly along the south shore of the St. Lawrence throughout the map-area and tidal shoals, the largest known as the Gentilly Shoal, occur in midstream between the villages of Champlain and Gentilly.

Despite the marginal shoals, flats and seasonal flood plains, the St. Lawrence is a youthful river. Its currents range from 0 to 8 knots and numerous rapids are known. Incision is marked by steep cut-banks (mainly on the north shore in this area) opposite gentle slip-off slopes. Sand bars (e.g. Batture à Bigot and Gentilly Shoal), and broad, lake-like expansions of the channel (e.g. Lake St. Pierre) are characteristic features of the central and lower parts of the course. These features place the geomorphic age of the St. Lawrence River at no greater than middle to late youth. Tributary streams range in age from extreme youth to early youth.

CHAMPLAIN RIVER

Champlain River is the only large tributary stream in the area north of St. Lawrence River. It is approximately 30 miles long and rises near the village of Valmont, 12 miles northeast of Trois Rivières, at an elevation of about 400 feet. In the first 9 miles of its course the river flows southeasterly to a point 5 miles east of the St. Maurice River and then bends sharply eastward along what may have been an early post-glacial channel of the St. Lawrence. Where it enters the west side of the map-area, the Champlain River has an elevation of approximately 90 feet. It meanders for 8 miles northeastward and then makes a right-angled bend southward to join the St. Lawrence River. Through its upper course in the map-area the river flows in a valley incised 50 to 75 feet into a sandy plain underlain by thick marine sediments. In its lower course it emerges from the deep valley into a low terrace, elevation approximately 25 feet, through a notch in the 75-foot escarpment cut earlier by the St. Lawrence River. From the

scarp to the St. Lawrence the Champlain Valley is 10 to 20 feet deep, but its banks are nearly vertical in most places and meanders have migrated very little. This indicates rather rapid incision of the Champlain River, and therefore, rapid recession of the St. Lawrence from its 25-foot terrace to its present level. Incision of the upper part of the valley of the Champlain suggests equally rapid recession of the St. Lawrence from about the 100-foot level.

OTHER NORTH-SHORE STREAMS

A few short, straight, spring-fed streams rise from sand and muskeg areas on the north bank of the St. Lawrence within 3 miles of the shore. Some are intermittent and all are extremely youthful, having incised shallow V-shaped valleys in the alluvial sand and underlying soft marine clay. Many such streams have been dredged to increase their rate of flow and improve the drainage of the rather flat plain across which they flow.

BÉCANCOUR RIVER

This river has its headwaters in Bécancour Lake, elevation 1,312 feet, south of Thetford Mines, Quebec, about 100 miles from the mouth of the river. From its highland source the river flows northward to the vicinity of Lyster Station then westward and southwestward along the south side of the Drummondville moraine and then, at Maddington Falls (Daveluyville), in the Aston Sheet (31 I/1), the river cuts diagonally across the moraine and finally turns sharply northward to find its course down the north flank of the moraine to the St. Lawrence. Only part of the northward course is shown on the Bécancour map-sheet.

In the Bécancour area the river is in early to middle youth. Its valley is deeply incised between steep banks and has no flood plain. Rapids form a nearly continuous series between St. Wenceslas River and Bécancour village. In that section of its course the river-bed is carved in soft red shale of the Ordovician Bécancour River formation. Upstream from the rapids the river gradient is less steep and an incipient flood plain is seen in a few places.

OTHER SOUTH-SHORE STREAMS

Tributaries flowing northward into the St. Lawrence within the map-area, with the exception of Bécancour River, are relatively short; they have steep gradients and deeply incised V-shaped valleys. Rivière Gentilly, Rivière aux Orignaux and Petite Rivière du Chêne rise in the crest and north flank of the Drummondville moraine. In 15 to 20 miles they drop from elevations of nearly 300 feet to the level

of the St. Lawrence River (generally 10 to 18 feet in this area). Gentilly River has one series of rapids caused by an outcrop of bedrock. Other rapids in both Gentilly and Orignaux rivers are caused by accumulations of boulders from morainic areas crossed, or by masses of material that have slumped or flowed into the channel.

Ruisseau de la Ferme, Rivière du Moulin, and Rivière aux Glaises rise from springs at the toe of the Ste. Gertrude-Ste. Sophie-Ste. Philomène escarpment. The longest of the rivers is about 8 miles in overall length. Shorter streams less than a mile to 5 miles long occupy deep V-shaped ravines. In dry seasons some carry very little water. Landslides and mudflows are very common along their banks as most are cut in very soft marine or varved lacustrine silts and clays.

GENERAL GEOLOGY

The study of many hundreds of natural and artificial sections exposing from a few feet to nearly 200 feet of unconsolidated sediments forms the basis for the Pleistocene stratigraphy summarized in the Table of Formations. The Palaeozoic stratigraphy is after Clark (1947).

BEDROCK GEOLOGY

The absence from the St. Lawrence Valley of known deposits of consolidated sediments younger than the Palaeozoic indicates an extremely long erosional period preceding the Pleistocene glaciation. Unconsolidated Pleistocene sediments rest directly on relatively flat-lying Ordovician strata in the Bécancour map-area. No bedrock exposures are known in that part of the area north of the St. Lawrence River, and south of it limited exposures occur in active or abandoned stream valleys.

There are a few outcrops of the Pontgrave River formation on abandoned terraces of the St. Lawrence River west of the village of Rivière Gentilly, on the south shore of the St. Lawrence. They occur also in escarpments along highway 3 at points south of the village of Ste. Angèle (highway 3 just west of the map boundary), west of Bécancour, and between the villages of Rivière Gentilly and Gentilly. Another exposure on Ruisseau de la Ferme below the culvert on highway 3 is abundantly fossiliferous. Sediments in these outcrops comprise gritty calcareous grey shales and thin beds of grey limestone.

Type sections of the Bécancour River formation (Upper Richmond) (Clark, 1947), thick red shales with some thin beds of red sandstone, occur in the valley of the Bécancour River between the village of Bécancour and the mouth of St. Wenceslas River. Other exposures

TABLE OF FORMATIONS

Era	Period	Age	Formation and Lithology
CENOZOIC	Pleistocene and Recent	Wisconsin and Younger	Bog deposits: mainly peat, some muck
			Low Terrace sands: mainly alluvial sand, some silt and peat; old alluvium of abandoned channels of the St. Lawrence River, minor modern alluvium
			High Terrace sands: well-sorted, medium- to fine-grained sands, some fine gravel, of fluviatile and estuarine origin
			Crête de Coq sands: very well sorted aeolian sands in elongate sharp-crested dune ridges
			Champlain Sea sand: shallow-water sediments of the Champlain Sea; mainly fossiliferous, fine to medium sand and some gravel
			Champlain Sea clay: deep-water sediments of the Champlain Sea – mainly fossiliferous silty clays in three facies, 1) massive, 2) massive with dark mottlings of organic matter, 3) laminated with some layers of sand
			Wave-washed till: a shore deposit of the Champlain Sea developed on glacial till exposures; chiefly boulder-strewn sand and gravel deposits with some fossil localities
			Gentilly till: grey, sandy and calcareous glacial till; varied texture
			Deschaillons varved sediments: sediments of glacial Lake Deschaillons (Karrow, 1959); grey varved silts and silty clays
		St. Pierre Interval	St. Pierre sediments Peat: highly compressed Sphagnum and Carex peat, with much wood in some layers (older than 40,000 C_{14} years) Sand: stratified and crossbedded fine to medium sands
		Unconformity	
		Pre-Wisconsin	Bécancour till: generally calcareous sandy till of varied texture; commonly brick-red in colour
			Red varved silts
Unconformity			
PALAEOZOIC	Ordovician	Richmond	Bécancour River formation: red sandstone and shale
			Pontgrave River formation: grey calcareous shale, some limestone

of similar rocks are found in the escarpment between 50 to 75 feet elevation that parallels highway 3 between the villages of Bécancour and Rivière Gentilly. Thin-bedded red and green shales, probably a basal part of the Bécancour River formation, are exposed in a picturesque waterfall and in the steep walls of a small gorge on the Gentilly River near latitude 46°20' N and longitude 72°15' W.

PRE-WISCONSIN DEPOSITS

Red Varved Silts

The oldest glacial deposit in the vicinity of the Bécancour area is one of reddish varves. The best exposure is a 5-foot section at the base of a 65-foot river-trimmed escarpment on the south shore of the St. Lawrence River at Cap Levrard, 3 miles downstream from the village of St. Pierre les Becquets (Grondines map-area, 31 I/9).

Brick-red to reddish grey varves comprise dark winter layers about half an inch thick and lighter-coloured summer layers in a regularly alternating series of nearly horizontal beds. They are composed principally of material of silt size; summer layers contain small partings of crossbedded, very fine sand. The summer layers generally are strongly calcareous and the winter layers are commonly non-calcareous.

In addition to the Cap Levrard section, only two other exposures of red varves have been observed; one along Rivière aux Orignaux and the other along the St. Lawrence River near Deschaillons. In all three exposures the varves are contorted and overlain by red till. The sediments are apparently proglacial in origin, but because outcrops are so few it cannot be said whether the three exposures are part of one large lake deposit or belong to separate small deposits.

Bécancour Till

Pre-Wisconsin red till of the Bécancour area is named Bécancour till for the river on which its type section occurs. The type section coincides with that of the Ordovician Bécancour River formation (Clark, 1947) and consists of exposures near the base of river banks along the west side of Bécancour River between the village of Bécancour and the St. Wenceslas River, a tributary of the Bécancour. In these exposures, Bécancour till which is brick-red sandy clay till, directly overlies the shales and sandstones of the Bécancour River formation; the till is commonly about 10 feet thick. It is overlain by Gentilly till and/or clay of the Champlain Sea and younger estuarine

sands. Other exposures in the area are along abandoned scarps south of Lake St. Paul and east of Bécancour, and in surface exposures at Précieux Sang and in the southeast quarter of the map-area. The greatest thickness of Bécancour till observed in the area is 55 feet in an exposure 500 feet northwest of St. Wenceslas River on the east bank of Bécancour River.

No red till or correlative is known north of the St. Lawrence River. South of the river it is common in the Aston area, south of that described here, and has been observed by the writer outside the area as far southwest as the Richelieu Valley. Positive correlation of red tills in the St. Lawrence Valley is impossible at present. Probably the first glaciation, here represented by the Bécancour till, extended far beyond the limits of the Bécancour area, but its southern limit is not known.

The till derives its rich red colour from underlying Queenston shale of the Bécancour River formation. Shale fragments constitute much of the fine fraction of the till and there are many shale pebbles and cobbles, but boulders of the red shale are rare. Most constituents of pebble, cobble and boulder size are of igneous and meta-sedimentary Precambrian Shield rocks, with grey and pink granite and granite gneiss dominant. Also common in the red till is a green to greenish grey hypersthene granite with large microcline phenocrysts. This rock is common in the Shield areas north of Trois Rivières. Generally the granitic rocks dominate the assemblage and the till is quite sandy, but locally, where red shale or other soft sedimentary rocks are abundant, the till is clayey. The carbonate content decreases with the increase of clay content but generally the Bécancour till is very strongly calcareous. Sand and gravel lenses within the till are rare, but sands and gravels in layers interbedded with irregular masses and sheets of till occur in a thick section on the east bank of the Bécancour River opposite the mouth of St. Wenceslas River.

Except for the few places where red varves have been observed below the till, the Bécancour till rests directly on the bedrock. It is overlain by St. Pierre sand and peat, by Gentilly till, and by Champlain Sea clay in many exposures along the Bécancour River. Thus the till is older than deposits dated greater than 40,000 C_{14} years and is, therefore, designated in this report as being of pre-Wisconsin age. No evidence is available to assign the Bécancour till to any particular pre-Wisconsin time.

St. Pierre Sediments

The name St. Pierre, introduced here, applies to pre-Wisconsin non-glacial sediments consisting of sand and peat, the interval during which they were deposited, and to the type section in which the sediments were discovered. The name is provided by the community nearest the type section, St. Pierre les Becquets, a village on highway 3, south of the St. Lawrence River and half a mile north of the boundary of the map-area. The type section, is in a ravine half a mile south of the northern boundary of the area, on the property of Lucien Laroche in lot 4, con. I, of the parish of St. Pierre les Becquets, Canton de Levrard (or St. Pierre les Becquets), Nicolet county, Que. An intermittent stream, a little more than a mile long, occupies the ravine and flows northeast then northwest before crossing highway 3 and emptying into the St. Lawrence River. Four-tenths of a mile upstream from the highway a layer of compressed peat, 1 foot thick, occurs in the lip of a 10-foot waterfall. The St. Pierre section described in detail below is on the north face of the ravine beside the waterfall. Sands and peat occur along the sides of the ravine for several hundred feet downstream from the waterfall and in other areas occupied by map-unit 2 on the geologic map. They are not mapped separately because their outcrops are very nearly vertical.

Sands

Within the map-area, buried deposits of non-glacial fluvial sands are exposed along the south bank of the St. Lawrence River northeast of Gentilly (map-unit 2). The greatest observed thickness is 25 feet, but the maximum thickness is not known. The sands in most exposures are stained buff to yellowish with iron oxides; unoxidized sands recovered from borings are light grey. They are well sorted, uniformly fine to medium grained, have few pebbles and exhibit characteristic stream crossbedding structures. Silty sand deposits commonly observed beneath thick deposits of interglacial peat are thought to represent deposition in abandoned channels and depressions by interglacial streams. Relatively poor vertical drainage through the silty deposits may have contributed to the initial growth of bog vegetation and to the accumulation of peat.

Peat

In the type section the St. Pierre peat beds occur in sands beneath about 70 feet of Deschaillons varved sediments. Measured downward from the base of the varves the type section is as follows:

Lithology	Thickness (feet)
Medium-grained, very compact silty sand with sufficient finely disseminated organic matter to produce a distinct brown colour	1.5
Mainly organic matter with some organic silt; peat, much compressed, but well preserved, and flattened twigs and branches of wood	1.75
Medium-grained, grey to greenish grey silty sand; very compact, massive	3.0
Mainly organic matter with much compressed peat (mosses and rushes) and flattened twigs and trunks of trees; some beetle-wing covers observed	0.5
Medium-grained grey sand, some silt; very compact	2.5
Mainly organic matter with much compressed peat and wood in upper few inches; beetle remains common	1.25
Medium-grained, compact grey sand, silty near contact; well-sorted, stratified near base of section	2.5
Total thickness	13.0 feet

The peat beds characteristically are much compressed, and because of their relative hardness, stand out in relief against the more readily eroded inorganic sediments. The upper layer of peat in the section described, forms the lip of a 10-foot waterfall and also forms the stream-bed for about 10 yards above the falls. The peat beds are lenticular and discontinuous, but the upper layer described above can be traced along the wall of the ravine for about 200 yards downstream from the waterfall. No organic deposits are exposed 500 yards downstream, but a deposit of leached silty sand marks the horizon of bog deposition.

Terasmae (personal communication) reports that each of the thick peat layers contains a more or less complete natural sequence of organic bog deposits beginning with coarse detritus gyttja, fresh water lacustrine organic ooze at the base, followed in turn by Carex peat and Sphagnum peat with abundant remains of trees as flattened

trunks, branches, twigs and roots; some as nearly complete trees. The trees and other plants have relationships that indicate growth in place in bogs that were rarely flooded; woody layers, some which have a minor amount of associated charcoal, attest to several dry periods in the development of the bog.

Exposures in the clay pits of the Montreal Terra Cotta Company's workings at Deschaillons have small amounts of wood and peat in fluvial sands (St. Pierre sands) a few inches below the base of a thick section of varves. The outcrop of varves can be traced continuously from Deschaillons to the St. Pierre section. Thus the stratigraphic position and age (samples from St. Pierre section dated at greater than 40,000 C_{14} years) of the peat and wood layers at the two localities are the same. Small flecks and patches of vivianite, a hydrous ferrous phosphate (GSC sample No. 4318), $Fe_3P_2O_8.8H_2O$, in this area generally a brilliant blue colour, are associated with the wood at Deschaillons. In other sections the horizon of the peaty or woody layers is indicated by the presence of blue vivianite in the silts and sands.

All plants and other organic remains identified from the St. Pierre peat by Terasmae are of freshwater genera and species representing a somewhat cooler climate than the present. The insect remains identified by W. J. Brown of the Entomology Division, Department of Agriculture, Ottawa, were species of Donacia. These are freshwater bog insects that live on aquatic, semiaquatic and palustral plants and their pollen (W. J. Brown, in Gadd, 1955, p. 101). Frances J. E. Wagner of the Geological Survey of Canada has tentatively identified a few fragmentary tests of ostracods from the peat of the St. Pierre section as being of freshwater genera.

The association of fluvial sands with organic remains of distinctly freshwater origin indicates that a freshwater system existed in the St. Lawrence Valley during the glacial recession recorded here. There is no evidence in any area studied by the writer of marine or brackish-water deposition during the same interval.

WISCONSIN AND YOUNGER DEPOSITS

Deschaillons Varved Sediments

The name Deschaillons varved sediments is introduced here for grey varved clays and silts of pro-Wisconsin age occurring in the Bécancour map-area and vicinity. The type section is in the south face of the clay pits of the Montreal Terra Cotta Company at the village of Deschaillons (Grondines map-area, 31 I/9). There Gentilly till (Wisconsin) 8 feet thick overlies distorted varves at the top of a continuous section of varves about 85 feet thick; these in turn rest on a 22-foot

section of St. Pierre sediments. Other good exposures having thick sequences of horizontally stratified Deschaillons varved sediments are in the St. Lawrence River bank below the Roman Catholic church at St. Pierre les Becquets, and overlying the type section of St. Pierre sediments (see above). Between these three sections the outcrops of Deschaillons varved sediments may be traced almost continuously over a distance of about 6 miles along the south shore of the St. Lawrence. They may be observed also at many places for some 15 miles downstream from Deschaillons.

The outcrop area of grey varves within the map-area is very small. The varves occur in near-vertical banks along the south shore of St. Lawrence River downstream from Gentilly and along tributary streams near the St. Lawrence. They are not known to occur more than a mile south of the St. Lawrence. The glacial-lake basin where the varves were deposited appears to have been an elongate valley much like an expansion of the present St. Lawrence. This lake was named Lake Deschaillons by Karrow (1959).

Of an estimated 500 individual varves, 325 are half an inch or more in thickness. They occur in a 67-foot section that lies on interglacial sediments at the St. Pierre section. About 75 feet of varves is exposed in the river bank below the Roman Catholic church at the village of St. Pierre les Becquets, half a mile beyond the northern edge of the map-area along highway 3. Sections at the mouths of Rivière aux Glaises and Rivière aux Orignaux show several feet of grey varves overlying stratified interglacial sands.

The varves are mainly silt with minor clay; the summer layers of some thick varves have partings of very fine crossbedded sand. Light grey summer layers are calcareous, but the dark grey to black winter layers are non-calcareous and relatively impervious. Cementing of summer layers by carbonates concentrated by evaporation of laterally percolating ground waters occurs at exposed faces and is the principal cause of the formation in the varves of large tabular concretions. Some of these collected near Rivière aux Orignaux from the St. Lawrence River escarpment were about 9 inches in diameter and 1 1/4 inches thick at the centre, tapering to about 1/4-inch thick at the edges, thus giving the concretion a bi-convex shape in cross-section. Their circular form in plan probably derives from solution along vertical desiccation or shrinkage fractures in the clay that occur within about 30 inches of the exposure face.

In the Bécancour area grey varves directly overlie interglacial sands. They are therefore younger than material dated as older than 40,000 C_{14} years and presumably were deposited sometime during the Wisconsin. The varves are conformable with the sands and there is no evidence of a break in time between their periods of deposition. Gentilly till (map-unit 3) overlies the varves in many

sections and some upper layers of varves have been crumpled and distorted by ice action that laid down the till. Thus, the Deschaillons varved clays are probably the deposits of a proglacial lake that occupied an elongate narrow basin, whose location corresponds generally with that of the present St. Lawrence River. Glacial Lake Deschaillons was marginal to Wisconsin ice advancing southward from the highlands of the Precambrian Shield and was overridden by it.

Gentilly Till

Grey glacial till of the Bécancour map-area is named Gentilly till. The type exposures are in the vicinity of the village of Gentilly, which gives the sediment its name. The best exposures were in temporary excavations for the foundations of the Genty theatre and for fire-protection reservoirs in the village. The Gentilly till is generally grey in colour and of sandy texture; dominant constituents of pebble size and larger are Precambrian granites and gneisses, with black and grey limestone abundant in the type area; the matrix contains mainly finely divided local bedrock and is generally grey, but where it contains fragments of red Bécancour River formation, the matrix is reddish and gives the till a reddish to pink hue in some of its exposures. Downstream along the St. Lawrence from Gentilly, in the vicinity of the St. Pierre section, 2 or 3 feet of till overlie varves at the top of the St. Lawrence River bank. Grey till occurs in the banks of the Bécancour River particularly along the northeast shore near the village of Bécancour. The best exposure is at the northeast end of the bridge over Bécancour River at the south end of the village. Sheets of till in natural exposures in the map-area are as much as 10 feet thick, but outside the area the same till has observed thicknesses of about 60 feet. Most of the information on the nature and distribution of grey till in the map-area is derived from hand-auger borings. One of the few borings to penetrate the till sheets, at the village of Manseau, intersected 20 feet of sandy till.

Gentilly till has many boulders and is strongly calcareous. Its high proportion of sand to silt produces a high permeability. The components larger than silt are dominantly of granitic origin. Sand grains are chiefly discrete grains of quartz and feldspar; larger particles ranging from pebbles to large boulders, are chiefly of granitic igneous rocks among which pink and grey biotite granite and granite gneiss are most abundant. Pebbles and cobbles of local sedimentary rocks, chiefly black, grey and brownish limestone, are common. Rock flour in the matrix of the till contains much limestone.

In several sections along the Bécancour River, Gentilly till directly overlies red till or is separated from it by thin deposits of non-glacial sand. Near the St. Lawrence River in the northeast part of the map-area, Gentilly till is separated from the Bécancour till by

thick deposits of varves and interglacial sediments. Gentilly till rests on Deschaillons varved clays in several sections. The till, therefore, was deposited by an ice-advance post-dating the St. Pierre Interval and was heralded by the proglacial deposition of the Deschaillons varved clay; in this report it is considered to be of Wisconsin age.

As a result of extensive erosion during the St. Pierre Interval, Gentilly till rests on bedrock near Bécancour village and along the lower terraces of the St. Lawrence River, but is superposed on Bécancour till or on interglacial deposits at most other places in the area. Such unconformity results from the younger ice advancing over an interglacial drainage system that scoured bedrock in a channel more or less down the present course of the St. Lawrence.

Grey till exposed in the small outcrop shown by the area of map-unit 3 in the northwest corner of the map-area is only very slightly calcareous and contains a higher percentage of igneous rocks than the Gentilly till of the south shore. It is less dense and more friable than its south-shore counterpart. In composition it is more closely allied with the till of the St. Narcisse moraine farther north, which is not known to contain calcareous sedimentary-rock material. There is no evidence that the small area of till has the same age relationships as the St. Narcisse moraine (which overrides marine sediments of the Champlain Sea), and therefore it is correlated with the Gentilly till rather than with the St. Narcisse moraine. It could be expected that an ice-sheet moving out of the Laurentian highlands southward through the Bécancour map-area would encounter very little Palaeozoic sediment by the time it entered the north boundary of the map-area, but from that point onward it would encounter Palaeozoic rocks continuously to the south of the area. The glacial till deposited should therefore contain chiefly igneous rocks and be only slightly calcareous at the north edge of the map-area, and should become progressively more calcareous towards the southern limit of the area. This is true of the Gentilly till in the Bécancour area.

Reworked Till

Large parts of the map-area are characterized by concentrations of boulders, gravel and sand derived from glacial till (map-unit 4). They are associated with the Drummondville moraine. Deposits 4 to 6 feet thick that grade directly and abruptly into underlying glacial till are common. Some thinner accumulations are included in areas mapped as Gentilly till.

In these secondary sediments there is little evidence of anything but very limited, local transportation, the deposits generally being heterogeneous and unstratified. Thus, they probably formed more or less in place as lag gravels when waves pounded and washed

over the morainic area and removed fine sand and silt.

Shells found in the lag gravels are of species of Hiatella and Macoma, commonly found as single valves and rarely in concentrations. It is assumed from this that the shells have been transported from their natural environment by wave action. The coarse sediments represent the storm-beach environment and are mapped separately from the offshore shallow-water facies (Champlain Sea sands) that are characterized by an abundant molluscan fauna whose bivalve components occur principally as paired valves.

Champlain Sea Deposits

Classic literature on the Champlain Sea establishes two names for distinctive sediments: "Leda Clay" for the deep-water sediment and "Saxicava sand" for the shallow-water or shore facies. These names are based on the common occurrence of molluscan genera, Leda and Saxicava. According to currently accepted nomenclature (see Grant and Gale, 1931; and Dodge, 1950), generic names that have precedence are Yoldia and Hiatella respectively. Further, this report will show that much of the sand described as "Saxicava sand", in earlier literature, is non-fossiliferous and probably not marine. In addition, some clay described as "Leda clay" is non-fossiliferous and of other than marine origin. For these reasons the marine deposits are perhaps best described as marine clay and marine sand.

In common usage the name Champlain Sea denotes the marine embayment of the St. Lawrence Lowland in late glacial time. Marine sediments deposited in its waters are named in this report Champlain Sea clay and Champlain Sea sand to denote "Leda clay" and "Saxicava sand", respectively, as originally defined by Dawson (1893).

Champlain Sea Clay

Champlain Sea clay deposits are widespread, and they have been described from many localities all along the St. Lawrence Valley as far west as the lower end of Lake Ontario. They are also well known in the Ottawa Valley as well as in some broad valley re-entrants such as the Lake St. John and the Lake Champlain basins. The clays have been reported from elevations exceeding 600 feet, but typically they occupy the lowest parts of the St. Lawrence Lowland. In the Bécancour map-area, for example, clays of this type do not occur above an elevation of 350 feet.

Large volumes of clay have been removed from the area by erosion, but thick deposits remain. Exposures of 50 feet or more of massive clay are common in the belt 4 to 5 miles wide that trends northeast across the centre of the map-area and that includes areas mapped as map-unit 5. Data from well-borings indicate many deposits more than 100 feet thick in this same belt. Marine clay is found in most of the area south of the St. Lawrence that lies below 250 feet elevation, and in all parts of the area north of the St. Lawrence except in that small part underlain by grey till (map-unit 3).

Champlain Sea clay of Bécancour map-area is commonly massive and uniformly fine grained. In exposure it stands in nearly vertical faces, commonly wet from springs and seeps at the base of superjacent sands. Where wet and freshly exposed the clay has an anomalous blue-grey sheen that gives rise to the popular name "blue clay" ("la glaise bleue"). The true colour is grey and the shade becomes progressively lighter on drying until, when thoroughly dry the clay is very light grey to creamy white; sunlight reflected from its surface is sometimes quite dazzling.

Marine clays of this region shrink greatly on drying. Resultant columnar joints extend several feet from the surface and, as drying progresses, horizontal fractures develop. In this manner the material obtains a secondary blocky structure.

Near the base of some thick sections and in isolated basins south of the Drummondville moraine, the Champlain Sea clay contains finely divided organic matter. Blotches and streaks of jet black, unctuous organic material, and remnants of roots (as black hollow tubes) are common. Calcareous fossils are rarely preserved in this facies of the marine deposits, but some organic matter found lining cavities having the shape of some of the typical pelecypods is interpreted by the writer as being the periostracum of pelecypod shells whose carbonate structures have been dissolved since deposition.

Facies of the clay in which marine macrofossils are well preserved are horizontally stratified and commonly have partings of fine and coarse sand. Clay or silt bands from an inch to several inches thick alternate with sand layers up to an inch thick in deposits on the north bank of the St. Lawrence near the village of Champlain. Marine macrofossils are concentrated in sandy layers. Banding is very distinctive where sand is present, but in many places banding results from alternation of clay and silt-sized materials and but for the fossils, could readily be mistaken for glacial varves.

Although commonly referred to as clays, much of the deep-water sediment of the Champlain Sea is not clay in the strict sense. It is soft, pliable, slippery when wet, and has other physical characteristics

commonly attributed to clays, but generally does not pass the 'bite' test - i.e. it is gritty when ground between the teeth. Therefore the material should be called silty clay and silt, in most localities. Mechanical analyses from St. Lawrence Valley areas (Peck, et al., 1951, p. 4) record a predominance of silt-sized material and, in the clay-size range, very little clay mineral but rather finely divided mineral grains of quartz, feldspar etc., i.e. rock flour.

Generally the natural condition for these clays is that they have a water content above the liquid limit. Thus, the clays become fluid to liquid when remolded and the sensitivity factor (ratio of unconfined compressive strength remolded to unconfined compressive strength in natural state) approaches infinity. Clays with such properties are classed as extrasensitive by soil mechanics engineers (Peck, et al., 1951; Terzaghi and Peck, 1948). It is well known that such clays are unusually susceptible to large retrogressive landslides of mud-flow type. Some such land movements in Champlain Sea clays have claimed human life and many have caused extensive property damage.

Drying of the clay greatly increases its strength, thus it might be supposed that exposed banks of clay subject to drying in air could be sufficiently strong to be quite stable. However, the clay has increased strength only while it is dry, and quickly reverts to its unstable state on rewetting. Development of blocky structures in dry clay and the tendency for lumps of clay to rapidly disintegrate to sludge on rewetting, are important causative factors in the mechanism of landslides. Slopes temporarily stabilized by desiccation are subject to very sudden denudation when the air-dried layer of clay rapidly becomes soft, and particularly when loose material produced is carried away by slope-wash, and gullying during rainy periods. The toe of a slope may be unloaded by the rapid removal of a mass of slumped debris by ice action, by floodwaters or by human activity. These serve as trigger mechanisms that will quickly release a potential mud-flow.

In view of the very unstable nature of the clays all construction on or near steep clay banks is precarious. The danger of landslides can only be intensified by procedures for disposal of surface waters, sewage, etc., where such disposal involves concentration of flow water down any marine clay slope, or if it involves periodic rewetting of the surface. Careful planning of communities, especially in their control of surface waters, may help to prevent major mud-flow landslides in built-up areas. Preventive measures probably cannot be carried out economically in rural areas.

The Champlain Sea clays have an abundant molluscan fauna in some sections. Most common species are Yoldia arctica Gray, Macoma balthica Linné, and Hiatella arctica Linné (identified by F. J. E. Wagner). Yoldia arctica is the characteristic fossil of sand partings in laminated marine sediments along the north shore of the St. Lawrence near Champlain village.

Microfossils, chiefly foraminifera, from all facies of the Champlain Sea clay, indicate brackish-water conditions for the environment of deposition (from identification by F. Staplin, in Gadd, 1955). The macrofossils named all have tolerances for arctic conditions and low salinity. Yoldia arctica, (according to Wright, 1937, p. 327), now lives in sea water at temperatures below 0°C and thrives in muddy waters discharged by glacier streams. This fact combined with the temperature and salinity tolerances of the typical fossils, and with the varve-like lamination of some facies of the clay, gives credence to the hypothesis that the Champlain Sea was a body of brackish water that received meltwater from waning glaciers.

Champlain Sea Sands

The writer considers that the area of shallow-water marine deposits in the Bécancour area is very limited. This is in disagreement with the distribution shown by Logan (1863, Atlas) which implies that all sand below the limit of marine submergence is "Saxicava sand". Much of this so-called marine sand is of fluvial and estuarine origin.

Within the Bécancour area, Champlain Sea sand is limited to those areas mapped as unit 6 that includes fossiliferous sand, and some gravel, in shore deposits associated with well-marked wave-cut escarpments, storm beaches and bars. Some dune sand in minor dunes of the beach environment are included to simplify mapping. Also in this area, fossiliferous sands and gravel occur only above 200 feet elevation and are most abundant above 250 feet elevation. The thickest known marine sand deposits do not exceed 10 feet and their lateral extent along escarpments is limited and discontinuous. In the Drummondville moraine areas beach bars and escarpments are superposed on and are roughly conformable to the elongate ridges of the moraine.

A typical marine sand section is at the water-supply wells of the village of Ste. Gertrude, about $1\frac{1}{2}$ miles southeast of the village. There a marked escarpment is cut in glacial till. A lens of gravel and sand, 10 feet thick at a short distance from the toe of the scarp, thins rapidly northward towards the terrace plain, and the materials grade from coarse to fine in the same direction. In the excavations of the seepage galleries of the water-collecting system for the village,

workmen have excavated sands and gravels containing an abundant marine fossil fauna, that includes:

Mya truncata var. uddevalensis Forbes
Tethea logani Dawson
Hiatella arctica (Linné)
Balanus sp.
Mytilus edulis Linné
Macoma balthica (Linné)
Mya arenaria Linné
unidentified gastropod columella — length about 2 inches.
(identifications by F. J. E. Wagner)

Characteristic marine beaches of the area are poorly developed and contain only shallow deposits of beach sediment. This suggests that the marine level was stable for only a short period of time at any one level within the range 400 to 200 feet above sea-level and that recession of the marine embayment was continuous and rapid.

Non-marine Sediments

Crêtes de Coq Sands

Crêtes de Coq is a local name, meaning coxcomb ridges, that is applied to elongate, sharp-crested ridges of sand, a few of which occur in the Bécancour map-area (map-unit 7). The name is introduced to supplant the name "marine crevasse fillings" proposed by Osborne (1950b) for the sand ridges. In the Bécancour area the V-shaped ridge that encloses Lake Louise in its apex is Osborne's type example of the "complex arrowhead" variety of "crevasse filling" (Osborne 1950b, p. 897, Figure 4). The writer's study of this and at least twenty other similar ridges leads to the conclusion that the Crêtes de Coq are neither crevasse fillings nor marine, but rather are large transverse dunes. The materials are very well sorted, medium- to fine-grained sands; mechanical analyses show that the grade size is typical of wind-blown sands (Gadd, 1955). Frosted and rounded grains of quartz and other mineral constituents of the sand can be recognized with the aid of a hand lens, and examination by microscope shows the rounding to be well advanced.

The Crête de Coq mapped in the Bécancour area has a maximum relief of about 75 feet. The ridge is highest at its apex and diminishes in height eastward until it merges with the plain. As with most such features in adjoining areas, the major ridges conform with the lineation of marine shore features of the region, and it seems that the dunes result from accretion on pre-existing shore ridges. The common V-shaped form results from the formation of a dune on a

ridge that truncates another; most of the Crêtes de Coq are simple straight ridges and presumably represent deposition on a single straight beach feature. Internal structure indicates that northwesterly winds were dominant in the formation of the major transverse dunes. Orientation of blow-outs, though irregular, generally conforms with that prevailing-wind direction.

In the gravel pit at Villeroy, west of the map-area, the dunes are superposed on a marine gravel ridge, but there are no fossils in the dunes. It is concluded that the Crêtes de Coq are post-marine transverse dunes that owe their basic form to pre-existing marine beach structures.

High Terrace Sands

High Terrace sands (map-unit 8) were included among sands called "Saxicava sand" by Logan (1863, Atlas) because in much of the area they are superposed on marine clay. Proof of marine origin taken from the sands themselves is lacking in this early classification.

Sands mapped here as unit 8 are fine to medium grained and their bedding structures generally are nearly horizontal or have very small dips. Locally, over small areas, they have the steeply cross-bedded cut-and-fill structure of braided stream-deposits. The bedding indicates flow downstream with respect to the St. Lawrence. No fossils have been found in the High Terrace sands.

These non-fossiliferous sediments, showing structures characteristic of varying current action, lie in a vertical zone between elevations of 275 and 100 feet (i.e. between distinctly marine and distinctly fluvial deposits). There is no evidence of a time break in the sequence from marine sand, through High Terrace sands to fluvial deposits. Thus it is postulated that the High Terrace sands were deposited in the St. Lawrence system while an estuary occupied this part of the Lowland. The period of deposition ended with a rejuvenation of this part of the area when scarps that limit the riverward extent of High Terrace sands were cut.

Low Terrace Sands

Alluvial sands of map-unit 9 occupy all St. Lawrence River terraces in the vertical zone below 75 feet elevation, and in this report are named Low Terrace sands. Modern alluvial deposits in flood plains, deltas, tidal flats and shoals, are included. In this map-area the "low" terraces occupy incised channels limited by steep escarpments (see above).

The alluvial sands are generally not more than 10 feet thick. In colour, they are buff to rusty above the water table, and are light to dark grey or light brown below it. Sorting of the sediments is good and porosity is high, the material ranging from fine gravel (rare), to fine sand; medium-grained sand is characteristic. Organic matter is disseminated or occurs as thin layers within the sands. Essential components of the sands are sub-angular to rounded quartz, white and pink feldspar; minor accessories include magnetite and black and bronze-coloured mica. Most outcrops show regular, uniform bedding with gentle dips. In coarse sands, steep crossbedding and channel structures are common. Boulders accumulated as lag deposits are included in this map-unit, but most are mapped with the glacial till from which they are derived.

The Low Terrace sands lie unconformably upon marine clays and older sediments of the area.

Bog Deposits

Peat bogs (map-unit 10), a few hundred feet to several miles in maximum diameter, dot the poorly drained surface of the Bécancour area. They occupy closed and partially closed basins in which vertical drainage is poor and where lateral through drainage at the surface does not exist or is slow or intermittent.

HISTORICAL GEOLOGY

Tentative correlation of the glacial history of the Bécancour and adjacent areas has already been published (Gadd, 1953). That correlation was influenced by a radiocarbon dating on wood from the St. Pierre sediments. The date was in error as a result of A-bomb-test fallout. Reruns and datings by more refined techniques have indicated a a much greater age for the material (see below). In this report a new interpretation is presented for the correlation of the Pleistocene stratigraphy of the Bécancour and adjacent areas.

The first glaciation is now thought to be Pre-Wisconsin rather than Cary as previously reported. Sediments of the interglacial epoch were overridden by Wisconsin ice and in the area under discussion a single till sheet represents most of the Wisconsin. The waning of the second ice-sheet led to invasion of the Lowland by the Champlain Sea. Much of the present topography reflects the transition from marine to present fluvial conditions. The correlation of glacial and non-glacial events in the central part of the St. Lawrence Valley region is discussed further in following paragraphs.

PRE-WISCONSIN GLACIATION

More than 40,000 years ago an ice-sheet advanced southward from the Laurentian Highland to cross the St. Lawrence Valley. The first record of its presence in the vicinity of the Bécancour area was the formation of a glacial lake or lakes in the valley, presumably as advancing ice or other glacial material blocked the preglacial St. Lawrence River. In this lake reddish grey and pink varves were deposited. These were subsequently overridden by ice that distributed the Bécancour till over a wide area within, south, and southwest of the Bécancour area. The southern limit of this glaciation is not known.

Retreat of this first ice-sheet of the area is recorded in extensive deposits of silt and sands. Outwash gravels are rare and are found in only one outcrop in the Bécancour area. This is on the east bank of Bécancour River opposite the mouth of St. Wenceslas River where thick masses of till are interstratified with sand and gravel. This may mark a minor recessional halt of the ice-front.

In adjacent areas,varved clays overlie the red till, indicating that a post-glacial lake formed in the St. Lawrence Valley in pre-Wisconsin time, but the record is fragmentary. In many areas such varved clays may have been removed by erosion during the St. Pierre Interval.

In many of its outcrops the red till of the pre-Wisconsin glaciation is overlain directly by sediments of the St. Pierre Interval that contain peat beds more than 40,000 C_{14} years old. Hence it is older than any known Wisconsin and must be designated here simply as pre-Wisconsin.

St. Pierre Interval

During the ice-free period directly following the retreat of the pre-Wisconsin ice-sheet, northeastward drainage was established and some erosion took place. Thick alluvium of medium-grained sand and silty sand was laid down in broad channels, and large streams meandered within them. In poorly drained areas, such as abandoned channels and meander scars, organic matter accumulated as peat beds. These deposits were later buried by more alluvial sand.

The floral assemblage of the St. Pierre peat, as studied by Terasmae (1955, 1958) indicates a freshwater environment and a temperate climate that was somewhat cooler than at present. It was found incompatible with Sangamon climate as known elsewhere and because of its apparent age is here classified as probably pre-Wisconsin. There is room for speculation that the St. Pierre Interval may prove equivalent to very late Sangamon, or that it may belong to a very early Wisconsin time.

Regardless of age, the St. Pierre Interval was represented by a freshwater fluvial environment in the Bécancour and adjoining areas. No marine deposits have been found in the equivalent stratigraphic position even though logical interpretation of the published literature on the St. Lawrence region has permitted Coleman (1932) and Flint (1953) to postulate a marine invasion of the Lowland at each period of deglaciation. Until positive evidence to the contrary is uncovered, it will be assumed that marine waters did not occupy the St. Lawrence Lowland during the St. Pierre Interval. Correlation with glacial and post-glacial history of other regions would be necessary to explain this seeming anomaly and will require further study in many areas. Meanwhile, the writer prefers to rely on the available evidence from the Bécancour and adjacent areas where the St. Pierre Interglacial sediments are consistently of freshwater origin.

Age of the St. Pierre Peat

From preliminary studies of the type section of the St. Pierre sediments, Terasmae tentatively correlated the St. Pierre Interval with the Alleröd and the Two Creeks Interval (Gadd, 1953). This report was apparently corroborated by radiocarbon dating of wood (L190A)[1] (but see L369A, Olson and Broecker, 1959) from the same section which gave an age of 11,050 ± 400 C_{14} years. However, this date was later found to be in error because of radioactive fallout at the time of the original count. Further investigation by Terasmae revealed certain differences between St. Pierre and Two Creeks material. These differences indicated that climate during the St. Pierre Interval was warmer than Two Creeks, but cooler than the present.

Reruns and checks on the dating of the St. Pierre wood have resulted in dates, commonly beyond the limit of method, greater than 30,000 C_{14} years (Y242 >29,630; >30,840) (Preston, et al., 1955) and greater than 40,000 C_{14} years (W189) (Rubin and Suess, 1955). Correlative material from Les Vieilles Forges, Quebec (Y254, Y255) (Preston, et al, 1955) and from Pierreville, Quebec, (Y256) (Preston, et al., 1955) has provided radiocarbon dates of the same order, i.e. >29,630, >30,840, >29,630, respectively. Using a new method employing lignin extracted from St. Pierre wood, Lamont (L369A) (Olson and Broecker, 1959) now proposes an age greater than 44,000 C_{14} years. Still further refinement of method enabled de Vries[2] to postulate an age of the order of 60,000 C_{14} years.

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[1] Numbers and letters in parentheses indicate the laboratory number for a radiocarbon sample and the laboratory in which an analysis was made, e.g. L190A - sample 190A of Lamont Geochronometric Laboratory; Y = Yale, W = Washington, GRO = Groninger.

[2] Personal communication to J. Terasmae, 1958.

In consideration of the agreement of these more recent datings and in consideration of more precise palynologic findings, it is concluded that correlation with Two Creeks and Alleröd is disproven and that more probably the correlation should be with Sangamon (middle to late) or possibly with early Wisconsin. For simplicity the St. Pierre Interval is termed pre-Wisconsin in this report.

WISCONSIN GLACIATION

Advance of the Wisconsin glacier closed the St. Pierre Interval. As a result of blocking the St. Lawrence somewhere below Donnacona, the advancing ice impounded in the St. Lawrence Valley a large elongate glacial lake (named Lake Deschaillons by Karrow, 1959). At least 500 varves were laid down on the St. Pierre sediments. Pollen studies by Terasmae (personal communication) show no evidence of a time break between fluvial and glacio-lacustrine deposition but indicate a continually decreasing mean temperature up to the level where pollen disappears. The lack of pollen presumably coincides with the close approach of the ice-front. The ice-sheet advanced through Lake Deschaillons overriding varved sediments, contorting some, and advanced an unknown distance southward.

The advance that deposited the Gentilly till closed the pre-Wisconsin St. Pierre Interval but there is abundant evidence to show that the retreat of the same ice-sheet did not occur until much later in Wisconsin time. The relationship between the upper surface of the Gentilly till and overlying marine sediments of the Champlain Sea, as seen in the Bécancour area, gives support to this view. Where buried, the till is strongly calcareous throughout its thickness, is oxidized only by ground-water action, and shows no other signs of subaerial erosion. Indeed, even where exposed at the surface, the Gentilly till has only an incipient soil development comparable with marine clays in similar topographic positions. This implies that there was no significant erosional interval between Gentilly till glaciation and Champlain Sea.

Some glacio-fluvial and glacio-lacustrine sediments are found on the top of the Gentilly till in other areas, and are in turn overlain by marine clay. Where these occur there is direct transition upward into the marine sediment, and that, over only a few inches in most cases. Thus all evidence indicates at best a short interval between ice recession and marine invasion, but for practical purposes, virtual contemporaneity. From a few observations made in the southern parts of the Aston map-area (south of Bécancour) where some thick deposits of glacio-fluvial sands and gravels are found between the till and the laminated marine clay, there is a suggestion that there was a longer interval between glacial retreat and marine invasion and that as one progresses northward through the Bécancour area the thickness of sediment intercalated between till and marine clay gradually decreases.

Thus it would seem that by the time the ice-front had reached the vicinity of the present St. Lawrence River, the area must have been flooded by the Champlain Sea. For areas south of this there may have been a period of normal glacio-fluvial and glacio-lacustrine deposition before flooding of the area by the arm of the sea. This relationship compares with that found by MacClintock (1958) between the Fort Covington till, Lakes Iroquois and Vermont, and the Champlain Sea in New York State. The similarity of the Drummondville moraine, which is made of Gentilly till, to the Fort Covington moraine, and the similarity of the contact relationship with overlying Champlain Sea sediments of the Gentilly and Fort Covington tills, make it possible to propose, tentatively, a correlation between the two. It has been suggested by MacClintock (personal communication) that the Drummondville moraine may extend southward from the position shown on the Glacial Map of Canada (1958) then westward across the Richelieu Valley near the International Boundary trending towards Covey Hill. This suggests a further possible correlation between Fort Covington and Drummondville moraines. It is not yet known whether Drummondville moraine is a terminal or recessional moraine of the ice-advance that laid down Gentilly till, and therefore its significance in the stratigraphic sequence cannot be established. It is, however, older than the Champlain Sea deposits, but probably not much.

Relationships between Gentilly till and superjacent and subjacent sediments are consistent over nearly 2,500 square miles. These indicate that one glaciation spanned the time between the St. Pierre Interval (approximately 40,000 to 60,000 C_{14} years) and the Champlain Sea (approximately 8,000 to 12,000 C_{14} years). Further stratigraphic work in areas between Drummondville, Que. and Fort Covington, N.Y., is greatly needed. For the time being any correlation between the two areas must be regarded as highly speculative, more especially as the single stratigraphic unit common to the two areas has been variously dated by radiocarbon analyses and these dates have been variously interpreted.

The Champlain Sea

The Champlain Sea occupied the Bécancour area and inundated it completely as soon as ice had receded from the Drummondville moraine. Several facies of sediments, mainly clays, silts and sands, all suggest a single marine episode in the Cornwall area (Owen, 1951), on Montreal Island (V. K. Prest, personal communication) and in the Bécancour and immediately adjacent areas. In none of these areas are two distinct marine episodes recorded that can be compared with the Champlain Sea and Ottawa Sea invasions postulated by Antevs (1925) for the Ottawa Valley. The present paper proposes for the St. Lawrence Valley a single marine episode, the Champlain Sea, that ended as a result of differential uplift of the land and was replaced in pro-

gressive stages, first by estuarine, then by freshwater lacustrine and fluvial ancestors of the present freshwater drainage system. Some doubt is cast on the validity of Antevs' proposal of an Ottawa Sea and investigations have been initiated in the type area to study the question further.

The end of a Wisconsin glaciation is correlated with the initial flooding of the central part of the Lowland by waters of the Champlain Sea. Until further evidence is available the age of the Gentilly till must depend on the interpretation of the age of the Champlain Sea.

Until recently the C_{14} datings available have been based on shell material, and the validity of the datings has been questionable because of the possibility that contamination of easily replaced carbonates could produce anomalously "old" C_{14} dates. The following shell dates (Preston, et al., 1955) have been criticized:

Y215 - Hull, Que. (elevation 392 feet)	10,630 ± 330
	(11,050 ± 400)
Y216 - Uplands, Ont. (elevation 323 feet)	10,850 ± 330
	(8,900 ± 320)
Y233 - Notre Dame des Neiges, Que. (elevation 545 feet)	11,370 ± 360

All these dates, if accepted as reliable minimum dates for Champlain Sea, must place the marine invasion of the area as late-Wisconsin and possibly as old as, or even older than, the Two Creeks Interval that separates Cary and Mankato substages of the Wisconsin.

New radiocarbon dates on peat deposits overlying marine sediments of the Champlain Sea also indicate their age as late Wisconsin, but leave open the question of maximum age and positive correlation. The St. Germain bog, near the village of St. Germain de Grantham, approximately 3 miles southwest of Drummondville, rests on fossiliferous reworked till of the Drummondville moraine and is younger than the Champlain Sea invasion. Its peat as dated by Lamont (L441C)[1] has a radiocarbon age of 9,430 ± 250, or 9,550 ± 600 for the humic fraction. A peat bog near the village of St. Adelphe, in the Grondines map-area on the north shore of the St. Lawrence, rests on marine sediments and therefore also gives a minimum age for Champlain Sea sediments. Dating of C_{14} from that bog (GRO1922)[1] gives an age of 8,480 ± 80.

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[1]Published with the permission of J. Terasmae who collected the material in the writer's field area during a cooperative field program in 1953.

Probably also of interest here are new dates obtained by Terasmae (personal communication, 1959) which permit reappraisal of the correlation of Champlain Sea invasion with the occurrence of Glacial Great Lakes. The first date produced by Isotopes Incorporated on Terasmae's field sample TB-58-50 gives an age of 10,150 ± 450 C_{14} years for plants from lake sediment 200 feet below present level of Lake Ontario in a bore-hole (HEPC[1] boring F-1, sample 36) at Hamilton, Ontario. A second date, of more direct application, was obtained from a bog in the Fossmill Outlet (Chapman, 1954). Its dating, 6,090 ± 85 C_{14} years (GRO1924; Terasmae's field number TB-57-N1) is interpreted as follows (Terasmae, personal communication):

> "The vegetation at the level of sampling shows a climate warmer than present for the area, therefore, obviously does not represent the time of retreat of ice from that area. Thus ice retreat was older than the date and possibly of the order of 9,000 years to correspond with dates of about 9,500 years from Manitoulin sites that showed sudden lowering of lake levels."

The correlation of the Champlain Sea invasion with glacial and post-glacial events in other parts of Canada and the United States hinges on the interpretation of the minimum dates given above. The least speculative, being based on peat, indicate ages of the order of 9,000 years. There are suggestions of major drainage of the Glacial Great Lakes to the St. Lawrence Lowland at about that time. If shell dates are accepted as valid the minimum age of recession of the Champlain Sea is placed at the order of 11,000 years and the question of its being equivalent to Two Creeks Interval (also about 11,000 C_{14} years) or older is reopened.

Positive correlation of late Wisconsin glaciation and marine invasion of the St. Lawrence Lowland will depend on further intensive field work in critical areas. Until details are available it is apparent that hypotheses covering a wide range of time and events must be entertained as plausible. From what is known in the area under study, the Champlain Sea closed a late Wisconsin glacial event at least 8,000 years before the present and may have flooded the Lowland as early as Two Creeks time or even earlier. It is now accepted as established that Champlain Sea is not post-glacial as inferred in earlier writings. Contemporaneity of some glacial and marine events is indicated above in the interpretation of the marine sediments.

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[1]Hydro Electric Power Commission of Ontario.

Post-marine Events

As land rose and as water of the Champlain Sea fell below about 300 feet in elevation, an estuarine environment began to replace the marine, and all surface deposits below the elevation of perhaps 275 feet in the Bécancour area are either estuarine, lacustrine, or fluvial in origin. With continued uplift of the land, currents became stronger and channels narrowed until finally the function of currents became dominantly erosional and the St. Lawrence River as such came into being. Because the St. Lawrence River remains in a youthful stage of development in the Bécancour and adjacent areas of the central part of the Lowland, it is believed that uplift continues today that was initiated several thousand years ago just after invasion by the Champlain Sea. The Gulf of St. Lawrence may be the vestigal remains of that relatively short-lived arm of the sea.

ECONOMIC GEOLOGY

The normal sandy facies of the Bécancour till supplies adequate water to some small farms of the map-area. Some drillers, misled by the red colour and mistaking the till for the unproductive red shale bedrock, have continued to drill to bedrock aquifers and have thereby overlooked the small, yet useful water-bearing potential of the red till. In some wells the water available from red till is superior to that from underlying bedrock.

The St. Pierre sands probably constitute a good aquifer; wherever penetrated by soil auger borings they have produced much water. Prospecting for water in them is very speculative as the areal extent and shape of the deposits are not well known. However, where thick deposits of grey varved silts occur, and where surface sands and springs are inadequate sources of supply for individual farm needs, borings to depth to examine materials underlying the varves may be warranted. If interglacial sands are encountered beneath varves, properly screened or gravel-packed wells should produce good supplies of water from them. There is also the possibility that borings through thick layers of varves may encounter the red till whose water-bearing capacity is mentioned above.

Varved clay and underlying interglacial sands are the basis of a long-established brick and tile industry at points along the St. Lawrence Valley. The brickyard nearest the Bécancour map-area is at Deschaillons where the Montreal Terra Cotta Company has been active for many years. Keele (1915) has indicated that these clays are superior for brick making to marine clays of the same area which shrink excessively when baked. Some brick and tile are produced from the marine clays, but only by careful treatment.

The Gentilly till has a sandy facies that provides water of good quality sufficient for small farm requirements. Most of the wells in this aquifer are hand-dug and have, therefore, relatively large diameters, ranging upwards from about 3 to 10 feet.

Marine clays of the area are the basis for productive sandy loam supporting important mixed-farming in many of the Eastern Townships of Quebec. They have minor importance in brickmaking. On the other hand, the unpredictable physical properties of the marine silts and clays already described, have been the direct cause of numerous destructive landslides and foundation settlements of the entire lowlands region.

Well-sorted gravels and more commonly coarse sand in shore deposits, though of excellent quality for most purposes, are rare and lenticular and of small volume in the Bécancour area, and therefore have little economic importance.

High Terrace sands constitute the most important and most productive single aquifer in the Bécancour area. Water from this source supplies the villages of Gentilly, Ste. Sophie, Ste. Cecile and Champlain, each village employing large springs that issue from the lower part of the sands where their contact with underlying, relatively impervious material is exposed by a major escarpment. Large rural areas south of the St. Lawrence River are served by the same water systems, "aqueducs", as the south-shore villages mentioned above.

Particularly on the north shore of the St. Lawrence, Low Terrace sands constitute an important aquifer, although the sands commonly are only a few feet thick. As they generally lie on relatively impervious material that prevents or impedes downward movement of ground water, the lower part of the sands becomes saturated with water. In dry seasons the water-bearing zone may be only a few inches thick just above the contact with impervious material and the normally used type of well would become dry. Many farmers of the region use a very effective water-collecting system that overcomes this normally unsatisfactory condition. The system consists of a deep reservoir dug in impervious clay that is fed by drain tiles laid radially from the reservoir on or just above the surface of the clay, within the sand and including the narrow zone that is saturated even in dry seasons. By these drains, water is collected in the central reservoir. The effective diameter of some of these wells may be as much as 60 feet with tiles being laid out for distances of up to 30 feet in all directions from the centre.

Some bogs of the region are exploited commercially for agricultural organic matter, insulating material, and fuel. Certain bogs north and northeast of Red Mill are the source of raw material for paint pigment. In these bogs thick accumulations of gelatinous

muck (decomposed vegetal matter) lie on marine clay. The muck is overlain by peat. Both peat and muck have been enriched in oxides and hydroxides of iron derived from the ground water seeping laterally towards the southern margin of the bog where it is truncated by an abandoned stream channel. The truncation produces a small hydrostatic head and thus a directed flow of the ground water.

The iron-enriched muck and peat, in appropriate proportions are charged into furnaces at Red Mill where, with a small amount of additional fuel the material is burned to remove the organic matter and produce as an end-product, red iron oxide. In 1952 the Sherwin Williams Company of Canada, Limited, with head office and paint works at Montreal, was deriving iron oxides from this source for its entire Canadian production of "mineral colours — red oxides of iron, umbers, siennas, rouge". Apparently this production did not require full-time operation of the pits and furnaces.

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