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SURFICIAL GEOLOGY OF THE CORNWALL AND ST. LAWRENCE SEAWAY PROJECT AREAS, ONTARIO

By J. Terasmae

**DEPARTMENT OF
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PREFACE

The construction of the St. Lawrence Seaway between 1954 and 1958 provided the opportunity to study many new excavations in the surficial deposits between Brockville and Cornwall. Geological Survey studies of these deposits commenced in 1956 at the invitation of the Ontario Hydro-Electric Power Commission, and culminated with the detailed mapping of the surficial deposits in the Cornwall area in 1958 and 1959. During this four-year period the author had access to many temporary excavations that are now covered by Lake St. Lawrence and was able to provide much geological information to engineers on the Seaway project. In this report, the author describes the various glacial and post-glacial features, and draws upon additional evidence from archaeological investigations and his own palaeobotanical studies to discuss authoritatively the glacial and post-glacial geological history of the region.

The close cooperation of Survey geologist and Seaway engineer during the Seaway construction proved beneficial to both, and served to point out the extreme usefulness of geological studies to large-scale construction projects.

J. M. HARRISON
Director, Geological Survey of Canada

OTTAWA, November 16, 1962

Bulletin 121—Die Oberflächengeologie des Gebiets von Cornwall und St.-Lorenz-Seeschiffahrtsweges in Ontario

Von J. Terasmae

Eine Beschreibung der glazialen und postglazialen Ablagerungen; eine Zusammenfassung der glazialen und postglazialen Geschichte mit Berücksichtigung der paläobotanischen und archäologischen Verhältnisse, und eine kurze Erörterung der Verwendungsmöglichkeiten der Gesteine, der Bedeutung der Moore für die Landwirtschaft, der Grundwasserverhältnisse und einiger technischen Probleme der Bodenbeschaffenheit.

Бюллетень 121 — Поверхностная геология районов Корнуолл и морского канала Св. Лаврентия, провинция Онтарио.

Я. Теразме.

В работе описываются ледниковые и послеледниковые отложения района, подводится итог его ледниковой и послеледниковой истории, включая палеоботанические и археологические находки, кратко обсуждаются нерудные ископаемые, отложиния болот, запасы грунтовой воды, а также некоторые проблемы инженерного дела.

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SURFICIAL GEOLOGY OF THE CORNWALL AND ST. LAWRENCE SEAWAY PROJECT AREAS, ONTARIO

Abstract

Evidence has been found of three different movements of glacier ice—Malone, Fort Covington, and a post-Fort Covington readvance. The Champlain Sea covered the area some 10,000 to 11,000 years ago, and freshwater organic sediments began to accumulate more than 9,430 ± 140 years B.P., as shown by radiocarbon dating.

Palynological studies indicate that the early forest, about 9,500 years ago, was composed of spruce, balsam fir, jack pine, and birch, with a minor component of hardwood species. An improvement in climate followed, and the early boreal forest was replaced by a mixed hardwood forest with pine and hemlock. The clearing of land in historic time was marked by a sudden increase in weed pollen.

Résumé

On a découvert des indices de trois progressions différentes de la calotte glaciaire: Malone, Fort Covington et une récurrence postérieure à Fort Covington. La mer Champlain couvrait toute la région il y a 10,000 ou 11,000 ans; les sédiments d'organismes lacustres ont commencé à se déposer il y a plus de 9,430 ± 140 années, comme l'indique la datation au radiocarbone.

Les études de palynologie indiquent que la forêt primitive d'il y a 9,500 ans se composait d'épinettes, de sapins baumiers, de pins gris, de bouleaux et d'une faible proportion d'essences à bois dur. La forêt boréale du début fut remplacée par une forêt d'essences à bois dur parsemée de pins et de pruches. Le déboisement dans les temps historiques a été suivi par un accroissement brusque de la quantité de pollen provenant des plantes herbacées.

Chapter I

INTRODUCTION

The area studied includes the north shore of the St. Lawrence River from Brockville to Cornwall (extending 5 to 10 miles north of the river) and the Cornwall map-area (lat. 45°00′ to 45°15′ and long. 75°00′ to 75°30′) (*see* Fig. 1). This report is based on 1958-59 field work in the St. Lawrence Seaway project area and mapping of the Cornwall map-area. Occasional studies of the Seaway area were made in 1956 and 1957.

By 1863 (Logan, 1863)[1] the surficial geology of eastern Ontario along the St. Lawrence River was known well enough to allow recognition of the main stratigraphic units comprising the surficial deposits. Glaciation of the area had been recognized on the basis of glacial till covering the bedrock. Logan (1863, p. 915) wrote ". . . a considerable portion of the region between the St. Lawrence and the Ottawa, to the east of the meridian of Kingston, are occupied by stratified clays; which . . . contain abundance of marine shells . . .. These clays are . . . overlaid by sands . . ., which also contain marine remains. The two are regarded as forming parts of one formation, . . ." Thus deposits of the marine episode following glaciation (the Champlain Sea) were recorded, as was the presence of modern alluvium overlying the marine sediments. Further early studies of the surficial deposits were made by Dawson (1893), Coleman (1901), and others. It is remarkable how much information was compiled by the early workers from the rather scattered field observations. Their interpretation of the field data necessarily differed from present interpretation because of numerous recent advances in theory and practice of glacial geology, but this in no way decreases the value of the earlier studies. However, it was the construction of the St. Lawrence Seaway and the associated projects, such as the relocation of towns, roads, and railways, and the opening of numerous gravel pits and quarries that provided the opportunity to study surficial deposits in a large number of exposures. Continuous sections excavated along the canal extended in places for more than a mile through the surficial deposits (*see* Fig. 1).

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[1] Names and/or dates in parentheses refer to publications listed in *References* at the end

Acknowledgments

Acknowledgment is due to the Ontario Hydro-Electric Power Commission for permitting access to their construction areas and for the use of maps, drawings of exposures, and drill logs of numerous site investigations and to O. E. Johnston, G. W. Brownell, W. M. Duncan, and J. O. Gorman for their generous assistance; to the engineers, especially J. N. Harris, of Uhl, Hall, and Rich, Engineers, Consultants to the Power Authority of the State of New York, for their help and cooperation; and to Paul MacClintock of Princeton University and A. Dreimanis of University of Western Ontario for critical comments and instructive discussions.

C. L. Laywine, A. J. Jenik, R. J. Mott, and E. D. Field gave able assistance in the field and office.

Historical Note

Following the retreat of the late-Wisconsin ice-sheet and the subsequent rebound of land, the early St. Lawrence River drainageway allowed the waters from the Great Lakes to drain eastward into the Gulf of St. Lawrence. It seems certain that from that time, beginning several thousand years ago, the St. Lawrence River had been used as an important waterway by the Indians. In 1535 Jacques Cartier sailed the first ships from Europe up the St. Lawrence River to the village of Hochelaga, the present site of Montreal, where his trip was stopped by the rapids. In 1541 he explored the river above Hochelaga and probably got the original idea of a 'seaway'.

The value of canals for bypassing the rapids was realized by Champlain and later explorers, traders, and missionaries, but their construction was not feasible at that time. About 1700 a beginning was made by Dollier de Casson on the construction of a canal at the Lachine rapids (then called Canal de la Châine); he hoped to open up a route to the 'inland seas' of the Great Lakes. Further history of canal building on the St. Lawrence has been well summarized by Chevrier (1959) in his book *The St. Lawrence Seaway*. The more romantic episodes of the earlier history have been the subject of two excellent books, *The St. Lawrence* by W. Toye (1959), and *Lights on the St. Lawrence* by Jean L. Gogo (1958). A picture story of the St. Lawrence Seaway *Gateway to the World* has been published (1959) by van der Aa as the first of a series about Canada and Canadians.

The need for the Seaway was twofold: the old canals and locks were inadequate for ocean-going vessels and the volume of traffic, and the demand for electric power was rapidly increasing in Ontario as well as in the State of New York. Both problems were solved by this remarkable construction project undertaken jointly by Canada and the United States. The project also helped to solve several problems that had long intrigued Pleistocene geologists but had remained unsolved because of lack of adequate field evidence. New Pleistocene problems, however, became apparent as the studies progressed.

Magnitude of the Seaway Project

Some figures on cost and amount of materials used in construction of the Seaway have been summarized in the *Engineering Journal* (1958). The total estimated cost of the entire Seaway and Power project (exclusive of improvement costs for navigation channels in the Upper Great Lakes) was in excess of $1,100 million. The Power project alone cost some $650 million, shared about equally by the New York State Power Authority and the Hydro-Electric Power Commission of Ontario. Canada's expenditure on navigation facilities was expected to reach $340 million, and that of the United States $141 million.

The construction of the Seaway involved 166 million cubic yards of dry excavation, 35 million of dredging, and 25½ million of materials placed in dykes; some 6¼ million cubic yards of concrete was placed. Of this total the Power project required 82 million cubic yards of dry excavation and 12 million of dredging, the placing of some 18 million cubic yards of earth in dykes and of 3½ million of concrete. Navigation facilities on the Canadian side required some 55 million cubic yards of dry excavation and 18 million of dredging, 7½ million of materials placed in the dykes, and more than 2 million of concrete.

Eight communities with a population of about 6,500 were rehabilitated when an area of some 20,000 acres was flooded for the headpond of the power dam. About 525 homes were moved; 450 new homes were built, together with schools, churches, shopping areas, streets, and services. Forty miles of mainline double railway track was relocated and 35 miles of new highway built.

Chapter II

PHYSIOGRAPHY

Physiographic Regions

The Cornwall and St. Lawrence Seaway project areas, extending from Lancaster to Prescott along the St. Lawrence River, are within the limits of the St. Lawrence Lowlands. Several physiographic regions in this division have been recognized by Chapman and Putnam (1951). The western part of the area near Prescott lies within the Edwardsburg sand plain, where the extensive sand cover overlies glacial deposits and bedrock. The overall relief is small and the water-table stands near the surface. The area is characterized by numerous parabolic dunes (Terasmae and Mott, 1959) and stands 300 to 400 feet above sea-level.

Most of the area lies in the Glengarry till plain, with an undulating to rolling surface, consisting of long till ridges and some drumlins with intervening clay flats and swamps. The easternmost part lies in the Lancaster flats, a lowland where the till plain is buried under marine clay and alluvial deposits. Only the stony crests of some till ridges and knobs outcrop above the level of this plain.

Drainage and Climate

Soil surveys have shown that 40 to 60 per cent of the soils have some drainage problem (Matthews, *et al.*, 1954, 1957). The fine-grained soils, when drained, are fertile and provide good farm land. Within a few miles of the St. Lawrence River, drainage is either parallel with the river (the Raisin River) or to the north (the South Nation River). Only small creeks drain into the St. Lawrence in the area studied. The St. Lawrence itself appears to be a relatively young river with no marked terraces along its banks, but with a few abandoned channels north of and parallel with the present river (*see* Pl. IV).

The map-area lies within the eastern Ontario climatic region (Matthews and Richards, 1954), its mean annual temperature being about 42°F. The extreme low recorded is —44°F and the extreme high is 104°F. The last frost generally occurs between May 11 and 24, and the length of the frost-free period ranges from 130 to 140 days. The average length of growing season is about 195 days. Precipitation varies between 34 and 40 inches annually, of which 17 to 18 inches fall during June, July and August. Drought frequency is low (*see* also *Climate of*

Vegetation

A botanical survey of the Seaway area in Ontario, with particular attention given to areas now flooded by Lake St. Lawrence, showed that, previous to human occupation, the better-drained terrain had been covered by a hardwood forest, in which hemlock and white pine were abundant (Dore and Gillett, 1955). The main hardwood species were sugar maple, beech, basswood, yellow birch, and red oak. Elm, ash, red maple, and white pine grew on poorly drained land. Elements of the boreal forest were scarce. Cedars were abundant in second-growth wet woods, dry rocky land, and steep banks of rivers.

The botanical survey also indicated that the flora of the Seaway area was poorer in species than that of the Ottawa Valley to the north. This rather peculiar circumstance led to the suggestion that in early post-glacial time drainage from Lake Ontario flowed north into the Ottawa River, possibly through the Rideau, Moira-Mississippi, Kemptville, and South Nation Rivers (Dore and Gillett, 1955). Later differential uplift of the land caused the drainage to follow the present St. Lawrence River.

Soils and Agriculture

The soils have been described in detail by Matthews, *et al.* (1954, 1957). Soil development has been strongly influenced by the parent materials and time. Matthews (1957, p. 31) suggested that ". . . the soil materials of this area have been exposed for from 4,000 to 8,000 years." In Glengarry county about 42 per cent of the soils have developed on glacial till, about 37 per cent on clays, silts, and sands, and about 8 per cent on organic deposits. The soils on glacial till are medium textured and well suited for general farming; those developed on clay and silt, when drained, provide excellent pastures. Shallow soils on bedrock are rather unsuited for any farming activities.

The forests furnished a livelihood for the early settlers, but as the land was cleared it was used for agricultural purposes, at first each farm producing according to its needs. Later on, as the land was developed, dairy farming proved to be most suitable, and the production of maple syrup and maple sugar has provided an important source of supplementary income in recent years.

Large parts of the area are classified as good cropland, and simple installation of open ditches and tile drains vastly improve the more poorly drained, but fertile, fine-grained soils.

Chapter III

GENERAL GEOLOGY

Palaeozoic Rocks

The map-area lies within the Ottawa-St. Lawrence Lowlands, an early Palaeozoic basin drained by Ottawa and St. Lawrence Rivers. This lowland is bounded on the north by the Precambrian Shield, on the south by the Adirondack Mountains, on the southwest by the Frontenac Axis, which connects the Shield with the western Adirondacks, and on the east by the Beauharnois anticline, a lesser axis partly concealed by the earliest Palaeozoic sediments and extending from St. Jerome, Quebec, to the eastern Adirondacks (Wilson, 1951). The Precambrian floor of this basin is overlain by about 2,300 feet of Lower, Middle, and Upper Ordovician sediments (Wilson, 1946). Later tectonic movements caused faulting in the Palaeozoic rocks (Wilson, 1956) and differential tilting of the individual blocks bordered by faults, but the dips of the strata are generally slight.

The extent and lithologic characteristics of formations in the Cornwall area have been mapped and described by Wilson (1946).

Surficial Deposits

Surficial deposits of Pleistocene and Recent age mantle the Palaeozoic rocks (Fig. 2). No evidence has been found of glaciations older than the last (Wisconsin). Erosion during both interglacial and glacial times removed pre-Wisconsin surficial deposits.

Glacial Deposits and Features

Glacial Striae

Glacial striae and grooves, which can be observed and studied on many fresh exposures of the bedrock surface, are best developed on fine-grained limestone (Pl. I). Both grooves and striae were made by the grinding and polishing action of granular rock debris carried under and in the base of the glacier that moved across the bedrock. Two or more sets of striae occurring on some rock outcrops indicate that the glacier moved first in one direction and then, for some reason, moved in a different direction. Careful examination can often show that one set

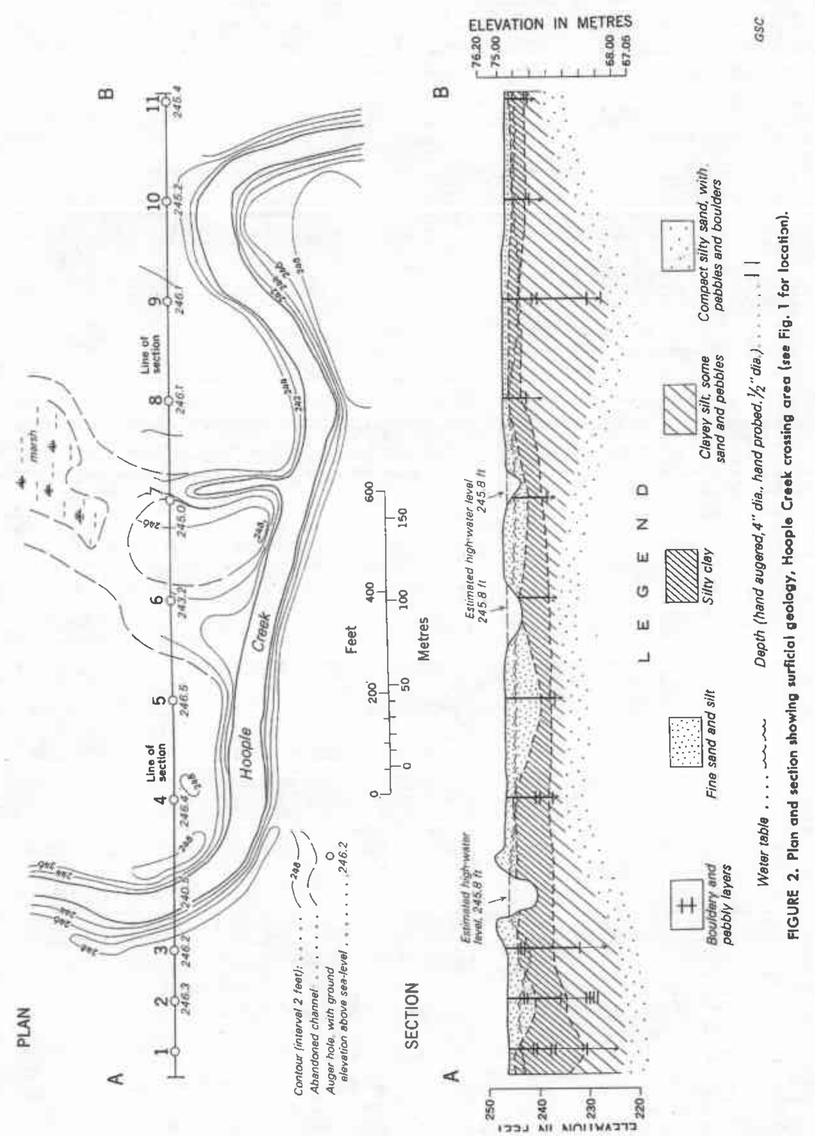


FIGURE 2. Plan and section showing surficial geology, Hoople Creek crossing area (see Fig. 1 for location).

FIGURE 3. Plan and sections showing surficial deposits in the vicinity of the power house. Geological data courtesy Ontario Hydro-Electric Power Commission.

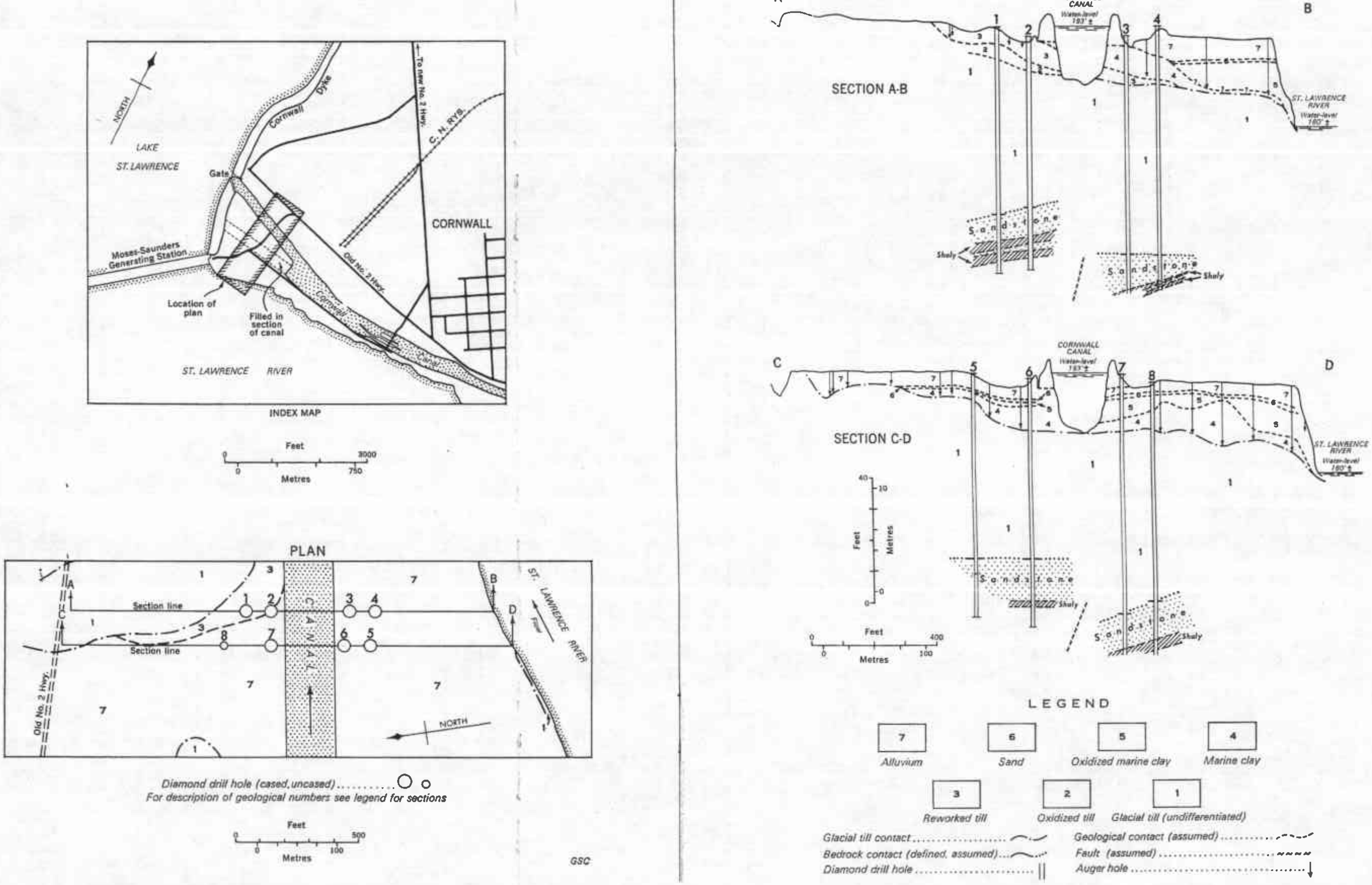
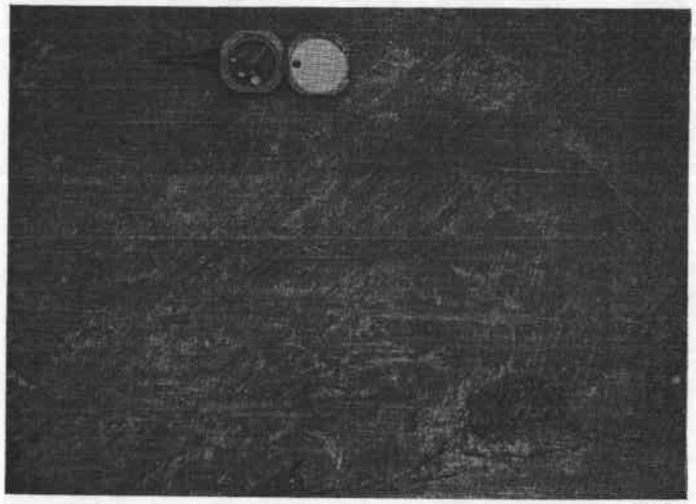


Table I

Pleistocene Formations

Era	Period or Epoch	Age	Formation and Lithology
Cenozoic	Pleistocene and Recent	Post-glacial	Bog and lake deposits
			Alluvial gravel, sand, and silt with some plant detritus; locally fossiliferous
			Dune sand
		Wisconsin	Brackish-water estuarine sediments; erosion and redeposition of older marine sediments
			Champlain Sea gravel and sand; shallow-water marine sediments, fossiliferous beach deposits, sand bars and spits
			Champlain Sea clay and silt; deep-water marine sediments, fossiliferous; grades downward into brackish-water silty clay containing fossil *Yoldia*; deposited during the initial phase of the marine inundation; commonly shows indistinct varving
			Varved sediments of local glacial lakes
			Glacio-fluvial sediments
			Fort Covington till: grey to buff (where oxidized) calcareous glacial till; generally more sandy and less compact than the Malone till
			Malone till: dark, blue-grey glacial till; clayey and compact. Includes locally glacio-fluvial and lacustrine sediments in upper part
			Unconformity
Palaeozoic	Ordovician		Limestone, dolomite, shale, sandstone



J.T., 11-8-58

PLATE I. Glacial striae on limestone near Maitland (east of Brockville) showing two sets of superimposed striae. The younger set trends south (to the right) indicating the post-Fort Covington ice-movement. The older set (from lower left to upper right) indicates ice-flow direction during the Fort Covington readvance.

Three different sets of striae are present in the map-area. The oldest indicates ice-flow from the northeast, a younger set trends slightly east of south, and the youngest set indicates ice-flow from the north. Figure 1 shows locations of striae in the St. Lawrence Seaway project area. In the Power Dam area grooves were observed (E. B. Owen, pers. com.) on dense glacial (Malone) till that had been eroded by a later ice movement.

North of the St. Lawrence River and west and northwest of Cornwall the south-trending set of glacial striae is most prominent.

Linear Troughs

During soil investigations for the Seaway project, certain linear features were noticed by G. W. Brownell of the Ontario Hydro-Electric Power Commission on aerial photographs taken north of the St. Lawrence between Cornwall and Morrisburg. These features were plotted on soil maps prepared by the Commission's soils engineers, but no satisfactory explanation of their origin was presented. Further studies were made by the writer. The troughs, which showed clearly on aerial photographs (Pl. II), were difficult to observe on the ground, but where ground observation was possible the troughs were shallow linear depressions with gently sloping sides. Their depth was generally 2 to 5 feet, but

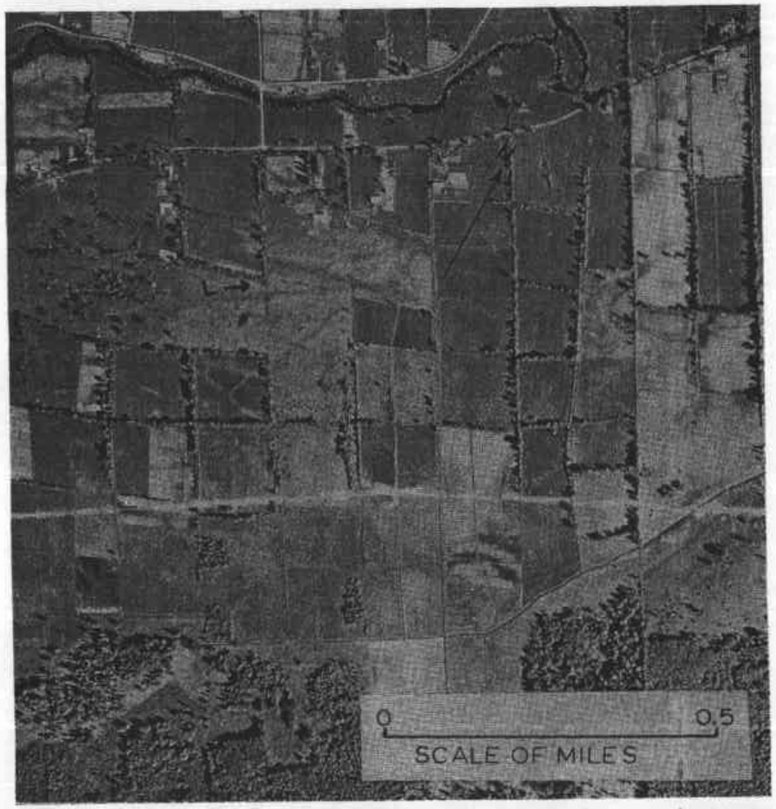


PLATE II. Aerial view of linear troughs 1.5 miles east of St. Andrews (about 5.5 miles north of Cornwall) in an area of glacial till and silty clay overburden. The troughs, indicated by L→, show as dark or light lines near the centre of the photo. (RCAF A16000-31)

are mostly parallel, but northeast of Cornwall some sets intersect. Near Morrisburg some are about half a mile long. Similar features ('linear trenches') have been reported from King William Island, Northwest Territories (Fraser and Henoch, 1959), where they are associated with a fault pattern in limestone. These 'trenches' are a few hundred yards to more than a mile long.

The linear troughs generally trend east and are not parallel to any known ice-flow direction. Some, however, are parallel to faults in the bedrock and near Morrisburg they are nearly parallel to the trend of north-dipping bedding planes

J.T., 10-4-59

PLATE III. View across ploughed field of linear trough (indicated by arrow) east of St. Andrews.

Linear features not related to ice-flow directions have been observed by O. L. Hughes (pers. com.) of the Geological Survey of Canada, in the Clay Belt west of Cochrane, Ontario. Hughes suggested that they are associated with bedrock relief.

In each of these three regions linear features occur in areas of shallow overburden, generally from 5 to 30 feet thick. In the Cornwall area the overburden consists of clay till, marine clay, or both.

The writer suggests that these linear troughs formed over faults, fractures, and bedding planes in the bedrock owing to seepage of groundwater into the rock. Laboratory and field experiments (Bozozuk, 1959; Bozozuk and Burn, 1960) have shown that 'soil moisture depletion' causes shrinkage of clay soil and that such soil does not regain all the lost water upon rewetting. Thus a cumulative shrinkage can occur, even when the clay is saturated at some time each year, and this cumulative soil-moisture-depletion results in the formation of surface depressions. If this interpretation is correct the linear troughs indicate lines of groundwater loss from soil into bedrock. Such features can occur where cohesive soils overlie bedrock and may show through some 30 feet of such overburden, but generally indicate shallow depths to the bedrock.

A different mode of formation has been suggested by Leighton and Brophy (1961, p. 1), who stated that in the marginal zone of a glacier some crevasses, both longitudinal and frontal, could cut through the ice, and eroding streams confined along them could cut straight shallow depressions.

Although this explanation offers another possible mode of formation of linear troughs, the writer favours the soil-moisture-depletion hypothesis for these

Glacial Till

Glacial till is one of the important surficial deposits in the area, geologically as well as in relation to engineering and groundwater. It differs from other surficial deposits in three important aspects. First, being physically and lithologically heterogeneous (MacClintock, 1958), it is unsorted and unstratified with pockets of granular material. Second, it generally shows compaction, indicated by tension and shear cracks, and preconsolidation caused by the load of glacier ice during deposition, which is often indicated by a crude parting or foliation somewhat similar to schistosity in rocks. The compaction and preconsolidation render the till more or less impervious to groundwater movement. Third, till cover, more so than other deposits, may be continuous over high and low topographic forms.

In the map-area glacial till has been divided into two members, the Malone (lower till) and the Fort Covington (upper till). Both names were proposed by MacClintock (1958), based on his studies in the Seaway project area south of the International Boundary. Satisfactory stratigraphic correlation has been established between the south and north shores of the St. Lawrence River.

The Malone till, which is the oldest surficial deposit in the map-area, is assumed to have been deposited largely by the main Wisconsin ice-sheet, glacier flow being from the northeast (Fig. 1). About 90 per cent of the pebbles found in this till are of Palaeozoic sedimentary rocks, which occur in the map-area and to the east and northeast. Pebbles from the igneous rocks that are dominant to the north are rare.

In fresh exposures the Malone till is dark blue-grey. The compact, silty-clay matrix contains varying numbers of pebbles, cobbles, and boulders, depending on the proximity and character of the bedrock. Owing to pressure from the overlying ice and the flow of the glacier, flat pebbles and cobbles having an elongated shape were oriented in the till matrix with their longest axis nearly parallel to the direction of glacier flow (MacClintock and Dreimanis, 1964).

The excavation for the Eisenhower lock, which cut through the surficial deposits down to bedrock, exposed three sheets of till separated from each other by clay and stratified granular deposits (MacClintock, 1958, pp. 16-17). The lower till was identified as Malone and the upper as Fort Covington. The middle till sheet had a fabric trending S60°W, similar to that of the Malone till; other features also indicated that the middle till belonged in the same episode as the Malone. Exposures to the west (Cut 'F' through the Long Sault Island) showed that the middle till might better be named a till complex, for it was commonly composed of stratified sediments mixed with what MacClintock called 'stratified subaqueous till' (1958, p. 20). In the Iroquois lock excavation the Malone till is separated from the Fort Covington by 30 to 40 feet of stratified glacio-fluvial and lacustrine sediments with embedded cobbles and boulders, probably dropped from floating icebergs. On this evidence MacClintock suggested that the 'middle till' was

p. 24). This conclusion is supported by the writer's observations made later along both sides of the St. Lawrence River.

The Fort Covington till differs from the Malone in that it was deposited by an ice-sheet flowing from west of north, as indicated by its fabric and by striae on bedrock eroded by the Fort Covington ice (*see* Fig. 1). Further evidence for this direction of ice-flow is found in the surface remoulding of some pre-existing till ridges. Barnhart, Sheek, and Long Sault Islands each has a core of Malone till trending southwest, but these cores being remoulded by the Fort Covington ice-advance added another set of till ridges trending southeast.

The Fort Covington till is much less compact than the Malone, indicating that the Fort Covington ice was thinner, probably due to considerable downwasting of the continental ice-sheet in late Wisconsin time when a general and rapid retreat of the ice-margin had begun. It is also sandy (*see* Table II) and may contain a larger proportion of pebbles of igneous rocks.

Table II

Grain-size Distribution in Tills of the Cornwall Area (and in areas to the west and north)

	Per cent			
	Clay	Silt	Sand	Pebbles
SEAWAY PROJECT AREA				
Point Three Points excavation (*see* Figure 1)				
Fort Covington till	10	28	51	11
Malone till (upper part)	13	32	46	9
Malone till (lower part)	20	30	37	13
Road-cut for highway 401 at Maitland, Ont.				
Till of the Johnstown readvance (?)	18	34	37	11
GATINEAU VALLEY				
Bois-Franc, Quebec	12	23	57	8
Brennan Hills, Quebec	11	18	50	21
Mont-Laurier, Quebec	18	18	56	8
RENFREW, ONTARIO	8	20	56	16
ST-JOSEPH-DU-LAC, QUEBEC	22	28	42	8

Where the Fort Covington till outcrops, as in crests of till ridges, it is commonly oxidized buff-to-brown to a depth of about 20 feet. The lower limit of this colouring is sharp, but there is no change in the till fabric; nor is there any lithological break or disconformity.

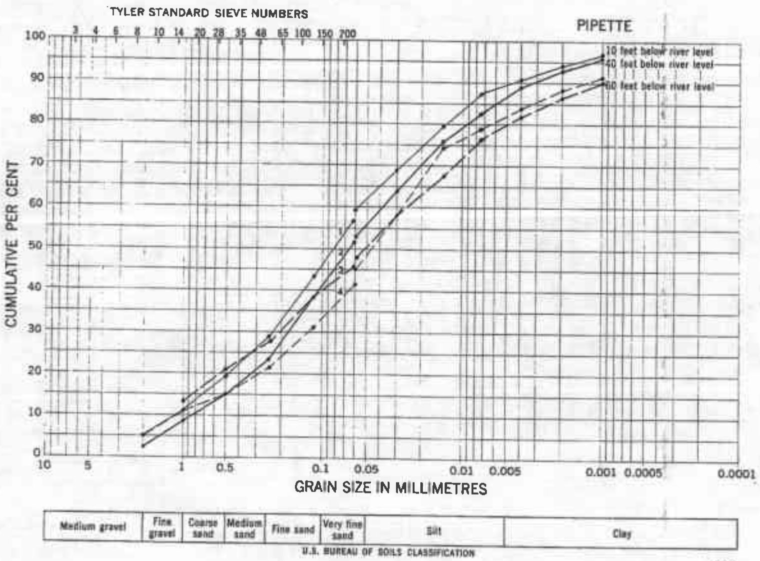


FIGURE 4. Grain-size distribution in tills of the Seaway Project area. Graphs 1, 2, and 3 are of till samples from the canal improvement excavation at Point Three Points east of Iroquois. Graph 4 is of till exposed in a road-cut at Maitland for Highway 401 exit construction. Sample 1 represents the Fort Covington till; 2 and 3 are of the Malone till, and 4 may represent the post Fort Covington ice readvance.

Grain-size Distribution in Tills

The Malone and Fort Covington tills differ also in their grain-size distribution. Results of numerous mechanical analyses of till samples from the Seaway project have been compared with those obtained from till samples collected in the regions west and north of Cornwall area (*see* Table II and Figures 4, 5, and 6). These results support the field observations that the Malone till is more clayey than the Fort Covington. Furthermore, the higher sand content in the Fort Covington till is consistent with the established ice-flow direction from the northwest where sandy tills are predominant (sand contents 50 to 57 per cent).

A rather interesting case is presented by a sample of till assumed to have been deposited by an ice-readvance near Johnstown. Both bedrock striae and till fabric indicate ice-flow from the north but grain-size distribution is very similar to that of the Malone till. Possibly some of the older till was eroded, redeposited, and remoulded without significant change in composition.

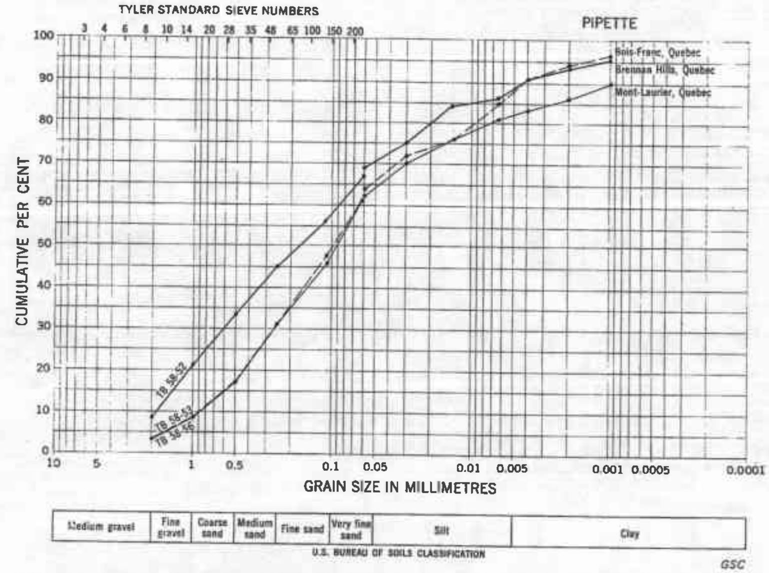


FIGURE 5. Grain-size distribution graphs for tills in the Gatineau valley: Bois-Franc, Quebec (sample TB 58-53 lat. 46°30'N, long. 75°59'W), basal till (blue-grey, compact) from a road-cut, 8 feet below ground surface. Brennan Hills, Quebec (sample TB 58-52, lat. 45°47'N, long. 75°55'W), till associated with glacio-fluvial sediments. Mont Laurier, Quebec (sample TB 58-56, lat. 46°32'N, long. 75°13'W), dark grey, upper till of the area, sample collected 10 feet below ground surface.

Glacial Tectonics

Certain structural features observed in the Seaway excavations were very similar to those in surficial deposits in Poland examined during the INQUA (International Association on Quaternary Research) Congress field trips in 1961 (Dylik, 1961, pp. 11-14). These features, which have been named glacio-tectonic disturbances, were caused by the weight and pushing action of glacier ice, and differ from those caused by slumping and frost action.

In the canal diversion excavation through the dyke, north of the power house at Cornwall (*see* Fig. 1), the disturbed structure of granular sediments and glacial till is believed to have been caused by glacial tectonics (Fig. 7). Similarly structural disturbances in the canal improvement excavation at Iroquois Point (*see* Figs. 1 and 7, and Pl. IV) are interpreted as glacio-tectonic structures.

Dylik (1961) described two major types of glacio-tectonic forms, *folded structures* and *monoclinal forms*. The folded structures include ice-pressed features such as those from Alberta described by A. MacS. Stalker (1960). The monoclinal

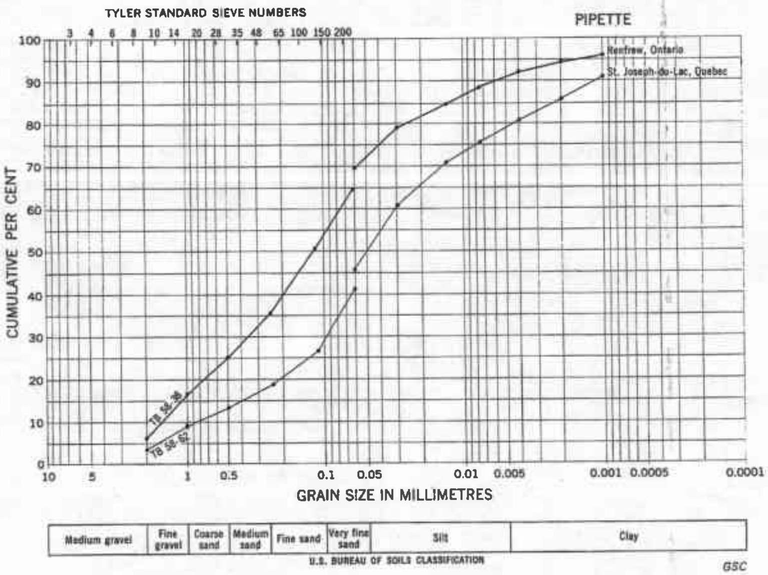


FIGURE 6. Grain-size distribution graphs for representative till samples from Renfrew, Ontario, and St. Joseph-du-Lac, Quebec. Renfrew (sample TB 58-38, lat. 45°28'N, long. 76°41'W), compact, dark grey basal till over bedrock. St. Joseph-du-Lac (sample TB 58-62, lat. 45°31'N, long. 74°05'W), dark grey basal till exposed in road-cut.

forms include shear and thrust faults and are believed to have formed as a result of the lateral pressure exerted by the advancing ice-sheet upon rigid, frozen material.

Drumlins

A group of drumlins trending southwest in the area east of Cornwall is shown on the physiographic map of Chapman and Putnam (1951). Such a trend parallels the flow of the Malone ice but is perpendicular to that of the Fort Covington ice. The presence of these features was readily confirmed by the writer, but their method of development is less certain. The till ridges are composed of the compact Malone till, locally with a capping of Fort Covington till, commonly much reworked by wave-wash of the Champlain Sea.

It is possible that some drumlins were formed in this area by the Malone ice, but the later Fort Covington ice-advance remoulded these features, even affecting and re-orienting the till fabric in the Malone till as observed by MacClintock (1958) and the writer. A good example of this phenomenon is Sheek Island (Fig. 1), which has a general southwesterly trend but is crossed by drumlins having a southerly trend.

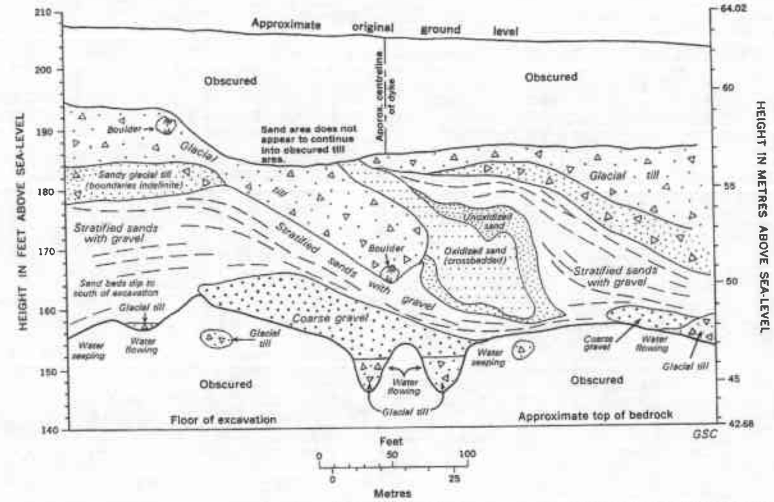


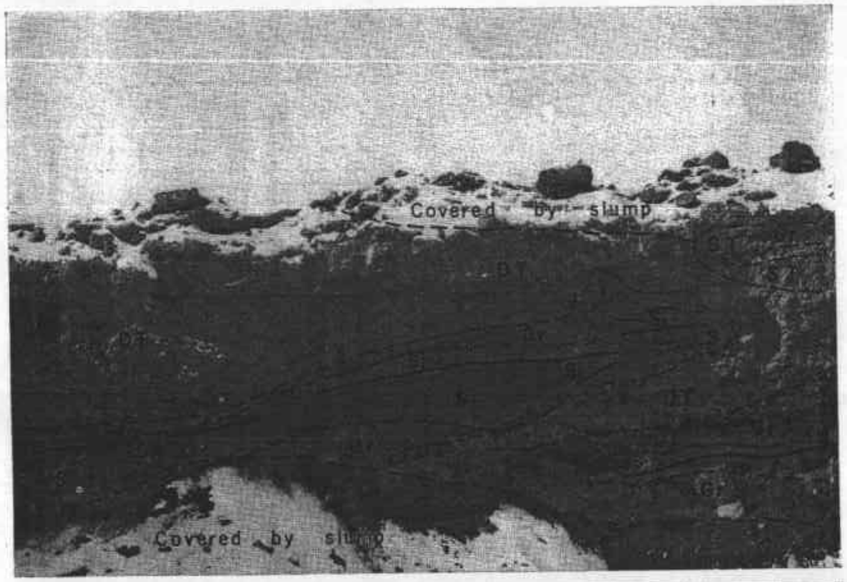
FIGURE 7. Canal diversion excavation through the dyke north of power house showing glacio-tectonic disturbances in surficial deposits.

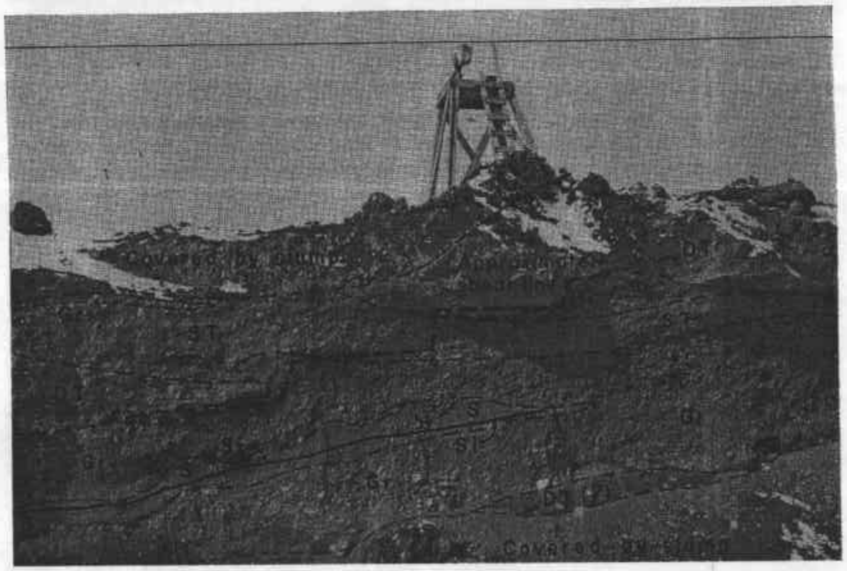
A further remoulding was made by a post-Fort Covington ice-readvance, as easily observed in the trend of islands along the Long Sault Parkway. East of Long Sault village, on the Parkway, small drumlins (Pl. V) trend south and a southerly trend of drift ridges on islands near Johnstown can be readily noted (Fig. 1). Southerly trending small drumlins have been mapped in several parts of Cornwall map-area; most of these are superimposed on pre-existing, southwesterly trending, large till ridges.

Glacio-fluvial Deposits and Glacial Lakes

Surficial deposits of glacio-fluvial and glacio-lacustrine origin are of insignificant volume and extent in the area studied, where they occur stratigraphically between Malone and Fort Covington till. Glacio-fluvial deposits have also been observed immediately overlying the Fort Covington till; some inclusions of granular material within the till sheets may be classified as glacio-fluvial. The 'middle till complex' (*see* p. 14), which was deposited during the recessional phase of the Malone glaciation, is largely composed of glacio-fluvial sediments.

Granular deposits and varved clay, separating the Malone till, the 'middle till', and the Fort Covington till in exposures south of the International Boundary have been described by MacClintock (1958). The thickness of the glacio-fluvial deposits between Malone and Fort Covington tills increases to the westward as





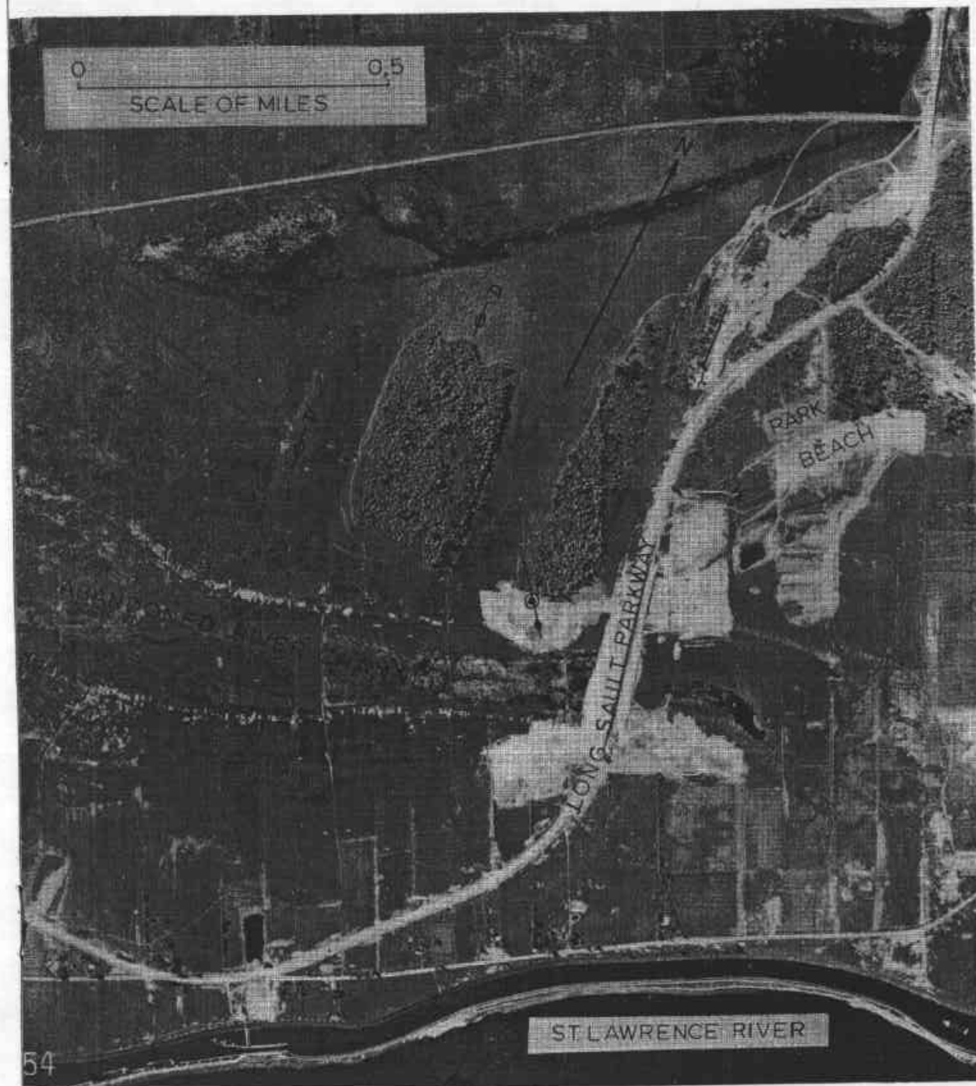


PLATE V. Aerial view of the eastern end of Long Sault Parkway (before flooding) showing parallel orientation

In the excavation for the Iroquois lock, Malone till was separated from Fort Covington by 30 to 40 feet of stratified sediments containing boulders. In the Point Three Points canal improvement excavation to the eastward, these stratified sediments were in part replaced by the 'middle till', comprising together the 'middle till complex'. West of Iroquois in excavations through Galop Island, MacClintock noted some 20 feet of stratified sand and silt with glacial stones of all sizes.

In the west wall of Cut 'C' at the Long Sault Control Dam (*see* Fig. 1) the Fort Covington till is overlain by some coarse gravel and stratified sand with cobbles, which in turn are overlain by varved clay. The varved clay grades into the marine clay upwards through a phase indicative of brackish-water deposition in which the varving fades gradually into a stratified, fossiliferous marine clay (Pls. VI A and B).

North of the St. Lawrence River glacio-fluvial deposits seem to be of little importance within the limits of the area studied. The till sheets form a single till sequence, which is locally overlain by some glacio-fluvial or glacio-lacustrine material but more generally by marine sediments.

The distribution of glacio-lacustrine sediments indicates that an ice-dammed lake existed between the glacier margin and the high ground to the south. During the major retreat of the Malone ice large quantities of sediments (the middle till complex) were deposited in the lake and later partly incorporated in the Fort Covington till. This lake was still in existence during retreat of the Fort Covington ice and the post-Fort Covington readvance. MacClintock (1958, p. 14) has suggested that "Fort Covington ice in turn calved back from its maximum stand, liberating an expanse of water confluent with the Fort Ann stand of Lake Vermont." He believed that this lake gradually expanded as far north as Ottawa, and that "a break in the ice barrier in the lower St. Lawrence Valley drained the Fort Ann lake to low sea level and exposed the varved clays to drying and fracturing," before the invasion of the Champlain Sea. The latter part of this suggestion by MacClintock may pose a problem in that certain exposures show a gradual change from varved clay to brackish-water clay and to marine clay without any apparent disconformities. Perhaps this post-Fort Covington drainage event exposed the previously deposited sediments at higher elevation to subaerial weathering, whereas those at lower elevation were not exposed.

Marine Deposits

Among the surficial deposits, marine sediments rank second in importance to glacial till. They can be divided conveniently into (1) the fine-grained sediments, and (2) beach deposits. The marine deposits are widespread and commonly overlain by alluvial and organic deposits, which considerably restrict their surface outcrop (Map 1175A; in pocket).

Three chronological divisions can be recognized in the sequence of marine deposits. Although they all belong to the Champlain Sea episode, a distinction

J.T., 8-7-61

PLATE VI. A. Cut 'C' at Long Sault control dam (Fig. 1) showing glacio-fluvial deposits and the base of varved clay with embedded pebbles and cobbles (at the level of the pick handle).

J.T., 8-18-61

B. Same exposure as A. Varved clay gradually changing to vaguely varved, brackish-water *Yoldia* clay. (Metal tray is a foot long.)

J.T., 8-4-6

C. Same exposure as A. Higher in the same exposure the massive marine clay becomes stratified and the sandy partings contain numerous fossils of can be made between those of the invasion phase of the sea, the deep-sea sediments, and the shallow-water sediments deposited during the recession of the sea-level.

A thin mantle of sand and gravel overlies the till on some of the higher slopes along till ridges north of Cornwall. Because this granular deposit is overlain in turn by stratified marine silty clay it has been assumed that the mantle of sand and gravel represents the rising phase of the sea-level. At somewhat lower elevations the glacial lake sediments, if present, gradually change into brackish-water *Yoldia* silty clay upwards. From these relationships it is concluded that the glacial lake, existing in the area during the retreat of the ice, was drained to a lower level and it is possible that lake sediments at higher elevations may have been exposed to slumping and oxidation (MacClintock, 1958). Furthermore, it is possible that the pre-Champlain Sea stratified sand and gravel on flanks of till ridges may be a lacustrine beach deposit.

In general, the submergence of the map-area by the Champlain Sea is indicated by deposition of the *Yoldia* clay, which is a brackish-water sediment that normally forms a transition from the varved glacio-lacustrine clay to the marine clay. The *Yoldia* clay resembles varved clay, but close examination shows that the varving is poorly defined and the sediment commonly contains *in situ* fossils of *Yoldia arctica* (Gray) (Pl. VII, figs. 1-4). In some places the *Yoldia* clay is composed of silty clay layers separated by thin sandy partings.

The Champlain Sea clay stratigraphically overlies the *Yoldia* clay. This marine clay is commonly fossiliferous and ranges from massive to stratified. Its thickness is variable, depending on pre-existing relief, and may be more than 50 feet in some parts of the map-area. The deep-water clay generally contains black streaks, irregular blotches or a speckling of amorphous monosulphide of iron. Ericson (1961) described this sulphide as hydrotroilite ($FeS.nH_2O$) and claimed that these black streaks were formed by the generation of hydrogen sulphide by anaerobic bacteria. The black colour disappears soon after exposure to air. Crawford (1961, p. 201) has reported anaerobic bacteria from Champlain Sea clay.

The name '*Leda* clay' (used for the Champlain Sea clay in several reports) is objectionable for two reasons. First, the fossil *Leda portlandica* has been properly named *Yoldia arctica* (Gray). Second, the main body of the Champlain Sea clay (=*Leda* clay) does not contain *Yoldia* (=*Leda*) as its characteristic fossil, but rather *Macoma balthica* (Linné), (Pl. VIII, figs. 5-10). For further comments on the name '*Leda* clay' *see* Gadd (1955, 1960).

The Champlain Sea clay becomes sandier upwards, where it is commonly composed of alternating silty clay layers and sand partings. Such depositional features were produced by the shallowing of the sea owing to uplift of the land, and gradually more sand was winnowed out from the tops of till ridges owing to wave-wash. In some exposures farther away from the till areas the nearly massive

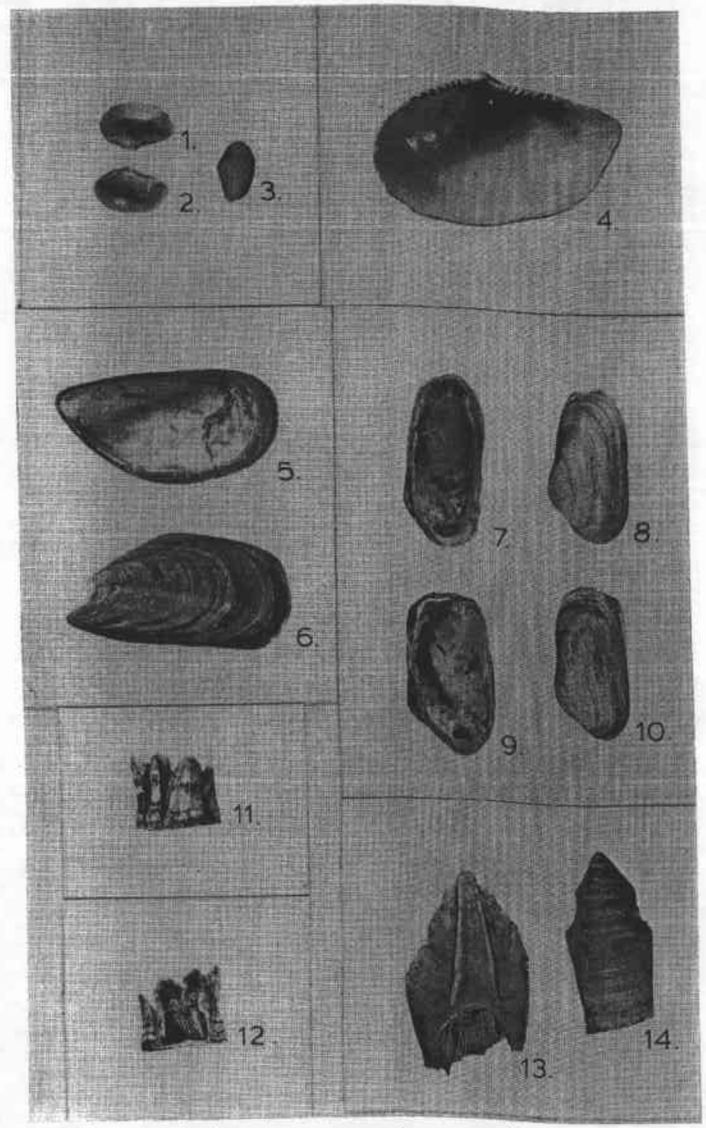


PLATE VII. Common fossils in the Champlain Sea deposits in the Cornwall area.

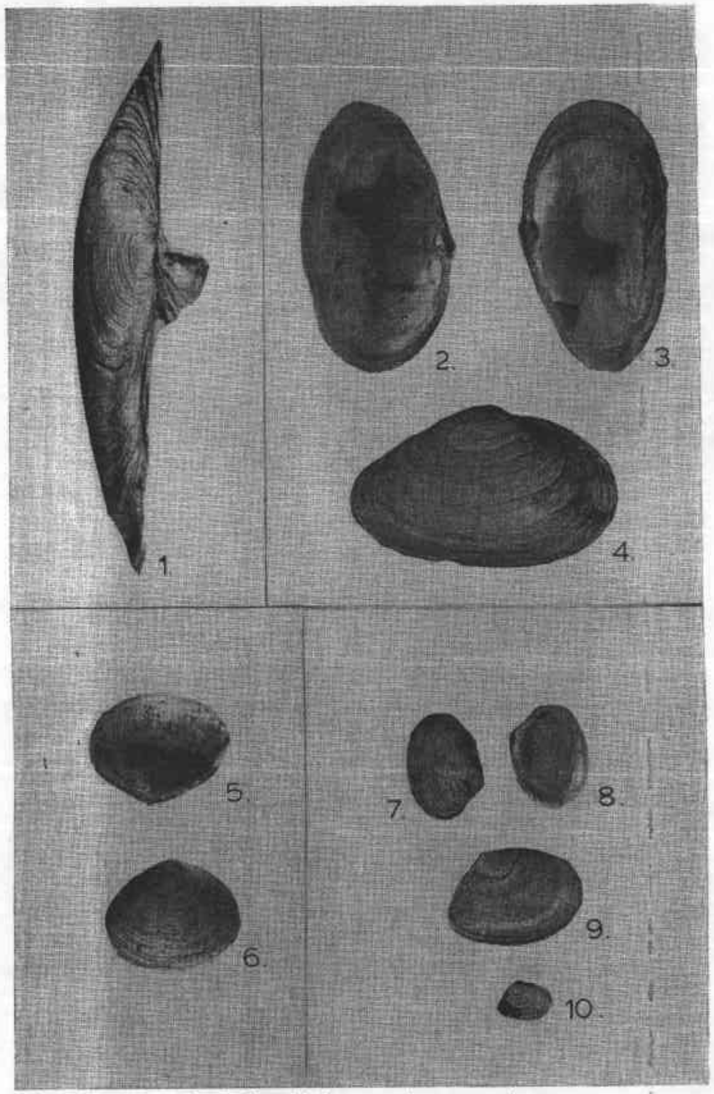


PLATE VIII. Common fossils in the Champlain Sea deposits in the Cornwall area.
Figure 1-4. *Mya arenaria*, Linné
Figure 5-6. *Macoma balthica*, (Linné)

abundant marine fossils. The origin of this sand is again related to strong wave-wash of higher till ridges and knobs, near the end of the Champlain Sea episode. This sand unit, which may be continuous over large areas, has been named the '*Saxicava* sand' in older reports (*see* Gadd, 1955, 1960). The term Champlain Sea sand for this unit is preferable to '*Saxicava* sand' because the fossil *Saxicava arctica* has been renamed *Hiatella arctica* (Linné) and, furthermore, *Hiatella* (Pl. VII, figs. 7-10) occurs in abundance only in the true beach deposits.

Another important group of sediments belonging to the Champlain Sea shallow-water phase is composed of beach deposits, which exhibit characteristic physiographic forms. Boulder beaches and beach ridges occur in abundance at the present elevation of 300 to 350 feet above sea-level. On the surface, extreme wave action is indicated by boulder concentrations on the slopes of the till ridges and boulder and gravel ridges (Pls. IX and X), which are normally a quarter to a half mile long but a few extend over 2 miles. These features can be readily recognized on aerial photographs. MacClintock (1958, p. 14) estimated that such hills have been lowered 40 to 50 feet by wave-wash. Assuming that this estimate is of the right order of magnitude the tremendous effect of wave-wash on fresh glacial till deposits becomes apparent, and it follows that the originally rough relief was much subdued. It is also reasonable to assume that a certain amount of evidence on glacier flow, expressed as surficial physiographic features, was removed by this process. The clay and silt fraction of the material winnowed from till ridges was deposited in deeper parts of the marine basin; sand and gravel were spread over pre-existing sediments from the sites of heavy wave-wash. Thus a gradational sequence of sediments was formed (*see* Fig. 8).

Other distinct physiographic forms of marine deposits are the spits and near-shore bars, which can be of considerable size. Such features are shown in the northwest corner of Cornwall map-area near Warina (Pl. XI). Similar but smaller features occur elsewhere within the map-area as well as to the west (Pls. XII and XIII). These features mostly occur at elevations between 300 and 350 feet above the present sea-level. They probably formed when the higher parts of the map-area came close to and emerged above the level of the Champlain Sea. At that time the wave-wash effect was most significant.

Estuarine and Alluvial Deposits

When the level of the Champlain Sea had receded to what is now the 200-foot elevation the marine environment changed to estuarine conditions as indicated by disappearance of marine fossils in surface deposits at lower elevations. Elson (1960) named this estuarine-lacustrine phase the *Lampsilis* lake. It is normally represented by thin deposits of stratified, non-fossiliferous silty sand near Lancaster, in the eastern part of Cornwall map-area. Gravelly beach deposits of the *Lampsilis* lake are rare and poorly developed. In a deposit some 2 miles north of Summerstown Station broken shells of fossil *Lampsilis siliquoidea* were found together with fragmentary fossils of a small gastropod

J.T., 8-8-60

PLATE IX. A curving bouldery beach ridge about a mile northwest of McMillan Corners. Such features show distinctly on aerial photographs, and help in locating sources of granular materials.

J.T., 2-6-60

PLATE X. Section through a gravel beach ridge developed on glacial till, 1.8 miles southwest of St. Andrews. Marine shell beds (mostly of *Hiatella arctica*) up to a foot thick occur at the base of many such gravel deposits.

Alluvial deposits, composed of poorly stratified silty sand with flakes of mica are extensive in the east half of the map-area and along the St. Lawrence River. Generally they are underlain by estuarine and marine beds and are 3 to 10 feet thick. These deposits locally contain fossils of modern species living in present rivers and creeks.

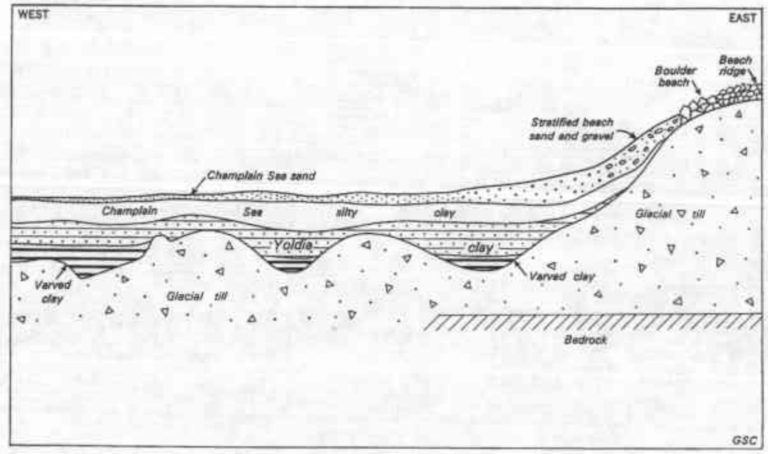


FIGURE 8. Generalized cross-section through surficial deposits on a west-facing slope of a till ridge.

Sand Dunes

Sand dunes are rare in Cornwall map-area; where present, as in the northwestern corner (Pl. XI), they are small. This paucity of dunes is the result of two factors. First, sufficiently large source areas of sand were lacking when dune development could take place at the close of the Champlain Sea episode. Although sea-level apparently stood at the present 325- to 350-foot elevation for some time, the map-area was then below sea-level. Later sea-level apparently receded rapidly and the unvegetated land was colonized quickly by plants.

Small dunes occur near Upper Canada Village west of Cornwall on highway 2. These were formed along the north shore of the St. Lawrence River as differential uplift of land caused the river channel to shift from north to south.

A large area of parabolic dunes occurs west and north of Prescott. These dunes are numerous and large, some more than 100 feet high. They were formed by winds from the east-northeast and are largely limited to elevations of 325 to 350 feet above sea-level. A reconnaissance study was made by Terasmae and Mott in 1959.

Organic Deposits

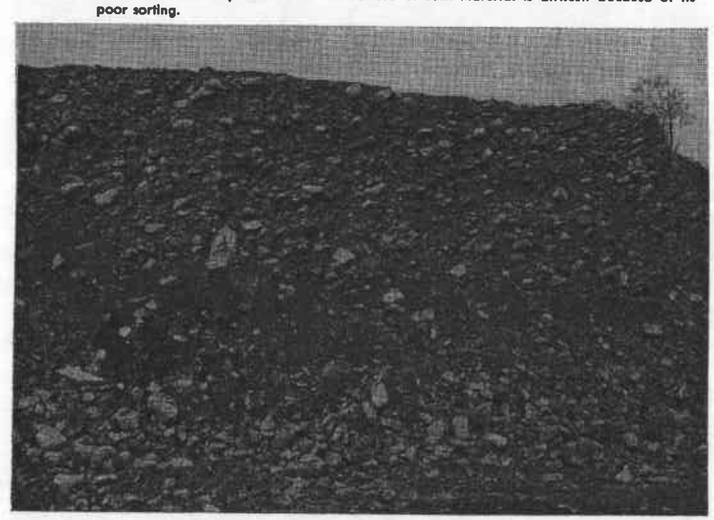
The appreciable areal extent of organic deposits in the map-area can be readily seen on Map 1175A. In general these deposits are shallow and less than 15 feet deep. Commonly they are 3 to 6 feet deep, largely because the pre-existing

PLATE XI. Aerial view of sand spits (SP) and sand dunes (D) near Warina. (RCAF A16245-18)

depressions were filled with inorganic sediments during the Champlain Sea episode. Seasonally wet areas have developed where sediments on bedrock are very thin and water is lost during the summer by evaporation and seepage into the fractured rock. Such areas can be extremely dry in the summer. Forest swamps, fens, and bogs compose the vegetation cover under which the accumulation of organic deposits occurs (Dore and Gillett, 1955). Borings have shown that many depressions, now filled, originally contained lakes and ponds. This is clearly indicated by the characteristic sediments and preserved plant and animal fossils.

J.T., 1-5-59

PLATE XII. Coarse, bouldery beach gravel on the northwest-facing slope of a till ridge, 1.5 miles southeast of St. Raphael West. Direct use of such material is difficult because of its poor sorting.



J.T., 10-3-58

PLATE XIII. Exposure in beach gravel on west-facing slope of a till ridge, about 1.5 miles north of

An interesting discovery of buried organic deposits was made about a mile northeast of Lunenburg in the south bank of Raisin River. There the surface 4 feet of alluvial silty clay and sand is underlain by about 6 inches of peat and sandy peat, which in turn rests on alluvial sand and fossiliferous marine deposits. About 2.5 miles southwest of Apple Hill, lake sediments are overlain by peat and woody peat, which in turn is overlain by a few inches of stratified sand and sedge and grass peat at the surface. These occurrences of buried, post-glacial organic sediments suggest the possibility that in later post-glacial time there was an episode of increased surface run-off depositing sand and silt over organic deposits. Such an episode would indicate, furthermore, a climatic change with increased wetness. Similar occurrences of peat buried under thin alluvial deposits have been found more recently by N. R. Gadd near Ottawa and by J. J. L. Tremblay near Rigaud, Quebec (pers. com.).

Chapter IV

HISTORICAL GEOLOGY

Glacial History

Accounts on the glacial history of the map-area have been published recently by MacClintock (1958), Terasmae and Mott (1959), and MacClintock and Terasmae (1960). However, the present study has revealed new information and certain changes in the previous outlines are necessary.

The oldest preserved evidence of movement of the Wisconsin ice-sheet (the Malone till) indicates flow from the northeast, i.e., up the St. Lawrence River valley towards the Lake Ontario basin. It is probable that at the height of Wisconsin glaciation the main ice-flow direction was from north to south, but evidence for this has not been found in the map-area. In late-Wisconsin time, after considerable thinning and retreat of the ice-margin, the northern slope of the Adirondacks south of the St. Lawrence became free of ice. Following further retreat of the ice-margin a narrow lake, or lakes, formed between the Adirondacks and the ice, and the margin of the Malone ice retreated in a lake environment, which expanded northward and eastward. According to MacClintock (1958, p. 12) "the retreat of the Malone ice was interrupted by a readvance that deposited a layer of upper Malone till, 'the middle till', over lake sediments and moulded both Malone tills during oscillatory retreat."

The northern limit of the ice-retreat previous to the Fort Covington readvance is not known, but in the Cornwall area this limit was somewhere north of the present St. Lawrence River. Whether this retreat allowed the ice-dammed lake to drain down the St. Lawrence valley has not been established; it is a possibility. Certainly no marine invasion of this part of the St. Lawrence Lowlands occurred at that time.

A considerable rearrangement of the glacier regime must have taken place before the Fort Covington readvance, because the glacier flow during the readvance, which reached a limit south of the St. Lawrence (MacClintock, 1958, Fig. 5), was from the northwest. As the Fort Covington readvance occurred in a lake environment, the till may lie on varved sediments or stratified outwash deposits. The Fort Covington ice impinged against the north side of Covey Hill and gap, where a gorge was cut into the Potsdam sandstone (MacClintock, 1958; MacClintock and Terasmae, 1960). MacClintock (1958) wrote "into this lake of Fort Covington age (Lake Iroquois) were built deltas of the Chateaugay, Trout, St. Regis, and Racquette Rivers at about 1000-foot elevation and concordant with the Covey Gap. The St. Regis Delta lies on Fort Covington till at Dickinson Center."

Although much remains to be learned, the above statements make the beginnings of a regional correlation of late-glacial events. Assuming that the lake dammed by the Fort Covington ice is a correlative of Lake Iroquois (Karrow, Clark and Terasmae, 1961), which in turn was a correlative of a phase of Lake Algonquin in the present Lake Huron basin, a crude correlation of late-glacial events between the Great Lakes and the St. Lawrence Lowlands can be implied. This problem has been included by the writer in the scope of his palynological studies, now completed, across Ontario and southern Quebec.

All available evidence indicates that until the Fort Covington readvance, ice blocked the lower St. Lawrence valley. When the Fort Covington ice-margin retreated northward, away from the Adirondacks, the previous high-level ice-dammed lake found lower outlets along the north slope of Covey Hill and drained rapidly to a lower level, and some of the lake sediments at higher elevations probably were exposed to erosion and slumping. MacClintock (1958) suggested that this lower lake level was equivalent to the Fort Anne stand of Lake Vermont and deltas were built at Malone, Burke Center, and Dickinson at the present 700-foot elevation. He further implied that this lake extended northward to Ottawa, where varved clays have been observed overlying the uppermost till of that area.

The writer is somewhat hesitant to make such regional correlations at this time. There is evidence of other lake levels besides that of Lake Iroquois and the assumed equivalent to Fort Anne stage of Lake Vermont. Correlation between these lake stages and their areal extent are as yet insufficiently known, but there is evidence of other, and later ice readvances than the Fort Covington in this area. However, in a general way the high-level ice-dammed lake, or lakes, were drained to lower levels before the inundation of the area by the Champlain Sea (*see also* Mather, 1917, p. 543). The writer has found no supporting evidence for the assumption that the pre-Champlain Sea glacial lakes drained completely from the lowland areas (*see also* Prest, 1961), but there is clear evidence in the map-area, and the writer has observed similar sequence in the Ottawa River valley, that the change from glacial lake environment to a marine embayment was gradual (Pls. VI A and B).

The melting of the ice barrier in the lower St. Lawrence valley (perhaps between Quebec City and Rivière-du-Loup), allowed the glacial lakes to drain but also opened the lowlands to the west for the marine inundation, the Champlain Sea episode. It can be assumed that sea-level was much lower at that time, perhaps

ice. The land surface, too, was depressed after the Wisconsin glaciation, and the rapid uplift that followed probably had begun in the southern and western parts of the St. Lawrence Lowlands (Johnston, 1916). This rather delicate balance between the uplift of the land and the eustatic rise of sea-level controlled the transgression and regression of the Champlain Sea (Elson, 1960; Gadd, 1960). A great deal of further study is needed to untangle this complicated succession of events.

The present evidence indicates that the Champlain Sea rose to its maximum limits rather rapidly and followed the retreating ice both westward and northward. In the St. Lawrence Lowlands the ice readvanced at least once into the marine basin (the St. Narcisse readvance). The recession from the maximum limits was also rapid, but halts may have occurred. There is some indication that one such halt occurred when the sea-level in the Cornwall area stood at the present 350-foot elevation (Terasmae and Mott, 1959). Further recession of the sea-level changed the marine environment in the map-area into estuarine, lacustrine, and fluviatile environments.

Evidence of a Post-Fort Covington Ice Readvance

Earlier in this report mention was made of a readvance of ice younger than either the Malone or the Fort Covington advance. At several places within the map-area, and to the west at Johnstown, evidence has been found of south-trending glacial striae that cut striae eroded by the Fort Covington and the Malone ice-advances. In addition to striae on bedrock, remoulding of Fort Covington till into south-trending drumlins has been observed both at Johnstown (Fig. 1) and in the map-area (Pl. V). Along the Long Sault Parkway, the Fort Covington till is identified by its fabric (trending southeast) whereas small drumlins on the crests of till ridges trend south. No separate till belonging to this more recent ice-advance has been identified, and because of scattered and insufficient evidence no formal name has been proposed.

Chronology of Glacial Events

Dating of the glacial events in the map-area is still insufficient. Radiocarbon dates obtained for fossil marine shells from the Champlain Sea deposits indicate that the Fort Covington readvance is older than 11,000 years B.P. and hence, antedates the Two Creeks interstadial. As such, it may be the correlative of the Mankato, Port Huron stadials, which have been assigned an average radiocarbon age of 12,350 years B.P. (Jelgersma, 1962). The Malone ice-readvance therefore ought to be a correlative of the Cary stadial, which preceded the Mankato and Port Huron stadials in the Great Lakes region (Wright and Rubin, 1956). A satisfactory correlation of ice-advances in the Cornwall area with those to the west in the Great Lakes region is obscure in many important aspects and must await further information

The following radiocarbon dates have been obtained for shallow-water marine fossils of the Champlain Sea episode:

				Approximate elevation (feet) a.s.l.
11,300 ± 200	years B.P.	(L–639B)	Old Chelsea, Que.	500
10,630 ± 330	"	(Y–215)	Hull, Que.	392
10,850 ± 330	"	(Y–216)	Ottawa, Ont.	323
11,370 ± 360	"	(Y–233)	Montreal, Que.	545
10,550 ± 200	"	(L–604A)	Ottawa, Ont.	330
10,700 ± 200	"	(L–604B)	Ottawa, Ont.	330
10,600 ± 200	"	(L–604C)	Cornwall, Ont.	200
10,200 ± 200	"	(L–604D)	Ottawa, Ont.	350
10,870 ± 130	"	(GSC–90)	Pembroke, Ont.	450

Further dates may widen this age range somewhat when samples from the highest and lowest limits of the Champlain Sea are dated.

Minimum ages for early post-Champlain Sea sediments have been obtained from two sites (Terasmae, 1960):

9,500 ± 300 years B.P. (L-441C) Drummondville, Que.
9,430 ± 140 years B.P. (GSC-8) Cornwall, Ont.

A number of radiocarbon dates have been published in reports by Terasmae and Hughes (1960), and Karrow, Clark, and Terasmae (1961), pertaining to the Lake Huron and Lake Ontario regions. These dates have supported the view that some phases of Glacial Lakes Algonquin and Iroquois and the Champlain Sea were of the same age. Geological and palynological evidence is also in agreement with these correlations. However, much further field work is required to establish the necessary details of a satisfactory correlation.

A correlation of the Malone and the Fort Covington ice-readvance to the eastward is even more obscure and considerable work is required before attempting a reliable correlation. The St. Narcisse moraine (Gadd, 1955; Karrow, 1957) is probably younger than the Fort Covington readvance. Whether the St. Narcisse readvance can be correlated with the Valders substage of the Wisconsin glaciation is still an unsolved problem, although it is a definite possibility (Terasmae, 1959). The post-Fort Covington readvance in the Prescott area may possibly belong in the Valders substage, too, but no absolute age for this readvance has yet been obtained.

The Champlain Sea episode is, in part at least, a correlative of the Two Creeks interstadial (Terasmae, 1959). Later ice-readvances in northern Ontario and Quebec are outside the scope of this report.

Post-Glacial History

The sequence of glacial events in the map-area ended during the Champlain Sea episode and gave way to the following post-glacial events. First, drainage from the Great Lakes entered the Champlain Sea through the Lake Ontario basin.

Second, later (Terasmae and Hughes, 1960) when the ice had retreated north of the Ottawa Valley this drainage entered the Champlain Sea in the area west of Pembroke, Ontario. Third, uplift of the land caused shifting of drainage ways, and also controlled the western extent of the Champlain Sea.

Reconnaissance studies in an area limited by the towns of Brockville, Smith's Falls, and Kingston revealed no evidence to show that the Champlain Sea extended into the Lake Ontario basin across the Precambrian Frontenac Axis, as had been previously assumed (Coleman, 1901; Fairchild, 1906; Mather, 1917; Chapman and Putnam, 1951). However, Baker and Johnston (1934, p. 80) noted that the Champlain Sea undoubtedly extended up the St. Lawrence valley as far as (what is now) Brockville, but that the depth of the Trent valley outlet of Lake Algonquin below the present level of Lake Ontario discounted the possibility that the Champlain Sea extended west of the Frontenac Axis. Further evidence for the above reasoning has been presented by Karrow, Clark, and Terasmae (1961).

Borings made in lake sediments beneath the present level of Lake Ontario at Picton, Prince Edward county, yielded freshwater fossils only, which clearly disproves the assumed marine origin of the "lower beaches" at Picton, as suggested by Coleman (1901). No marine fossils have been found in beach deposits in that area above the present level of Lake Ontario (Mirynech, pers. com.). The often quoted occurrence of marine shells at Brockville, Ontario, is actually based on hear-say evidence. Although Coleman (1901, p. 134) claimed that Robert Bell obtained marine fossils at Brockville in clays penetrated by a tunnel under the town, other reports indicate that Bell did not himself collect any fossils there but had heard that such marine fossils had been observed in the tunnel excavation. Recent search by the writer in numerous exposures of surficial deposits in the Brockville area has yielded no marine fossils. East of Brockville, however, marine fossils (pelecypods, gastropods, foraminifera, diatoms, ostracods, and some whale bones) have been found in the Champlain Sea deposits (Baker, 1920; Wagner, 1957).

Continued uplift of land, particularly to the eastward, gradually limited the inflow of salt water and a change from marine to freshwater environment took place; the fossil *Lampsilis siliquoidea* appeared, followed by other freshwater fossils in gravel and sand below the lowest marine beaches (Elson, 1960). This change may have occurred some 9,500 years ago. It was followed by extensive downcutting by rivers into the marine sediments, as indicated by numerous river scarps and terraces, and redeposition of eroded deposits to the downstream.

Many river channels were abandoned in succession towards lower elevations, and lakes were left in isolated depressions where deposition of lacustrine sediments began shortly afterwards. Some of these lakes were filled with sediment and developed into swamps and bogs.

One apparent difference between the St. Lawrence River Valley in the Prescott-Cornwall area and the Ottawa River valley is that well-developed terraces while present along the Ottawa River are virtually absent along the St. Lawrence. In late glacial time the Ottawa area was more depressed, relative to the Cornwall area, than at present, and it was also closer to the source area of sediments—the melting ice-sheet to the north. Thus, in general the sediments are thicker along the Ottawa River and during the uplift of land the river cut deeply through these deposits and the river channel shifted but little. The St. Lawrence River, however, flows through a till and bedrock area and down-cutting has been difficult and slow. Uplift of the land caused the river to shift southward, which may be a reason for the youthful appearance of the St. Lawrence River valley near Cornwall. The differential uplift in the Ottawa-Cornwall region that tilted the land southward caused the formerly northward-draining rivers to cut deeper channels or change their courses, resulting in a rather disorganized drainage system. This matter is further illustrated by the fact that as much as 60 per cent of the soils in places is poorly drained. From botanical studies, Dore and Gillett (1955) suggested that "the waters of Lake Ontario may even have found other outlets (through the Rideau, Moira-Mississippi system, Kemptville Creek, or the South Nation) and the migration path of plants may have been directed towards the valley of Ottawa rather than down the St. Lawrence". Further studies may solve this problem of river divergence. It is conceivable that during a late phase of the Champlain Sea the drainage from Lake Ontario followed a northeasterly route from the Kingston area towards Smith's Falls and Kemptville and some sands there may be related to this event. The large area of sand west and north of Prescott probably has a complex history. Some of this sand may be glacio-fluvial, some of it may be a river deposit to which was added the sand derived from till knobs and ridges by wave-wash. The final accumulation of dune sand resulted from wind action in a late phase of the Champlain Sea episode.

The present, preliminary studies seem to indicate that the early St. Lawrence River came into existence not later than 9,500 years ago and probably began to flow along its present course at Cornwall some 7,000 to 8,000 years ago.

Palaeobotanical Evidences and Implications

On the basis of plant distribution in the area along the present St. Lawrence River, Dore and Gillett (1955, p. 4) observed "it is rather certain that the area along the St. Lawrence was not available for occupation by plants until relatively late in prehistoric time, perhaps not until a few thousand years ago, and long after the surrounding terrain was vegetated." Geologically, it is probable that plants had no major migration barriers at the eastern end of Lake Ontario in late-glacial time and could migrate up to the Ottawa area and eastward along the higher land between the Ottawa and St. Lawrence valleys. In the Cornwall-Prescott area, however, a rather wide body of water may have formed such a barrier. When the St. Lawrence River came into existence both botanical and climatic conditions may have prevented further migration of some plants.

Some features of the history of vegetation in the map-area can be described from palynological studies made by Potzger and Courtemanche (1956), and by the writer. Results of these studies have been compiled in two pollen diagrams (Figs. 9 and 10).

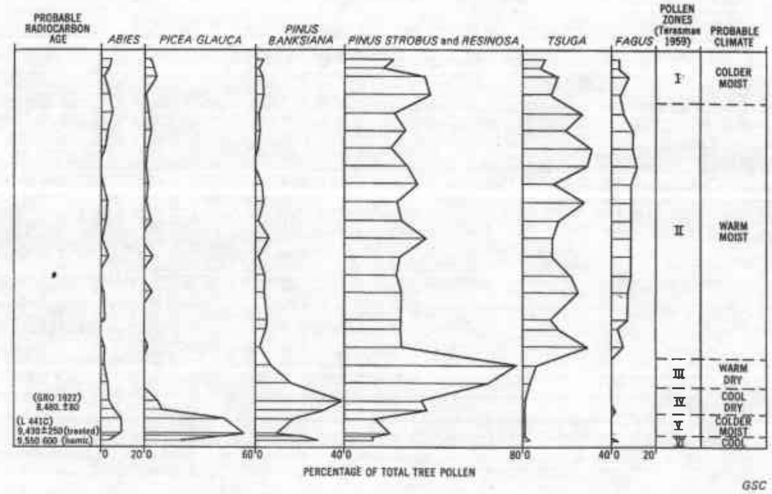


FIGURE 9. Correlation of pollen graphs (modified from the Newington bog diagram by Potzger and Courtemanche, 1956), pollen zones, probable post-glacial climate, and the radiocarbon dates which have been adapted from the Trois-Rivières, Quebec, region. The radiocarbon dates used here were later supported by one from the map-area.

Palynological evidence indicates that some 9,500 years ago, as shown by radiocarbon dates, the Cornwall area was covered by a boreal forest (pollen zones VI and V) where spruce, balsam fir, jack pine, birch, and some oak were prominent. Other forest tree species were of lesser importance. A change followed (pollen zone IV) when jack pine gained in importance, mostly at the expense of spruce. This was transitional to the next zone, when white pine, and probably red pine, gained in dominance (pollen zone III). Further change occurred when hemlock and several hardwood species increased considerably in abundance (pollen zone II). The relatively slight change towards more recent time (pollen zone I) is indicated by a certain increase in spruce pollen and a decline of hemlock.

The most recent change in the pollen assemblages, recovered from the top few inches of sediment, seems to reflect the disturbances brought about by human activities, and is accompanied by a marked increase in non-tree pollen species such as ragweed (Bassett and Terasmae, 1962).

The changes in forest composition as described correlate well with those in the St. Lawrence Lowlands (Terasmae, 1960). The radiocarbon dates obtained lend support to such a correlation. The writer is convinced that these changes regionally. This assumption is of fundamental importance when a regional correlation of post-glacial events is attempted on the basis of palynological evidence.

Iversen (1960) suggested that the changes in post-glacial forest composition can be explained by the normal succession and migration of forest tree species towards a climax forest in a given region. A normal forest succession depending on environmental conditions certainly does take place, as do local variations in the succession caused by fire and disease, but such changes are of relatively short duration and do not take thousands of years to reach a somewhat stable composition. Furthermore, many other lines of evidence have clearly shown that climatic changes of sufficient magnitude have occurred in the past to account for the observed changes (Terasmae, 1961). The writer supports Iversen's opinion that the post-glacial changes in forest type must be considered on the basis of dynamic plant sociology and that migration of species is an important factor in the interpretation of climatic changes as implied from fossil evidence. Therefore, a thorough knowledge of plant ecology is essential for such interpretations.

Margaret Bryan Davis (1960) recently claimed that the pollen percentages as shown in a pollen diagram do not reflect the true numerical composition of the forest in the surrounding area. This difficulty has been recognized and accepted by palynologists as one of the limitations of the method, but it is, nevertheless, important to know more precisely the numerical relationships between the pollen assemblages and the vegetation types that produced them.

Recent regional studies of pollen assemblages in surface samples (the sediment that has accumulated in the last 10 to 20 years) have proved beyond reasonable doubt that such pollen and spore assemblages definitely reflect the regional vegetation. The local site conditions, however, must be carefully considered. A generalized climatic interpretation of the pollen diagram has been attempted in Figure 9. A somewhat more detailed interpretation of the post-glacial climatic changes in the St. Lawrence Lowlands and Ontario has been described in other publications (Terasmae, 1960, 1961).

Archaeological Evidences and Implications

The archaeologists have provided important evidence on the post-glacial history of the area. Evidence of Early Man has been discovered in association with shores of Lake Iroquois and the Champlain Sea, for example, and the St. Lawrence River (Mason, 1960). Mason was able to show that the archaeological evidence alone indicated a greater age for Lake Iroquois and the Champlain Sea than had been accepted on other evidence some years ago. Investigations made by C. C. Kennedy (1961, and pers. com.) in the Pembroke area show the possibility of using archaeological evidence for correlating some post-glacial events in the Great Lakes region with those in the St. Lawrence Lowlands. This is possible because the Ottawa River-North Bay route must have been important to travellers in prehistoric times and, hence, facilitated exchange of archaeological

An archaeological group led by Dr. Norman Emerson of the University of Toronto made a rather hurried study on Sheek Island at the Ault Park site just before it was flooded by Lake St. Lawrence, but because of limited time somewhat unorthodox digging methods had to be used. A bulldozer scraped successive 3-inch layers off the site, and an archaeologist scanned for artifacts, which were exposed when sand piles were shifted by an air hose. Many finds were made of shaped arrowheads, pottery fragments, native copper awls, stone axes, and burned bones. Several burial pits lined with red ochre and containing artifacts were discovered. Dr. Emerson felt that this site belonged to the Point Peninsula culture, which existed in eastern Canada some 3,500 years ago.

The same site was probably used later by the Indians just as it was recently favoured by Cornwall residents as a popular picnic area, mostly because of its scenic setting.

The area along the St. Lawrence River has always been closely related to early Canadian history. During development of the Seaway project many historical landmarks were saved, thanks to the efforts of the Ontario-St. Lawrence Development Commission. These have been gathered in Upper Canada Village, now a popular tourist attraction.

Further and more extensive archaeological studies in eastern Ontario are most desirable, as such studies frequently have palaeoclimatological implications that can be of help in correlating post-glacial events and geological features.

Chapter V

ECONOMIC GEOLOGY

The economic geology of the Ottawa-St. Lawrence Lowlands has been discussed by Wilson (1946), and the limestone industry in particular by Hewitt (1960). Sand and gravel deposits in the Cardinal-Cornwall area were described by Owen (1951).

Rock Products

Limestone and Dolomite

Much of the limestone and dolomite bedrock of the area is suitable for crushed-stone production and was used extensively for the Seaway project. Large volumes of crushed stone are used in highway, railway, and building construction. The coarse cobble gravel frequently found in beach deposits of the Champlain Sea is also a source of crushed stone. Such gravel sources can be seen on aerial photographs, as the beach ridges stand out rather distinctly.

The local bedrock has been used also for riprap—large angular blocks of quarry stone from 200 pounds to 12 tons or more in weight—where such material was required for breakwaters, dykes, and piers. In past years the local limestone was used extensively for lime manufacture, as indicated by numerous old quarries and abandoned kilns. The local bedrock is, furthermore, suitable for concrete aggregate and probably could be used for portland cement manufacture, which would form a basis for a concrete block industry.

Some of the dolomite and limestone of the area has been used on a small scale for building stone. About 1½ miles west-northwest of Cornwall Centre a very dark, pure, fine-grained limestone is exposed in the wall of a quarry. According to Wilson (1946, p. 40) this limestone forms a long, low ridge across a number of lots in Conc. XII, Finch township, Stormont county. It takes a high polish, as partly shown by glacial erosion, and is used as ornamental stone for interior decoration. This limestone has been quarried by Silvertone Black Marble Quarries Limited of Crysler.

Field Stone

Glacial cobbles and boulders are locally fairly abundant and have been used in building and foundation construction. Because of a rather wide variety of colour and texture the field stone can be used effectively for ornamental purposes

Sand, Gravel, and Clay

Some local clay deposits were used for brick and tile manufacture in small plants that are now closed.

Sand deposits are rather local and are related to marine beach features. A more extensive, thin layer of sand commonly covers the marine deposits, but this sand has little economic value because of insufficient concentration. Nearly all the marine beaches, particularly in the northwestern part of Cornwall map-area, have sand aprons downslope from the boulder ridges. Sand spits of commercial value are found near Warina in the northwestern corner of the map-area, where some dune sand occurs in concentrations sufficient for exploitation.

West of Cornwall map-area along the north shore of Lake St. Lawrence and the St. Lawrence River smaller sand deposits are found in abandoned river channels. Small deposits of dune sand occur locally, except north of Prescott where large dunes are abundant (Terasmae and Mott, 1959).

Gravel deposits are plentiful and are almost exclusively related to beach features formed during the Champlain Sea episode, when heavy wave-wash winnowed the clay and silt fraction from glacial till ridges and knobs, leaving a mantle of residual gravel, boulders, and sand. This mode of formation gives a useful clue for finding gravel deposits. Such beach features were formed as the dominating winds came from the northwest, and now are generally found on the northwest- and north-facing slopes. Aerial photographs can be used successfully for finding such gravel deposits. Coarse material (Pls. XII, XIII) is found near the crest of the ridge and finer fractions down the slope. In some places exposed to waves, bars and spits were formed extending away from the parent till accumulation.

Owen (1951) discussed in some detail many gravel deposits in the Cardinal-Cornwall area, gave estimates on the cubic yards of available material, and suggested uses for these deposits.

Peat Deposits

The extensive organic deposits in the map-area (*see* Map 1175A) could be utilized to advantage for agricultural purposes, provided that proper methods are used for their cultivation and management. The feasibility of such projects has been particularly well demonstrated by the Ottawa River Farms on the Alfred bog, where many different kinds of vegetables have been grown with good results. In the Cornwall area, a further advantage would be the proximity of transportation routes to potential markets.

Groundwater Resources

Two main sources of groundwater exist in the map-area. Bedding planes, fractures, joints and faults in the bedrock allow movement and storage of water, and the presence of rather large quantities in the bedrock has been clearly shown by the rapid filling of the abandoned quarries. Wells drilled into the bedrock generally supply good water in sufficient quantity for farm use. Possible exceptions are those that yield strongly mineralized water, such as occur north of the map-area (Wilson, 1946). The origin of mineralized water may be the probably erratic occurrence of evaporites in the sedimentary rocks. Gypsum, for example, has been observed in drill-cores for site investigations in the Seaway project area (Uhl, Hall and Rich, 1957).

Groundwater can also be found in the stratified granular sediments that occur between Malone and Fort Covington till sheets. In some places these sediments contain masses of glacial till—the "middle till complex" of Prest (1961). Surficial sands and gravels contain water in small quantities. No deep, buried valleys in the map-area are known to date. Such valleys, commonly filled with granular sediments, have yielded large quantities of water farther east near Montreal (Tremblay and Hobson, 1962).

Marine clay and glacial till are nearly impervious to the flow of groundwater. Shallow wells in marine sediments may yield slightly saline water.

Some Engineering Problems

The magnitude and constructional variety of the Seaway project presented the engineers with many problems, among which were those related to soils and foundations. Some of these problems were outlined in the *Engineering Journal* (1958), and reports on different aspects of construction were presented at the 14th Canadian Soil Mechanics Conference in 1960 (Adams, 1961).

Some engineering geological problems of more general interest are discussed here.

Bedrock

Excavations for the canal and foundations showed that the bedrock was sufficiently fractured or permeable in many places to allow flow of groundwater in large quantities. Such conditions required grouting of the bedrock. Some of the grout penetrated shear fractures in the overlying glacial till and later could be observed as thin cement dykes (W. M. Duncan, pers. com.).

The permeability of bedrock can bring about an interesting groundwater condition of importance to construction activities when the impervious blanket of glacial till and clay is removed during excavation or dredging. This allows the water from a river or lake to escape into the bedrock, sometimes with a head of several tens of feet. Thus the surrounding till or clay mantle may come under artesian pressure and the removal or penetration of this mantle may introduce a serious groundwater problem for further construction. Such groundwater conditions existed during construction of the Upper Beauharnois lock. A knowledge of structural and stratigraphic geology of both bedrock and surficial deposits can be of great assistance under these circumstances.

Glacial Till

A great deal was learned about the properties, composition, and behaviour of the glacial till during construction of the Seaway. The dense till proved to be much more difficult and expensive to excavate than had been anticipated, resulting in an additional cost to the Seaway Authority of more than $10 million.

Glacial till was generally considered a useful construction material. It was included as the fill in the dykes, as a seal in all rock cofferdams, and has sufficient bearing capacity for foundations, as shown by construction of the Iroquois lock, where some 2,500 feet of the upper approach wall is lying on glacial till.

Occurrence of inclusions of granular groundwater-bearing material in glacial till also complicated excavation. Most of these inclusions were of local extent. One such occurrence of sand, gravel, and silt in till has been illustrated in Figure 7 and Plate V.

An interesting soil condition was discovered by the soils engineers of the Hydro-Electric Power Commission of Ontario in an area about 20 miles west of Cornwall where many bore-holes were made to investigate foundation conditions (Adams, 1961). In this area of low relief certain 'soft' deposits were encountered laterally between ridges of compact till. The soft till had a stiffer surface crust 5 to 15 feet thick and a maximum thickness of 50 feet. A soft clay layer locally separated the soft till from the underlying dense till. The soft till differs from the dense till by its lower penetration resistance—5 to 20 blows per foot compared with more than 50 blows per foot required for penetration in other till deposits of the area. The soft till has a slightly higher moisture content. The soils engineers concluded that the soft till originated from glacial accumulation but was not consolidated to the same extent as normal till on deposition.

One possible explanation for this soil condition is that during deposition, when the glacier margin advanced into a lake to the south, water originally present interstitially in the till was trapped and was unable to escape laterally, with the result that the pore water pressure may have been sufficient to prevent the over-consolidation that should have occurred because of the loading by glacier ice.

It can be implied from this example that consolidation tests on tills may or may not indicate a previous loading by the glacier ice. This example also has implication in the field of groundwater geology pertaining to permeability and storage capacity of such surficial deposits.

Marine Clay

The soft silty marine clay presented some difficulties during excavation as it was subject to flow slides and liquifaction when disturbed. Embankments required special attention because of the low bearing capacity of this clay. The properties of the Champlain Sea clay have been investigated extensively by scientists of the National Research Council, Building Research Division (Crawford, 1961; Legget, 1961).

Experience gained from the St. Lawrence Seaway construction clearly showed the need for further detailed study of the engineering properties of surficial deposits as well as their behaviour under specific conditions. A knowledge of the structure, stratigraphy, and extent of bedrock formations and surficial deposits was found to be a necessary prerequisite for many of the construction activities in the map-area.

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Appendix

SECTIONS THROUGH THE SURFICIAL DEPOSITS[1]

Section 1. North face of the Snell Lock excavation

Deposits	Thickness (feet) Approx.	Depth (feet) Approx.
Sand: alluvial and marine	4	4
Clay: marine, fossiliferous	10	14
Clay: varved; includes *Yoldia* clay (brackish water) in upper part	10	24
Sand and gravel: glacio-fluvial	4	28
Till (Fort Covington)	15	43
Silt, sand, and gravel: glacio-fluvial	3	46
Till (Malone)	15	61
Bedrock		

[1]All sections read from the highest beds downward. The various materials have been described in more detail in Chapter III. For location of sections see Figure 1.

Section 2. Canal improvement excavation (north bank) at Robinson Bay

Deposits	Thickness (feet)	Depth (feet)
Sandy silt: alluvial and marine deposit	8	8
Clay: silty, desiccated; marine sediment	15	23
Clay: marine silty clay; soft	10	33
Clay: firm, brackish-water and lacustrine sediment	13	46
Water level in excavation		

Section 3. Eisenhower Lock excavation, north slope

Deposits	Thickness (feet) Approx.	Depth (feet) Approx.
Sand and gravel: beach deposit, fossiliferous	10	10
Till (Fort Covington)	20	30
Sand, silt, and gravel with varved clay: glacio-fluvial and glacio-lacustrine	8	38
Till (Malone): "middle till" = upper part of Malone till	20	58
Silt, sand, and varved clay: glacio-lacustrine sediments	8	66
Till (Malone): "lower till" = lower part of Malone till	20	86
Bedrock		

Section 4. North shore of Barnhart Island, 2,500 feet east of power house cofferdam 'A'

Deposits	Thickness (feet)	Depth (feet)
Sand: alluvial	2	2
Clay: stratified, marine	4	6
Clay: varved, with pebbles and boulders; this clay occurs in local lenses and shows slump structure. May overlie unconformably the till beneath	4	10
Till (Fort Covington): stony and sandy, buff coloured	2	12
Till (Fort Covington): sandy till with few pebbles	2	14
Till (Malone): blue-grey, compact, silty clay till with few pebbles	16	30
Slump: presumably till (Malone)	10	40
Bedrock (Palaeozoic): dark grey bedded limestone		

Section 5. East end of Sheek Island in the west bank of the tailrace channel and 50 yards downstream from old dam

Deposits	Thickness (feet)	Depth (feet)
Sand: stratified, alluvial deposit	2	2
Clay: buff coloured, stratified, marine silty clay; fossiliferous	6	8
Clay: blue-grey stratified clay with sandy partings, less sandy downwards. Contains a few pebbles. Tentatively identified as the brackish-water *Yoldia* clay deposited during the early phase of Champlain Sea	7	15
Slump: may conceal some varved clay beneath the marine deposits. Varved clay reported from this site in earlier reports	10	25

Section 6. Northwest shore of Sheek Island

Deposits	Thickness (feet)	Depth (feet)
Sand: stratified alluvial and aeolian deposits	5	5
Silt and clay: sandy partings, horizontally stratified; marine. Few fossils (*Macoma*)	5	10
Clay: dark blue-grey with black streaks. Massive, fossiliferous marine clay with few thin seams of sand. Deposited during the main phase of Champlain Sea	5	15
Sand: medium to fine, stratified; marine, fossiliferous (*Hiatella*)	0.5	15.5
Clay: silty, blue-grey, vaguely stratified. Probably deposited during the early brackish-water phase of the Champlain Sea	2	17.5
River level		

Section 7. Cut 'C', west of Long Sault dam; west face of exposure

Deposits	Thickness (feet) Approx.	Depth (feet) Approx.
Sand: alluvial and marine	10	10
Silty clay with sand partings: marine, fossiliferous sediments	15	25
Silty clay: marine	10	35
Clay: vaguely varved to massive. Brackish-water *Yoldia* clay	5	40
Clay: varved, glacio-lacustrine	15	55
Sand and gravel: glacio-fluvial	3	58
Till (Fort Covington)	10	68
Slump		

Section 8. Cut 'F' through Long Sault Island. North face of excavation, where it cuts through the till ridge

Deposits	Thickness (feet) Approx.	Depth (feet) Approx.
Beach gravel: fossiliferous	8	8
Till (Fort Covington (upper till)): oxidized to about 18 feet from surface	30	38
Sand, silt, and gravel: stratified, glacio-fluvial deposits	10	48
Till: 'middle till' = upper part of Malone till	20	68
Silt, clay, sand, and gravel: about 3 to 5 feet of this silt and clay is varved	7	75
Till: lower till = lower part of Malone till	30	105

Section 9. North bank of the St. Lawrence River at the mouth of small creek at Farran Point

Deposits	Thickness (feet)	Depth (feet)
Sand: stratified, alluvial	2	2
— erosional disconformity —		
Clay: varved	8	10
Till: blue-grey, clayey with numerous stones	2	12
Creek level		

Section 10. West bank of Aultsville Creek at Aultsville; 100 feet north of old highway 2

Deposits	Thickness (feet)	Depth (feet)
Sand: stratified, alluvial	2	2
Sand and clay: stratified, marine (*Hiatella* and *Macoma*)	2	4
Till (Fort Covington (?)): grey, sandy; contains numerous pebbles from the Precambrian Shield and fewer from the local bedrock	1	5
Clay: varved (?), contorted with pebbles	1	6
Till (Malone): blue-grey, clayey, compact; contains scattered pebbles from local bedrock and a few from the Precambrian Shield	5	11
Slumped: presumably till (Malone)	5	16
Creek level		

Section 11. North bank of St. Lawrence River, 1.8 miles southwest of Aultsville

Deposits	Thickness (feet)	Depth (feet)
Sand: stratified, alluvial	3	3
Silt and clay: stratified, sandy; marine, a few fossils of *Macoma*	3	6
Silty clay: stratified, with some sandy partings. Marine fossils (*Macoma*)	6	12
Silty clay: vaguely stratified with thin layers and lenses of sand; brackish-water *Yoldia* clay	3	15
River level		

Section 12. North bank of St. Lawrence River at Point Three Points, east of Iroquois. Canal improvement excavation

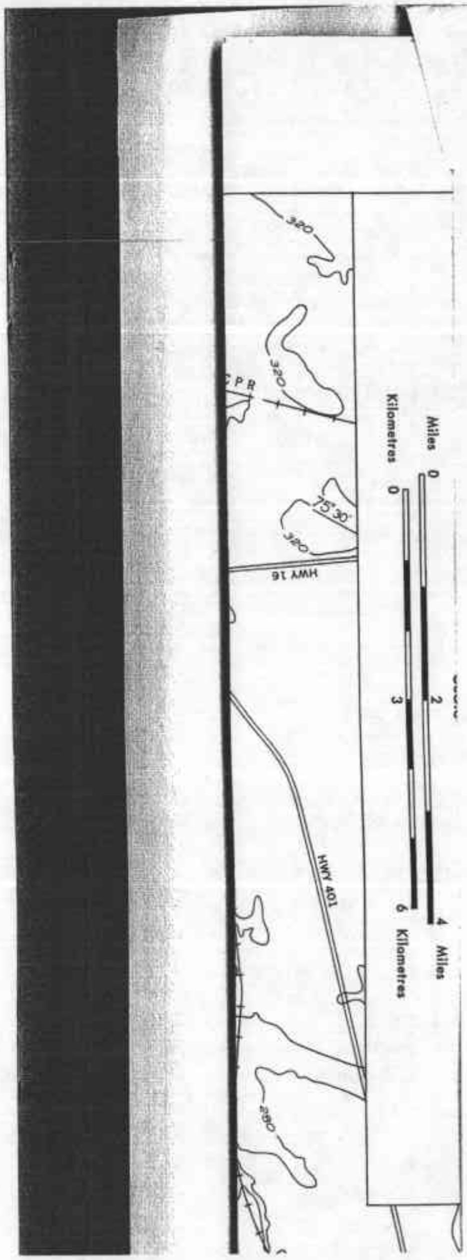
Deposits	Thickness (feet)	Depth (feet)
Till (Fort Covington): oxidized, sandy and stony; fabric from northwest	15	15
Till, gravel, and sand (Malone—"middle till complex"): the upper member of Malone till, recessional phase	10	25
Till (Malone): compact, blue-grey, clayey and silty with a fabric from the northeast	20	45
Bottom of excavation, some 30 feet beneath level of present Lake St. Lawrence		

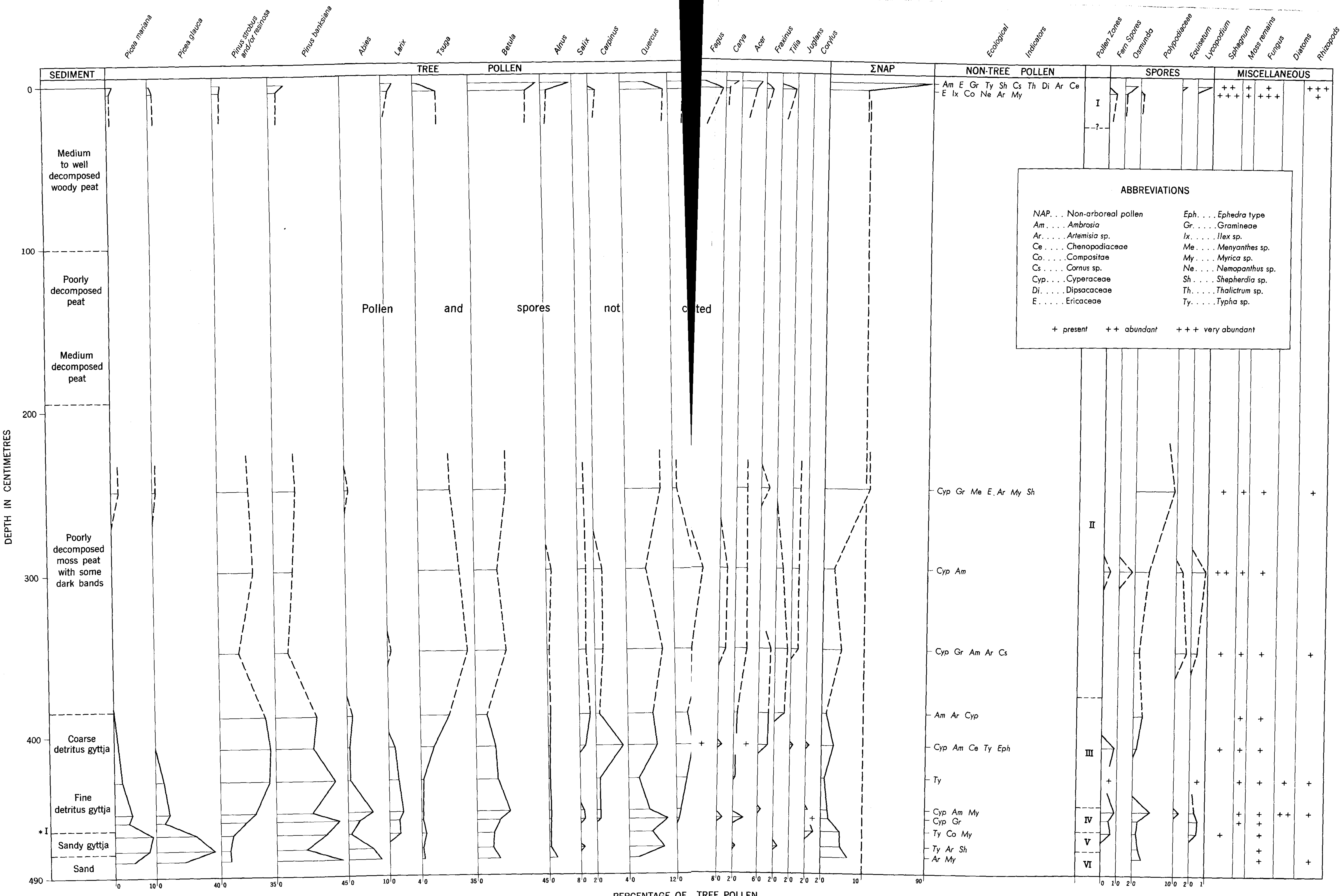
Section 13. Iroquois Lock excavation

Deposits	Thickness (feet)	Depth (feet)
Till (Fort Covington): sandy, silt till with numerous pebbles; upper 10–15 feet oxidized	25	25
Sand and gravel: stratified, glacio-lacustrine and glacio-fluvial sediments	35	60
Till (Malone): compact, blue-grey silty clay till	30	90
Bedrock		

Section 14. Galop Island. Canal improvement excavation (western end of island)

Deposits	Thickness (feet)	Depth (feet)
Gravel and sand: stratified, with silt and numerous boulders (ice-rafted drift according to MacClintock *1958*)	8	8
Till (Fort Covington): dense, brown, sandy till; oxidized	10	18
Till (Fort Covington): blue-grey, sandy silt till; unoxidized	6	24
Sand and silt: stratified	10	34
Slump: probably obscures the Malone till over bedrock		





* C-14 Date, 9,430 ± 140 yrs. B.P. (GSC-8)

To accompany G.S.C. Bulletin 121, by J. Terasmae

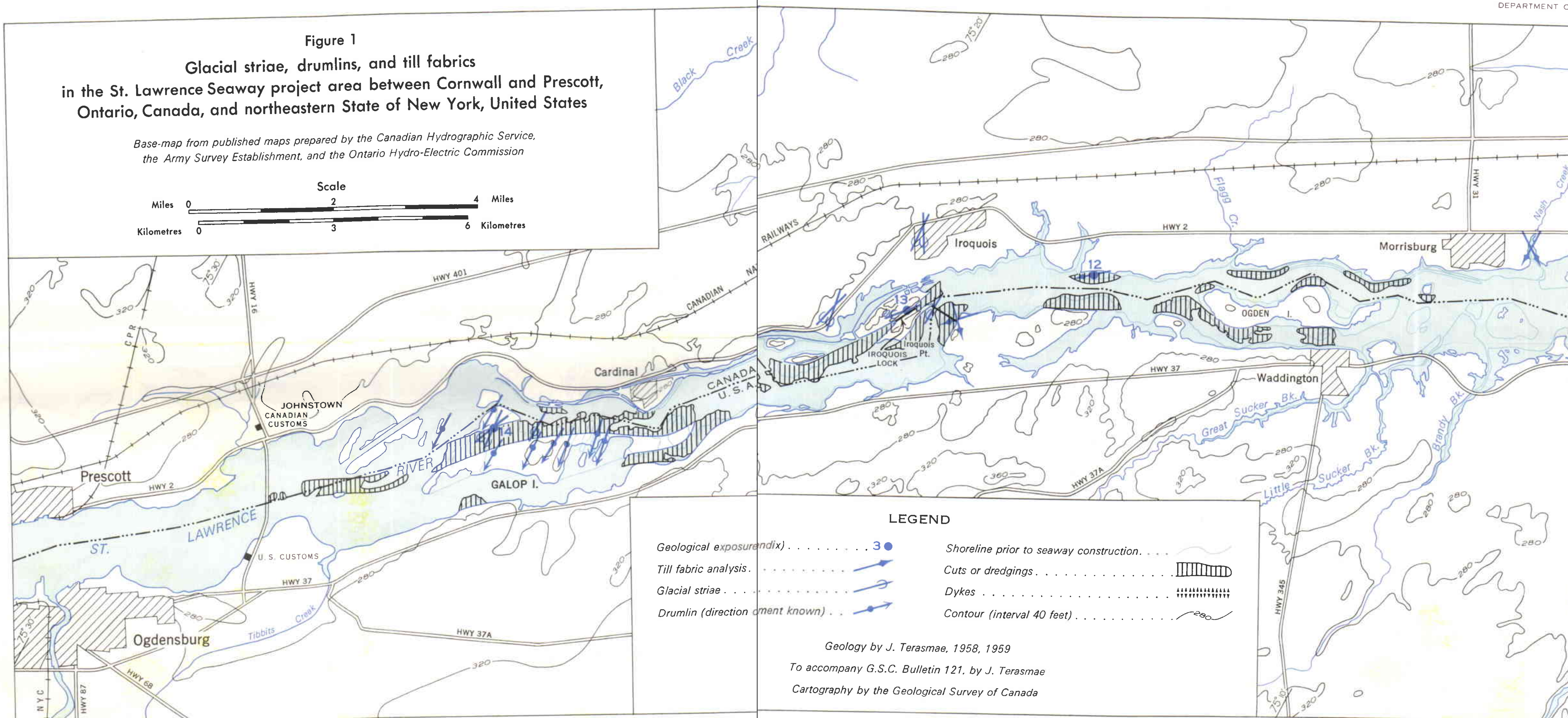


Figure 1

Glacial striae, drumlins, and till fabrics in the St. Lawrence Seaway project area between Cornwall and Prescott, Ontario, Canada, and northeastern State of New York, United States

Base-map from published maps prepared by the Canadian Hydrographic Service, the Army Survey Establishment, and the Ontario Hydro-Electric Commission

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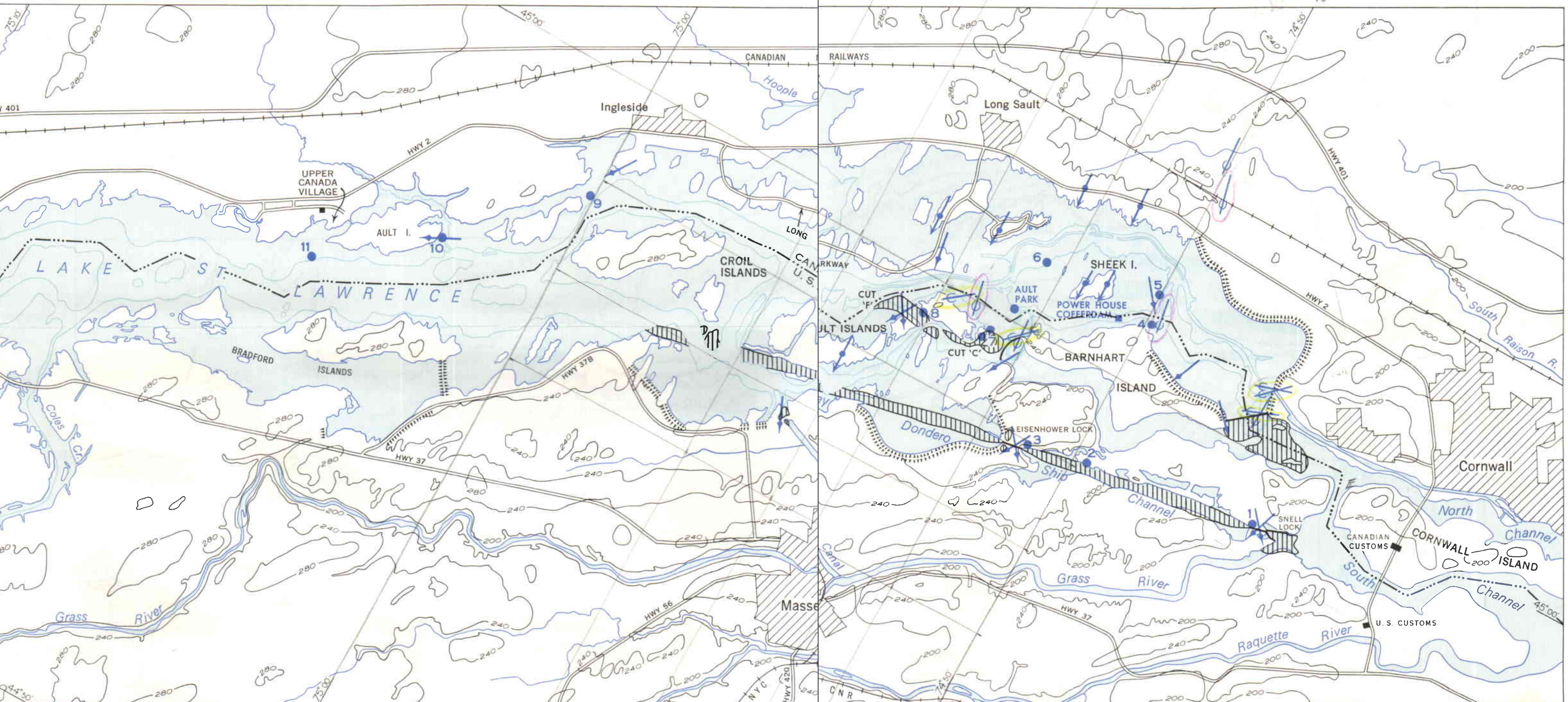

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Figure 1