THE SURFICIAL GEOLOGY AND RIVER TERRACES OF ALLUMETTE ISLAND AND ADJACENT PARTS OF ONTARIO AND QUEBEC

BY

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ABSTRACT

A surficial geology map (scale 1:50,000) of part of the Upper Ottawa Valley comprising Allumette Island, Chichester Township and the Pembroke area is presented and the major landforms described. Geologically, the study region is particularly important because it lies at the northwestern margin of the late-glacial Champlain Sea basin and was adjacent to the outlets of the Fossmill and North Bay-Mattawa channels.

Fieldwork involved geological mapping along selected traverses, soil augering and the investigation of the major surficial exposures. Barometric surveying provided information on the elevation and longitudinal profiles of the river terraces.

Below an elevation of 600 feet, thick surficial deposits (up to 300 feet in places) mask a bedrock surface of irregular relief. The major stratigraphic units recognised are, from oldest to youngest; glacial till, fluvio-glacial sands and gravels, marine clay and silt, nearshore sands and gravels, deltaic sands, terrace alluvium, and bog deposits.

Glacial till, which is assumed to be of Wisconsin age, varies in composition from calcareous, clay till in limestone areas to non-calcareous, sandy till in Precambrian areas. At elevations below 600 feet, the till commonly has a veneer of boulders where wave-wash or fluvial action has removed the finer fractions. The northern portion of the Indian Point moraine, which was traced from the Fort William Boom to Sheenboro, is the only major landform composed partly of till. This morainic ridge, which is composed mainly of large boulders but with some included till and fluvio-glacial gravels, pre-dates the Champlain Sea

episode and marks the last halt of the ice sheet before marine waters reached their maximum northwestern limit. In Chichester Township, two outwash deltas, the largest of which is located opposite Chapeau, were probably deposited in the Champlain Sea and indicate that deglaciation and the marine transgression were, in part, contemporaneous.

In contrast to Chichester Township, fluvio-glacial sediments in areas to the south have been wave-washed or buried beneath later marine deposits. In several instances the flanks of fluvio-glacial ridges below the marine limit (540 feet) are composed of thin beds of silty clay and silt interdigitating with sand and gravel (nearshore sediments). The latter were derived from fluvio-glacial sediments which were exposed to wave action on the higher parts of the ridges.

An early deep-water phase of the Champlain Sea is recorded by large areas of silty marine clay, locally fossiliferous, which rest unconformably on bedrock, till or fluvio-glacial gravels. Several exposures reveal that the clay grades upwards into unfossiliferous silt or laminated silt, a relationship which is interpreted as a change to less saline (near freshwater) conditions accompanied by an increase in the calibre of sediment reaching the marine embayment. Wave and current action was locally effective in reworking pre-existing glacial sediments and depositing them as the littoral facies of the Champlain Sea. This was especially the case on the flanks of the higher glacial features and along a narrow area between 500 and 540 feet, south and west of Pembroke. The only radiocarbon date pertaining to the Champlain Sea in the study region is of 10,870 years B.P. This date was taken from molluscan shells in nearshore sands and gravels 4 miles southeast of Pembroke.

The deposition of marine clay and silt was abruptly terminated when large volumes of fine sand were laid down in the form of a delta by overspill waters entering the marine embayment via the Fossmill channels. Several exposures show the direct superposition of deltaic fine sand over clay. No marine fossils occur in these sands and it is highly probable that the environment was essentially freshwater.

The marine limit is tentatively placed at 540 feet to the south and west of Pembroke and 600 feet in the northern portion of the study area in Chichester Township. No series of shorelines representing the regression of the Champlain Sea were observed, a feature which can be explained by a shifting shoreline of deltaic sedimentation during the later stages of the marine episode.

The transition from marine to fluvial conditions was a change from depositional to an erosional environment rather than a change in salinity. When the sea level stood at approximately 470 feet, the water became channeled and the dissection of the deltaic, marine, and glacial sediments commenced. Four paired river terraces mark the subsequent stages in the drainage evolution of the study region. The elevations of these terraces from oldest to youngest are: 450 feet (High Level Terrace), 420 feet (Upper Terrace), 400 feet (Main Terrace), and 375 feet (Low Terrace). The longitudinal profiles of the High Level Terrace indicated some isostatic warping which for the High Level Terrace is 0.4 ft. per mile. Radiocarbon dates (for the study region and adjacent areas) place the time of formation of the 450 and 420-foot terraces at sometime between 9,500 and 5,240 years B.P. The minimum date of 5,240 years B.P. suggested for the abandonment of the 400-foot terrace coincides with a drastic decrease in discharge of the Proto-Ottawa River and relates well to a date of 6,000 years B.P. for the termination of the North Bay-Mattawa drainage route. Because alluvial terrace sediments are thin and discontinuous, there was no period of aggradation related to any stage of the drainage evolution. The nature of the terraces is a reflection of a fine balance between isostatic uplift, discharge fluctuations and bedrock topography, related to successively lower base levels.

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INTRODUCTION

AND

METHODOLOGY

1. Introduction

The thesis involved the mapping of the surficial materials and landforms of a 150 square mile area in part of the Upper Ottawa Valley. The mapping included both extensive ground surveys and the analysis of air photographs.

The area studied, which had not been previously mapped, was selected because it provides evidence of the complex stratigraphical relationships between late-Wisconsin glacial, marine and fluvial sediments. The study area lies at the margin of a late-glacial marine basin (the Champlain Sea). The aim of the thesis is the compilation of a surficial geology and landform map and the reconstruction of the late-glacial and post-glacial history of the area.

To place the late-glacial and post-glacial history of the Ottawa Valley in a regional context, it is necessary to refer constantly to studies made in the St. Lawrence Lowlands where the stratigraphic record is more complete. A major part of Chapter 1 is devoted to a systematic discussion of the glacial, marine and fluvial events. Particular reference is made to the impact of the Upper Great Lakes drainages upon erosion, deposition and landform development in the Ottawa Valley.

The second chapter defines the study area and reviews the problems of stratigraphy and landform development. The reviews of Chapters 1 and 2 place the history of the study area in a regional context and provide a compilation and summary of the literature pertaining to the Ottawa Valley.

A discussion of the surficial geology and landforms comprises Chapters 3 and 4. Each stratigraphic unit is described systemmatically and the major problems of landform development and stratigraphy are then discussed under separate headings. For the purpose of these accounts, the study area (Fig. 9, p. 42) is divided into two regions which are separated by Chenal de la Culbute: (1) Allumette Island and the Pembroke area, and (2) Chichester Township as far north as the Shield escarpment. This division arises naturally from the contrasts of stratigraphy and landforms in the two areas. In Chichester Township the landscape (apart from the Shield escarpment) is dominated by a large body of outwash opposite Chapeau and other fresh glacial landforms, whilst on Allumette Island and in the Pembroke area, the glacial landforms are indistinct having been wave-washed or buried beneath later marine sediments. As integral parts of Chapters 3 and 4, the surficial geology map (Fig. 11; back pocket) and landform map (Fig. 15; back pocket) will require constant reference by the reader.

During the mapping of the surficial geology and landforms, field investigations revealed that a series of well-developed river terraces were a major landform assemblage of the study area. Consequently a separate chapter (5) has been devoted to the river terraces. This chapter describes the morphology of each major terrace, in particular their longitudinal profiles, and relates their morphology to certain environmental controls. Whereas Chapters 3 and 4 deal with the late-glacial history through the study of the surficial sediments and landforms, the investigations of the river terraces emphasises morphology and extends the geologic and geomorphic history of the study area well into post-glacial time.

In the execution of these studies, field observations, both in the form of geological mapping and barometric surveying, were of paramount importance and, as such, they feature prominently in this account. Although several major problems of the surficial geology and geomorphology of the study area are posed in Chapters 1 and 2, it is not the main aim of this dissertation to provide firm answers to these questions. Rather, the aim of this study is to provide, through the compilation of surficial geology and landform maps, a basis for further detailed study. Nevertheless, the interpretation of the stratigraphy should, to some measure, provide a tentative reconstruction of the late-glacial and post-glacial histories of an area hitherto neglected in Quaternary studies of the Ottawa Valley.

2. Methodology

There is a considerable body of literature devoted to the mapping of pre-Quaternary (generally consolidated) sediments but there is little or no literature pertaining to the principles and methods of mapping unconsolidated surficial sediments.

The special problems of Quaternary stratigraphy and correlation are discussed in several texts, the most recent being Flint (1971); such summaries provide sound principles for the field worker but do not aid him in the practicalities and methods of his mapping.

The nature of surficial mapping

The nature of surficial mapping in a particular area depends primarily upon the dictates of topography, vegetation and accessibility by roads and paths. In this respect, western Allumette Island and Chichester Township are particularly difficult areas to map because large areas are inaccessible by road and covered in forest. Consequently, it was felt that the superimposition of a grid over a topographic base map would not be suitable since many of the control points at the intersections would not be accessible.

To provide the most intensive coverage of the study area, ground traverses, by automobile and on foot, were conducted on every major and minor road and on every path. For this purpose, the study area was divided into 'blocks' of sufficient size, delimited by the grid-iron pattern of the rural roads, to permit the completion of a day-long traverse. When mapping by automobile, stops were made at one tenth of a mile intervals to ascertain the nature of the surficial materials. If the surficial material had changed between stops, the boundary was established and, terrain permitting, traced for a hundred yards on either side of the road. On foot, however, observations could be continuous. If there were no exposures such as road cuttings or ditches available at the control points on the automobile traverses, pits were dug to a depth of 4 feet or to a sufficient depth to be below the soil profiles. In the field, the boundaries of the surficial materials were drawn on the air photographs and transferred to the topographic map (1:50,000 N.T.S. Pembroke west; the largest scale available). The extensive analysis of air photographs was required to extrapolate the surficial boundaries delimited by mapping. This analysis followed the guidelines laid down by the American Society of Photogrammetry (see Chapters 4, 5 and 6). The mapping programme is summarised as follows:

(1) ground traverses by automobile and on foot using air photographs and soil maps as guidelines;

(2) the transference of data from field mapping, air photograph analysis and soil maps to a provisional geology map; and

(3) the selective checking of the provisional surficial geology map by a second survey of the study area, concentrating on those areas posing particular problems of interpretation.

<u>The description of materials</u>

A second phase of the field work consisted of a detailed study of every gravel pit in the study area. When several thick exposures of contrasting materials and/or stratigraphic relationships in one gravel pit were available for study, each different exposure was given a designation (A,B,C, etc.) to enable clarity of description in the text.

The following characteristics of the surficial materials in each bed (or beds in an exposure if the material appeared to be of the same origin) were noted:

(1) grain-size;

(2) degree of sorting;

(3) degree of rounding of constituent grains (if pebble size or larger);

(4) primary structures;

(5) secondary structures;

(6) color (Munsell classification);

(7) content of carbonates;

(8) topographic expression of the materials;

(9) presence or absence of fossils; and

(10) stratigraphic relationship to other materials.

From these observations, a conclusion was reached as to the origin and mode of deposition of the material. The roundness of pebbles was visually estimated according to the chart of Powers (1953) and till was described according to the guide of Scott and St. Onge (1969). The carbonate content of the materials was established by treating samples with dilute hydrochloric acid (HCl) and noting the degree of reaction (U.S. Department of Agriculture, 1951). Difficulties were encountered in the description of the surficial materials according to Munsell notations. In contrast to soils, which generally have distinct color horizons, a particular surficial material may have a wide range of color. Consequently, the descriptions are general insofar as Munsell color names only are used, and the Munsell notations (code descriptions) are omitted because they place too strict a classification on genetically similar materials with a variable range of color. For example, even a small exposure of coarse grained sediments, notably fluvio-glacial gravels, may show considerable variations in terms of Hue, Value and Chroma depending upon such factors as the degree of weathering and the degree of sorting. In order that color descriptions of the materials are standardised, particularly as regards Value, all color determinations were made from in-situ damp samples.

Surficial units

The surficial units of the surficial geology map are self-explanatory. Several qualifications to this classification, however, have to be noted. First, where the surficial cover over bedrock is less than two feet thick, then the surficial unit is given as bedrock. This qualification is also applicable to limited thicknesses (i.e. less than 2 feet) of surficial sediments which form a veneer over an area comprising a major unit. A third qualification applies to areas of sediments too small to be cartographically

CHAPTER I

A REVIEW OF THE GLACIAL AND POST-GLACIAL HISTORY OF THE OTTAWA VALLEY AND ADJACENT AREAS OF THE ST. LAWRENCE LOWLANDS

1. Glacial Stratigraphy

(a) General Considerations

In comparison with the St. Lawrence Lowlands, Quarternary studies in the Ottawa Valley have been neglected. Johnston (1917) was one of the first workers to publish a fully comprehensive regional study of the surficial deposits of the Ottawa area. Subsequent major contributions have been made by Antevs (1925,28,39), Burger (1967), Mackay (1949a,49b) and Gadd (1961,63a and 63b). Gadd (1961) revised the surficial geology map of the Ottawa area and pointed to inconsistencies in previous research. In addition to the maps of Johnston and Gadd, the only other surficial geology map of part of the valley is that of Chalk River (Gadd,1963a) which is adjacent to the study area.

Since the Ottawa Valley falls within the limits of the Wisconsin glaciation, it is probable that successive ice sheets have removed the evidence of previous glacial phases. The absence of evidence for the various stages of the Wisconsin in the Ottawa Valley may have a similar explanation. Alternatively, ice may have occupied the valley throughout the Wisconsin. Although Keele and Johnston (1913,p.136) have described an exposure of two till sheets separated by glaciofluvial sediments, only one till has been found by subsequent workers in the Ottawa area.

The stratigraphic record is more complete in the St. Lawrence Lowlands. Investigations by MacClintock (1958), MacClintock and Stewart (1965), MacClintock and Terasmae (1960) and Terasmae (1960,65) have revealed three late Wisconsin tills separated by lacustrine and fluvio-glacial sediments. These are: (1) Malone Till - ice movement from the northeast, (2) Middle Till - a minor readvance of Malone Ice in lake waters and, (3) Fort Covington Till - ice movement from the northwest. The Fort Covington ice (the latest readvance) did not extend over the Adirondacks but impinged against the base of these hills and impounded Lake Iroquois which established an outlet in the Covey Hill Gap (1010 feet) and drained into Glacial Lake Vermont (the predecessor of modern Lake Champlain). Prest (1970), however, suggests that this gap coincided with the Frontenac phase of the post-Iroquois lakes and not the main Iroquois stage. The position of the ice margin and its relation to the glacial lakes at the time of the Fort Covington readvance is shown in Fig. 1, p. 11. Retreat of the ice from Covey Hill was accompanied by successively lower lake levels of the post-Iroquois lakes. Deglaciation of the St. Lawrence Valley and southeastern Ontario permitted the expansion of lake waters as far as Ottawa but probably not as far as Pembroke.

The Fort Covington terminal moraine west of Lake Champlain is probably a correlative of the "Highland Front moraine" located between Granby and Trois Pistoles on the south side of the St. Lawrence Valley; this moraine has been provisioally dated at 12,500 years B.P. (Gadd, 1964; Lasalle, 1966). The last halt during ice recession across the St. Lawrence

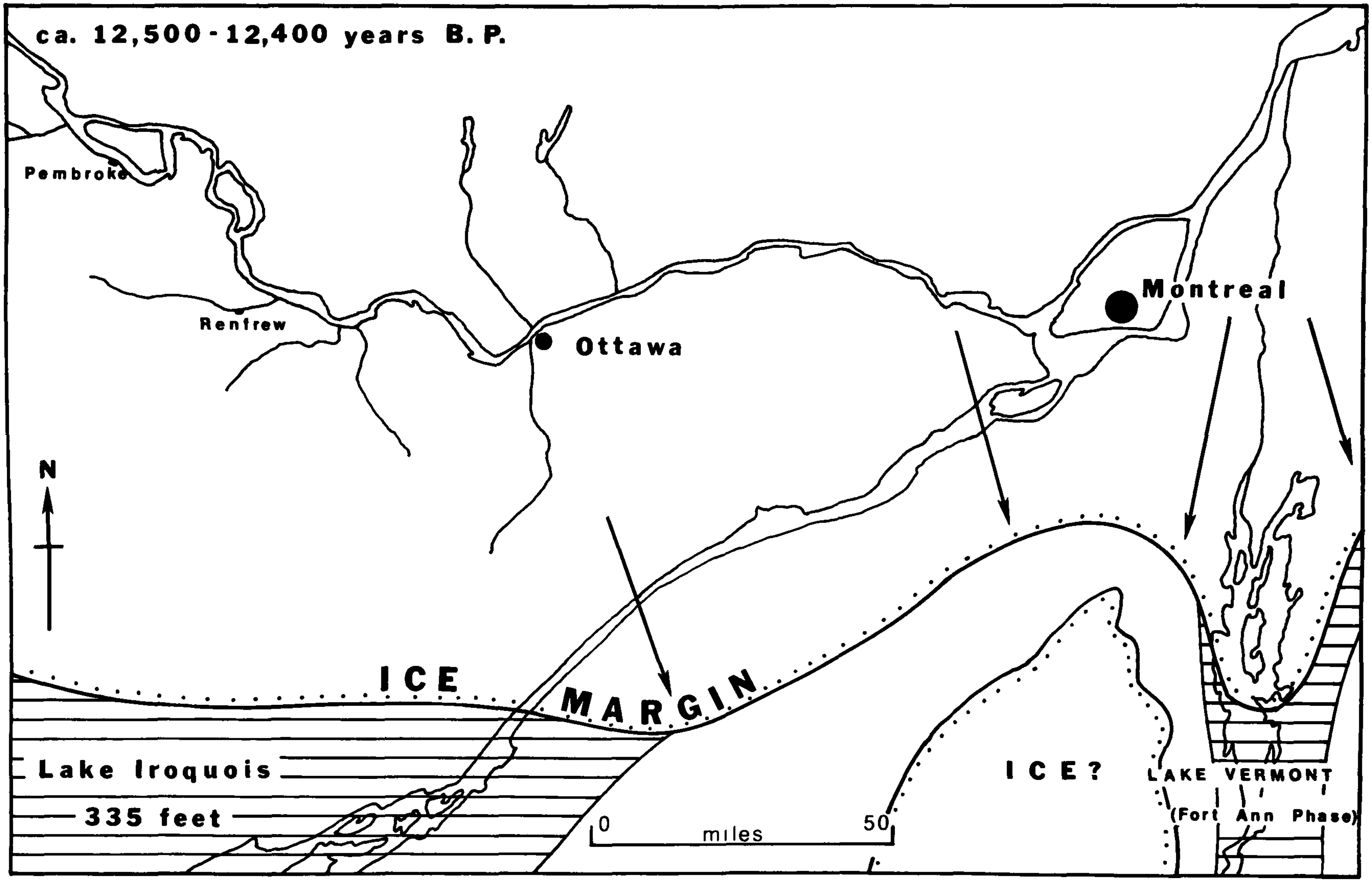

Fig. 1 Fort Covington Readvance (source: Prest, 1970).

Valley is marked by the Drummondville moraine which represents the last position of the ice sheet before marine waters could invade the lowlands (Gadd,1960a,64; Lasalle,1966) (Fig. 2, p.13).

Although no correlative of this ice halt has been found in eastern Ontario, in the Cornwall area, Terasmae (1960,65) has found evidence of a post-Fort Covington ice advance. In spite of the fact that no till associated with this glacial phase has been found, south-trending striations cut both the striations of the older Fort Covington and Malone ice sheets, and in addition, the Fort Covington till has been remoulded into south-trending drumlins. This is the postulated "Ottawa Advance" of Chapman and Putnam (1966). In the Ottawa area, ice movement was essentially north-south although the youngest set of striations indicate movement from northwest to southeast. Between Ottawa and Pembroke there is a considerable variation in the orientation of striations, but during the later stages of deglaciation ice movement appears to have been down valley (i.e. southeasterly) showing the increasing influence of topography upon ice motion as the ice thinned (Burger,1967).

The last major ice advance recorded in the lower St. Lawrence Valley is recorded by one till, the Gentilly Till, which is overlain by Champlain Sea sediments (Gadd,1960b). Gadd suggests that this area was occupied by ice from at least 44,000 years B.P. (the minimum date of the underlying St. Pierre interstadial beds) to 12,000 years B.P. (the maximum

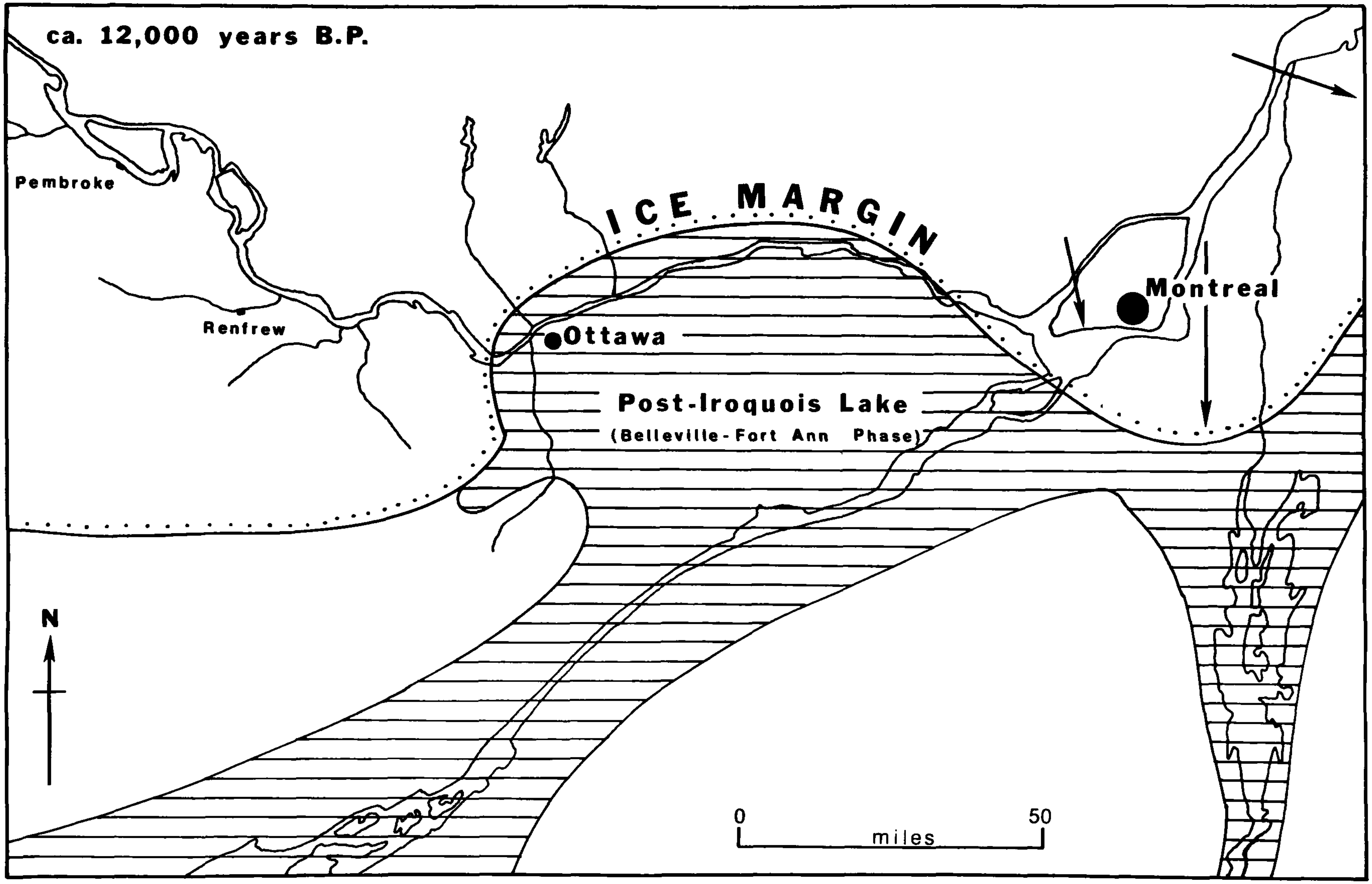

Fig. 2 Drummondville Halt and Post-Iroquois Lake in the Lower Ottawa Valley (source: Prest, 1970).

age of the Champlain Sea). The oscillations of the ice sheet observed in the upper St. Lawrence Valley did not occur in the lower St. Lawrence Valley and the intervening lacustrine phase between deglaciation and marine inundation is not represented.

(b) The St. Narcisse Readvance

During the Champlain Sea episode in the lower St. Lawrence Valley, there was a readvance of the ice into the sea after the ice had retreated an unknown distance to the north from the Drummondville position. This has been named the St. Narcisse Readvance. A discussion of this readvance is relevant to the problems of the study area because it has been suggested (Elson,1962,68) that the St. Narcisse stage may be a correlative of the "Pembroke Halt" recognised by Antevs (1928,39,62) in the Upper Ottawa Valley (Fig. 3, p.15).

An examination of the stratigraphic relationships between the deposits of the St. Narcisse moraine and the adjacent marine sediments may provide valuable indicators for the investigation of the glacial materials in the study area. In their study of morainic deposits in several Laurentian valleys, Parry and Macpherson (1964) noted that in many cases there was a similar down-valley sequence of sediments and landforms:

(1) Ice-contact features; e.g. kettle holes.

(2) Moraine; occasional marginal overspill channels in the valley side.

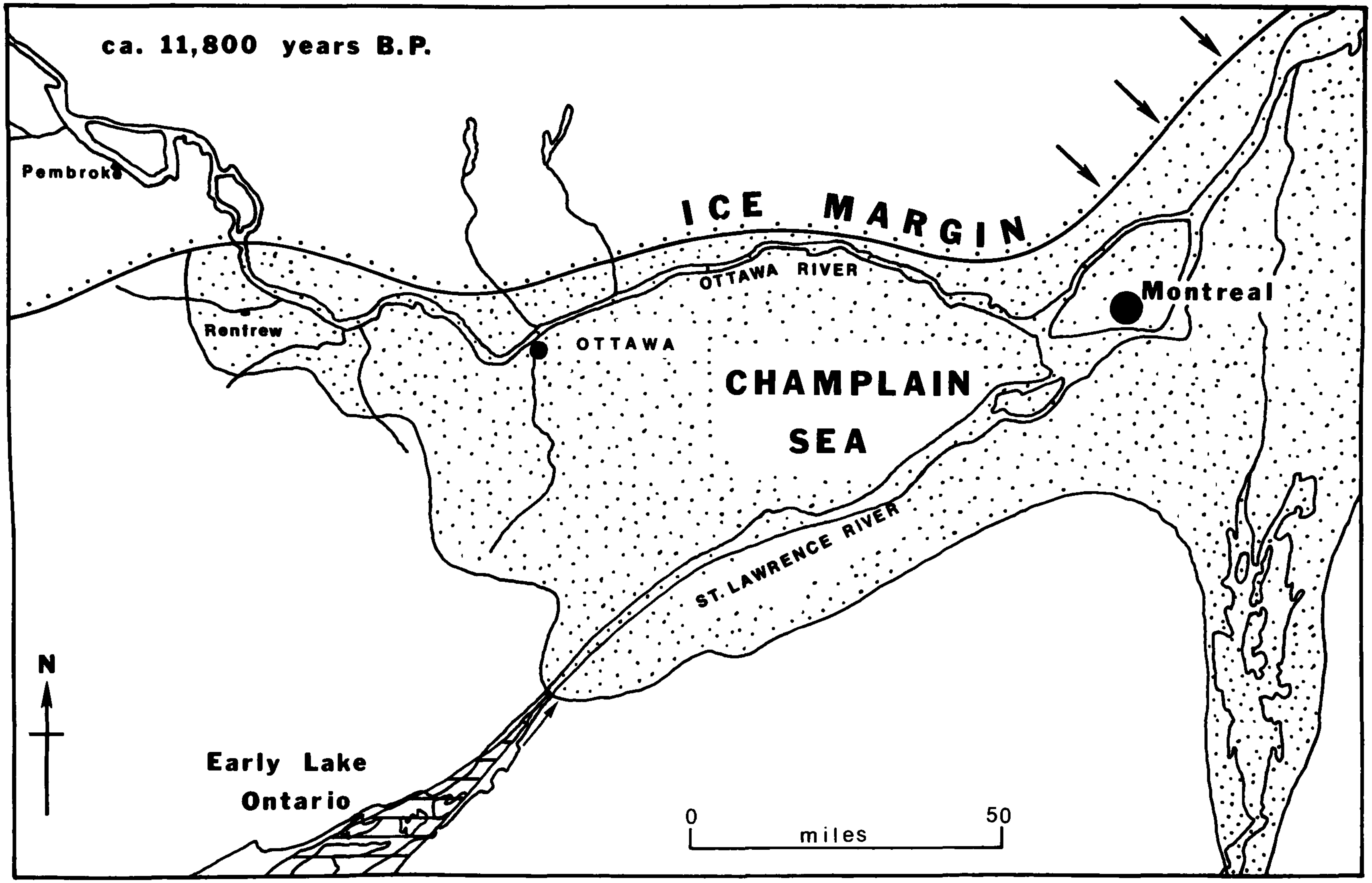

Fig. 3 St. Narcisse Readvance and Early Champlain Sea (source: Prest, 1970).

(3) Valley train delta; outwash.

(4) Foreset slope; outwash.

(5) Deepwater zone; deposition of silty clays.

These large glacio-fluvial deltas, which are present in all the valleys studied by these writers, exhibit a general accordance of height (between 700 and 750 feet) indicating the maximum elevation of submergence in the Champlain Sea. Many of the exposures reveal the direct superposition of marine sediments (silty clays) on outwash or ice-contact drift. Because the moraine has been modified by wave action, Parry and Macpherson suggest that the sea flooded the moraine following the retreat of the St. Narcisse ice. Similar observations have been made by Lasalle (1970) who found possible marine sediments lying unconformably on morainic materials north of Quebec City.

In the Grondines and Trois Rivieres areas of the St. Lawrence Valley, there is evidence that the St. Narcisse ice readvanced into the sea and incorporated fossiliferous marine sediments in the morainic materials (Gadd and Karrow, 1959; Karrow, 1959). In the Upper Ottawa Valley, however, there is only evidence of a possible halt during ice retreat in marine waters, and there is no evidence of the superposition of marine sediments on the highest (i.e. above 550 feet) glacio-marine features such as those described by Antevs at Beachburg and Forresters Falls.

The time ranges for the St. Narcisse readvance are rather broad. Lasalle (1966) has argued that the St. Narcisse moraine was formed before 10,500 years B.P. and Elson (1969b) suggests that the readvance occurred before 10,900 years B.P. at the time when there was a colder, shallower phase of the Champlain Sea. The large outwash features of the Upper Ottawa Valley must have been deposited between 11,600 years B.P. and 10,870 years B.P., the two delimiting dates for ice retreat in the valley obtained from Champlain Sea sediments at Ottawa and Pembroke respectively. Prest (1970) gives a tentative date of 11,800 years B.P. for the St. Narcisse readvance. However, until surficial mapping of the southern Laurentian Shield between Pembroke and Montreal is complete, the exact relationship of the St. Narcisse moraine to the glacial features of the Upper Ottawa Valley will not be known.

(c) Glacial-Marine Relations in the Upper Ottawa Valley*

If Antevs' interpretation of the ice margin position at the time of the fresh water/marine interchange is correct, then the Champlain Sea transgression must have followed the retreating ice up the Ottawa Valley from Renfrew to its northwestern limit. Antevs (1928,62) has claimed that the large outwash plains at Beachburg, Fort Coulonge, Kazabazua (in the

*In this account, the Upper Ottawa Valley is defined according to the generally accepted historical definition as that portion of the Valley which lies to the northwest of the City of Ottawa. The Lower Ottawa Valley is that portion of the Valley between the City of Ottawa and the confluence of the river with the St. Lawrence near Montreal.

Gatineau Valley) and Petawawa represent a marked halt, the "Pembroke Halt", in the retreat of the ice sheet. Because these features have a surface elevation corresponding to the marine limit in these areas, he contends that they were built into the Champlain Sea. Whereas the features at Fort Coulonge, Beachburg and Kazabazua are ice-contact and fluvio-glacial, the Petawawa sand sheets are deltaic and the product of deposition by overspill waters which drained into the sea from the Upper Great Lakes. Antevs does not make this distinction nor does he differentiate outwash sands from outwash gravels. The alignment of these features from Pembroke to Kazabazua with the St. Narcisse moraine and their similar relationships (in places) to the Champlain Sea sediments has led Elson (1962, 68) to postulate that they represent one and the same halt of the ice sheet. A major problem of the St. Narcisse stage is that there is no agreement on whether it was a readvance or recessional halt of the ice. In the St. Lawrence Lowlands, the stratigraphic sequence records a readvance (Gadd and Karrow,1959; Karrow,1959) but in the Ottawa Valley there is only evidence of a possible halt during ice retreat. North of Ottawa in the Gatineau Hills, the presence of fossiliferous glacio-marine gravels at an elevation of 500 feet proves that at an early stage of the Champlain Sea the ice front stood in marine waters for a time (personal observation). If the sea reached the Pembroke area somewhat later than at Ottawa, there is the possibility that it had surpassed its maximum transgression. As a result, the maximum marine limit in the Pembroke area may possible be lower. Sychroneity of the upper marine water plane at different localities in the Ottawa Valley cannot therefore be assumed.

2. The Champlain Sea

(a) General Considerations

When the ice barrier near Quebec City had been breached, marine waters invaded the St. Lawrence, Champlain and Ottawa Valleys. Stratigraphic evidence from Ottawa and Cornwall, where varved silts and clays grade without an erosional break into Champlain Sea clays, shows that the transgression covered some areas which were already submerged by lake water (Gadd, 1961, 63B; Terasmae, 1960, 65) and, presumably, while some other areas experienced sub-aerial conditions and others were still underlain by ice.

This lake phase was named "Frontenac" by Antevs (1925) abd "St. Lawrence" by Goldthwait (1933). Antevs located the position of the ice margin at the close of this lake stage by noting which type of sediment (marine, brackish or fresh water) was deposited first on the rock or till floor, at each locality, and which type rests above it. At the beginning of the marine episode, according to Antevs, the ice margin stood through Renfrew, Quyon, Ottawa, Hawkesbury and at least eight miles south of Montreal.

The maximum extent of the Champlain Sea is not precisely known and particularly so in the Pembroke area where there is a notable absence of beach features (Burgér,1967). For a considerable period of time the margin of the retreating ice probably formed the northern shore of the sea and thus prevented the formation of shoreline features in addition to controlling the area covered by marine waters. Fossiliferous Champlain Sea sediments have been found as far west as Brockville, Smith's Falls, Arnprior and Pembroke. The Lake Champlain Basin formed a major embayment whilst the major valleys of the Shield such as the Gatineau, Lievre and St. Maurice probably formed fjord-like extensions of the sea. The inferred maximum extent of the Champlain Sea is shown in Fig. 4, p.21.

It is not known if the Champlain Sea crossed the Frontenac axis and entered the Lake Ontario Basin. Chapman and Putnam (1966), like their predecessors, were unable to locate any distinct shorelines or beach materials related to the Champlain Sea in the Lake Ontario Basin. According to Terasmae(1965), the depth of the Trent Valley outlet below the present level of Lake Ontario discounts such a possibility.

Macpherson (1967) has plotted the elevations and isobases of the upper marine limit in the Montreal region. The maximum marine limits of 690 feet at Kingsmere (or 675 feet at Wilsons Corner), 520 feet in Renfrew County (Burger,1967)

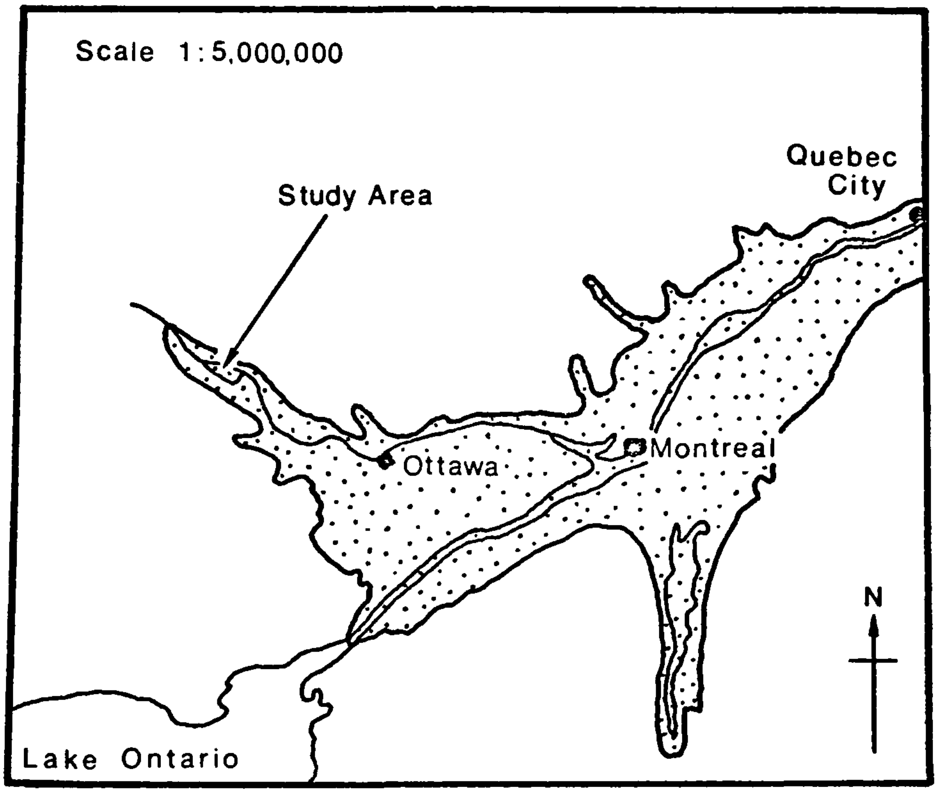

Fig. 4 Inferred Maximum Extent of the Champlain Sea (Source: Prest, 1967).

and 600 feet at Chalk River (Gadd, 1963a) would seem to indicate that the fulcrum through the isobases trends north-south through the Adirondacks such that the isobases in the Upper Ottawa Valley would trend northwest-southeast. This suggestion relates well to the pattern of isobases plotted by Macpherson further down valley and that shown in Flint (1971, p. 360). Table 1 (p. 25) summarises the data presently available for the elevations of the maximum marine limit in the Ottawa and Gatineau Valleys.

East of Renfrew, the Champlain Sea episode in the Ottawa Valley commenced with a changeover from fresh to salt water but in those areas occupied by ice at this time, the marine transgression followed the retreating ice margin (Fig. 2, p. 13). Because the ice margin formed the shoreline for a period of time, the maximum marine limit was not everywhere synchronous. When the sea stood at 600 feet in the Gatineau, near its maximum elevation, deglaciation was probably not yet complete in the northwestern part of the valley (i.e. the Pembroke-Petawawa area). A period of several hundred years had probably to elapse before the sea reached its greatest northwestern extent in the Chalk River area (Antevs, 1925,28; Prest, 1969). The speculative ice margin positions and associated dates during the retreat of the ice sheet in the Ottawa Valley are given in Fig. 5, p. 23.

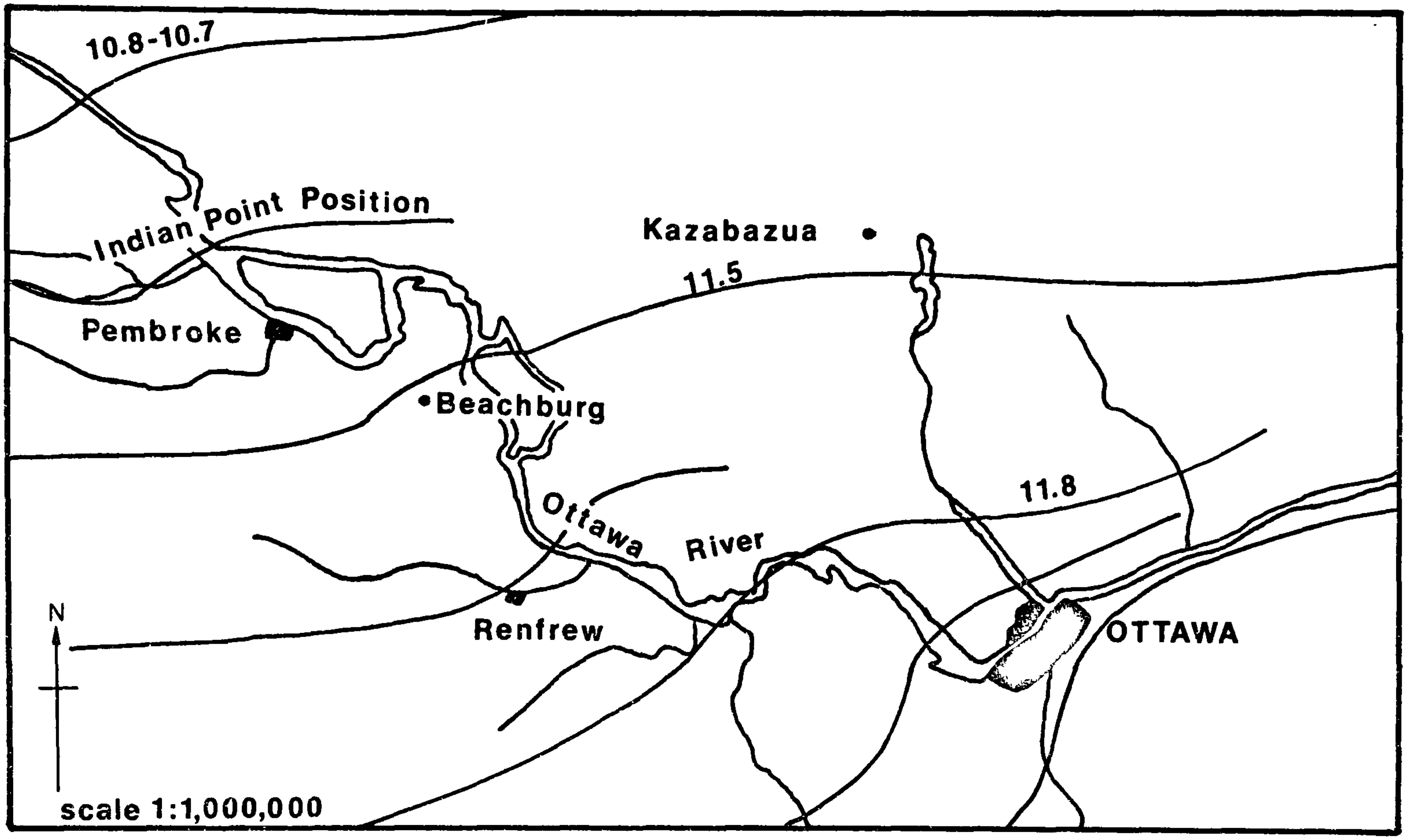

Fig. 5 Speculative Ice-Marginal Positions (in thousands of years B.P.) in the Ottawa Valley (source: Prest, 1969).

The Champlain Sea in the Ottawa area reached its maximum elevation rapidly since the oldest radiocarbon date from marine shells of 11,600 years B.P. (GSC-982), which relates to the time when the sea stood at approximately 600 feet in the Gatineau, is not substantially younger than the oldest Champlain Sea date of 11,880 years B.P. (GSC-505) from the St. Lawrence Lowlands. It is also considerably older than the only date from the Pembroke area of 10,870 years B.P. (GSC-90).

A study of the known elevations of the maximum marine limit (Table 1, p.25) reveals that marine limit is higher in or near the Shield than to the south of the Ottawa River. This might reflect better strandline development in more southerly areas. A comparison of the elevations of the marine limit at Brockville and Ottawa shows that this water plane has been tilled by post-Champlin differential uplift at approximately 5 1/2 feet per mile (Henderson, 1968). Macpherson (1967) has calculated that initially following the Champlain Sea maximum isostatic uplift was of the order of 20 feet per century but with the rate progressively decreasing. Consequently, at lower elevations there was more time available for the construction of shoreline features.

One of the major problems of the Champlain Sea is the nature of sea level changes and associated sedimentation. It is generally agreed (and well-supported by radiocarbon dates from different elevations) that the Champlain Sea rose to its maximum level and that its subsequent regression was

TABLE I: THE MAXIMUM MARINE LIMIT IN THE OTTAWA AND GATINEAU VALLEYS

Location	Elevation (feet)	Source	Comments
Kingsmere	690	Johnston (1916)	terrace in sand plain no fossils
Wilsons Corners	675	Kenney (1964)	highest proven marine strand-line
Kazabazua	600	Antevs (1928)	height of outwash plain built into Champlain Sea
Maniwaki	600	Wilson (1924)	inferred water level above flats of Champlain Sea sediments
Quyon	560	Wilson (1924)	terrace
Quyon	540	Wilson (1924)	beach ridge on outwash deposit
Renfrew	552	Goldthwait (1933)	gravel bar
Renfrew County	520	Burger (1967)	heights of terraces boulder pavements, lag concentrates; glacial features wave washed below 520 feet
Chalk River	600	Gadd (1963a)	maximum height of wave washed till and Petawawa sand plain
Beachburg/Forresters Falls	560	Antevs (1928)	glacial outwash deposited near to water level of Champlain Sea

equally rapid. In any interpretation of the stratigraphic sequence, it is important to note that, as Elson (1969a) observes, the four major basins of the Champlain Sea (Ottawa Valley, Lake Champlain Valley, Lake St. Peter region and Lake St. Francis) each have separate sedimentary and stratigraphic characteristics. For example, the clays in the Ottawa Valley and Lake St. Peter Basin are thick in comparison to those of the Champlain Valley and Lake St. Francis region. According to Elson, these differences reflect the availability of sediment most of which, except beaches and deltas, was derived from the retreating ice sheet rather than from the re-working of coastal materials by wave action. This would appear to contradict Karrow's (1961) suggestion that streams and shoreline erosion were more important than glacial ice as sources of sediment. In the Pembroke area, glacial ice was probably the most important source, at least during the early stages of the Champlain Sea when the transgression followed the retreating ice margin.

(b) The Marine-Fluvial Transition

The termination of the Champlain Sea episode in the Ottawa area must have occurred when sea level dropped to the 325-foot level because below this elevation the surface deposits are of non-marine origin (Gadd,1961). The salinity of the water changed rapidly (in time) causing the extinction of marine fauna. The regression of the sea was undoubtedly caused by crustal uplift but the change in salinity could have had several causes. As the marine embayment became smaller and the volume of water decreased, fresh water from rivers draining into the sea progressively diluted the remaining salt water. More probably, the change was brought about primarily by the influx of large volumes of fresh water from the Upper Great Lakes via the Fossmill and North Bay-Mattawa outlets (Gadd,1961). This would have been aided by isostatic uplift of the sill near Quebec City which would have restricted the exchange of fresh water and sea water (from the open ocean).

A considerable number of radiocarbon dates have been taken in the Ottawa area from marine shells in shallow-water or littoral sediments at elevations between 300 and 400 feet. These dates, which range from 10,880 years B.P. (GSC-588) to 10,200 years B.P. (L-604D), relate to at least part of the regressive phase of the Champlain Sea. The latter date is particularly important because it establishes the maximum age for the marine-fluvial transition. The reliability of dates obtained from marine shells in Champlain Sea sediments has been supported by a date of 10,800 years B.P. (GSC-570) taken from a marine algal bed (the only known occurrence in the Champlain Sea) in a sand pit 12 miles southwest of Ottawa (Mott,1968).

3. The Fossmill and North Bay - Mattawa Outlets

The nature of sedimentation, erosion and landform development in the Ottawa Valley has, to some measure, been controlled by discharge of water from the Upper Great Lakes via the Fossmill and North Bay-Mattawa outlets and from Glacial

Lake Barlow-Ojibway via the Upper Ottawa Valley. These discharges were, in part, contemporaneous with the Champlain Sea episode in the Ottawa Valley. They are also related to the history of post-Champlain drainage development in the valley. The study of these outlets with the aid of radiocarbon dates provides valuable links between the late-glacial and post-glacial chronologies of the Upper Great Lakes and the Ottawa Valley. In particular, deglaciation of the Ottawa Valley can be viewed in a regional context.

While ice still occupied the Nipissing-Mattawa Lowland, deglaciation of the Algonquin Highlands permitted waters from the Lake Huron basin to drain into the Ottawa Valley via the Petawawa and Barron river system. The opening of these routes, collectively called the Fossmill system, initiated the post-Algonquin Lakes which were characterised by progressively lower water levels. The Fossmill system, first investigated by Chapman (1954), consisted of several subsidiary routes which Harrison (1970) has designated as follows: South River, Genesee, Fossmill, Sobie-Guilmette and Mink Lake. Each provided successively lower routes for the drainage of the post-Algonquin Lakes as ice retreat gradually uncovered the Algonquin Highlands.

The sill of the Fossmill route (sensu stricto) was located at the eastern end of Kilrush Lake at an elevation of 1,140 feet (Fig. 6, p.29. A radiocarbon date of 9,860 years B.P. (GSC-1246) from basal lake gyttja establishes a

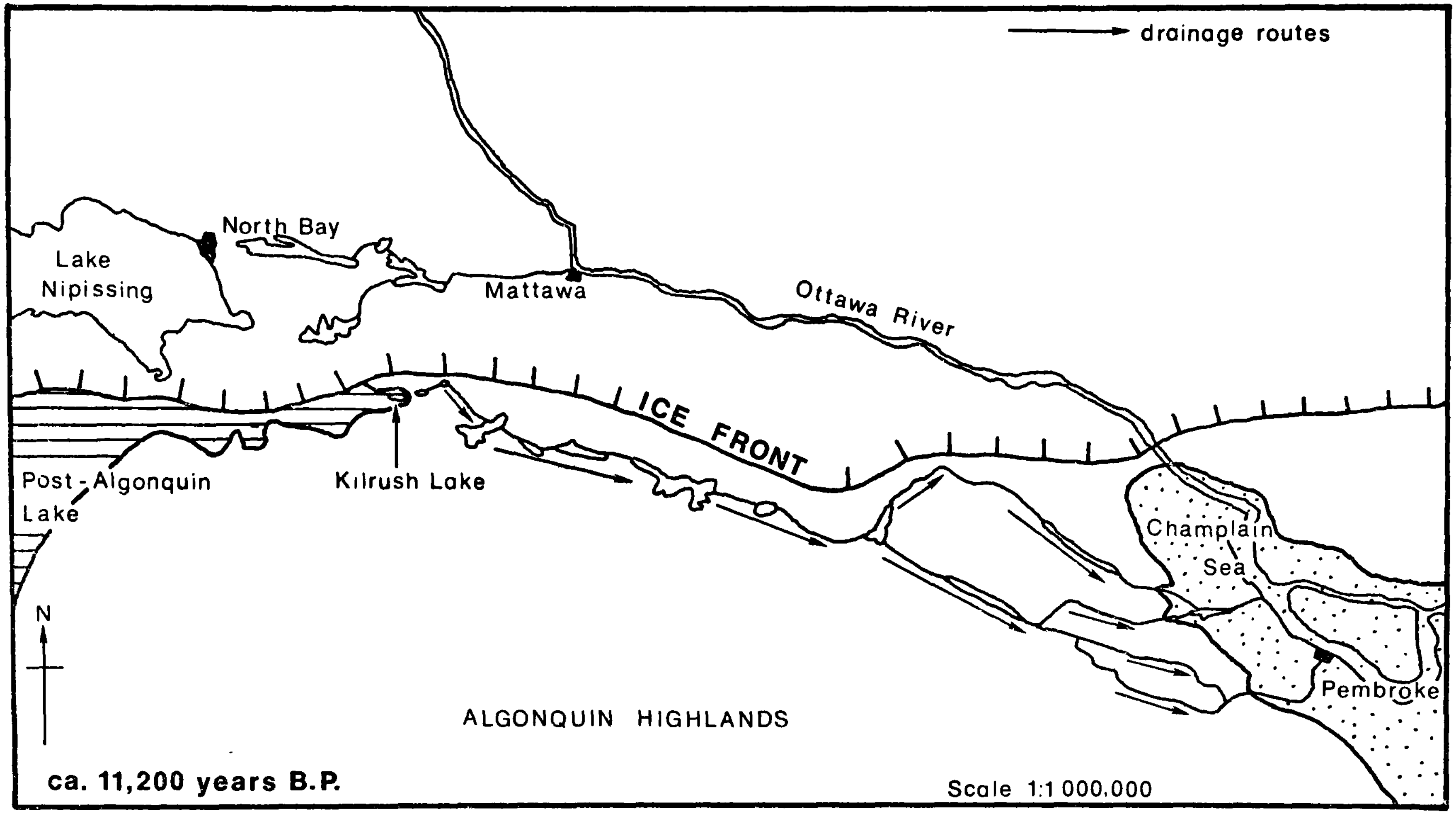

Fig. 6 Fossmill Outlet (after: Harrison, 1970; Prest, 1969, 70).

minimum age for the termination of this drainage route. Further ice retreat uncovered two lower routes via the Amable du Fond Valley (Mink Lake stage); a minimum date of 8,670 years B.P. (GSC-1097) for the termination of this outlet also sets a minimum age for the opening of the North Bay-Mattawa channel. Eventually deglaciation had uncovered the Mattawa Lowlands and the North Bay area; several radiocarbon dates in the region of 9,500 years B.P. pertain to this event (S-100, 9,570 years B.P. and GSC-638, 9,870 years B.P. at North Bay). These are minimum dates but Terasmae and Hughes (1960) have calculated that the deglaciation of the North Bay area and the opening of the outlet could have occurred as early as 10,970 years B.P. Most workers agree that the opening of the North Bay outlet caused the last major drawdown of water level of the post-Algonquin Lakes (Farrand, 1962; Hough, 1958, 63; Lewis, 1969; Prest, 1970; Wayne and Zumberge, 1965).

Initially drainage was ice-marginal or sub-glacial during the early North Bay outlet stage (Harrison's "Mattawa-Ottawa outlet:) because parts of the Ottawa and Mattawa Valleys were still occupied by lobes of ice (Prest, 1970). With the complete vacation of the lowlands by ice, drainage was controlled by the narrows at Trout Lake, east of North Bay, with a sill elevation of 680 feet, (Harrison's "North Bay Outlet Stage") (Fig. 7, p.31). During the operation of the North Bay outlet the Ottawa Valley also received discharge from Glacial Lake.

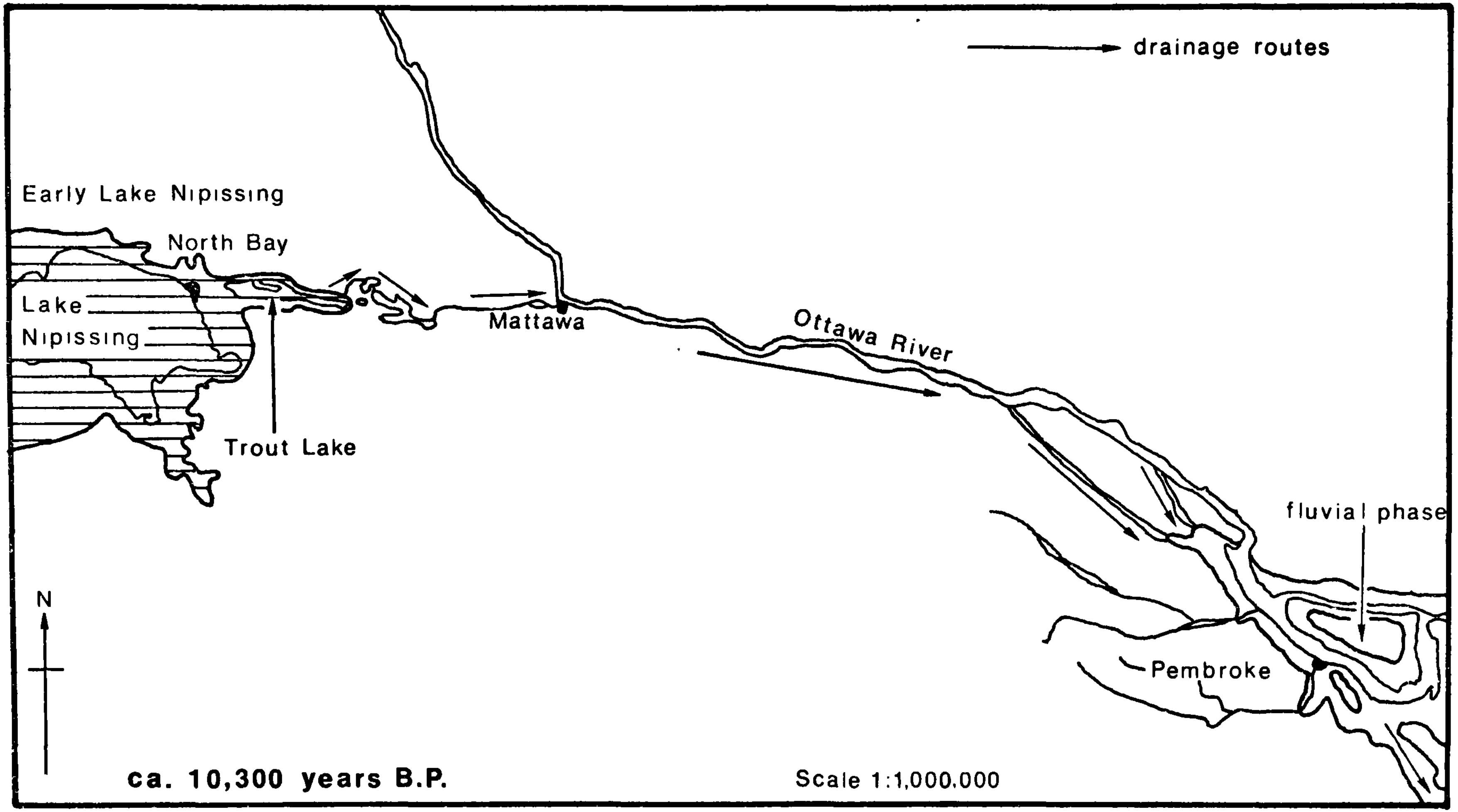

Fig. 7 North Bay - Mattawa Outlet (after: Harrison, 1970; Prest, 1970).

Barlow-Ojibway in northern Ontario which existed between 9,500 and 7,500 years B.P. (Terasmae,1968). Cessation of flow through the North Bay-Mattawa channel occurred sometime before 5,250 years B.P. (GSC-1162), a date obtained from wood fragments in an abandoned pothole in the Mattawa Valley.

It is apparent that the use of both the Fossmill and North Bay-Mattawa channels were in part contempraneous with the Champlain Sea episode in the Ottawa Valley but that the North Bay-Mattawa outlet, on the other hand, mainly postdates the marine transgression. It must be concluded, therefore, that for a period of about 6,000 years discharge into or through the Ottawa Valley was many times that of the modern river.

The Fossmill and North Bay-Mattawa outlets discharged large volumes of fresh water into the Ottawa Valley. Because drainage via these channels was ice-marginal or subglacial for a time, a considerable quantity of glacially-derived debris were available for transportation. During the Champlain Sea episode, discharge via the Fossmill system resulted in the deposition of a large delta, composed mainly of fine sand but with some interstratified gravels, in the Petawawa area. Prest (1970, p.729), commenting upon the delta, stated that

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> spillway system are unusually large, in places averaging 2 to 3 feet in diameter. They form ridges and hummocks up to 20 feet high that appear to be bars built by torrential streams.

The influx of large volumes of freshwater into the Champlain Sea also had important ecological consequences. In a systematic study of molluscan fauna. Goldring (1922) observed that species decreased in numbers, and individuals in size, westward from Quebec City into areas of brackish water. This study revealed a gradual transition from marine water at Arnprior to brackish water at Renfrew and near-fresh water at Pembroke. A similar transition was observed by Antevs (1925) whose studies of silts and clays in the Ottawa Valley indicated that lamination increased into areas of less saline water. The salinity of the Champlain Sea varied both in space and time. Major influxes of fresh water into the sea from the Upper Great Lakes (and locally from the St. Narcisse readvance) may have been responsible for the salinity changes observed in the St. Lawrence Lowlands (Elson,1963,69a 69b).

A recent revision of the history of the Upper Great Lakes, supported by radiocarbon dates, suggests that the Fossmill system was in operation about 11,200 years B.P. and the North Bay-Mattawa discharges commenced at about 10,600 years B.P. (Prest,1970). This would appear to contradict the observations of several writers who have ascribed the change from marine to fresh water conditions in the Ottawa Valley to the release of Great Lakes waters via these outlets (Gadd, 1963b; Kenney,1964; Chapman and Putnam,1966; Antevs,1962). Since drainage via the Fossmill system was responsible for the construction of a large delta in the sea at Petawawa, near the marine limit, a consideration of the date for the Fossmill system suggests that the introduction of large volumes of fresh water into the valley occurred well before the time of the marine/fluvial transition (approximately 10,000 years B.P. at Ottawa). It is more probable, therefore, that rather than a sudden salinity change during the last stages of the Champlain Sea, the erosive effects of the discharges and the accompanying salinity changes were felt progressively down-valley as the marine embayment retracted.

4. The Post-Champlain Drainage Evolution of the Ottawa Valley

Below the 320-foot level in the Ottawa Valley (somewhat higher in the study area) and the 250-foot level in the St. Lawrence Valley, the later stages of landform development are recorded by a series of lake and river terraces cut at successively lower elevations.

In his study of the Ottawa Valley, Mackay (1949a,49b) envisaged that with the gradual withdrawal of the sea the Proto-Ottawa River cut into the deltaic materials of the Petawawa area and transported some of the sediments downstream depositing them at successively lower elevations. Chapman and Putnam (1966) believe that one of these deltas was deposited to the east of Ottawa when a small embayment at 240 feet was present in the valley. The spreads of fluvial sands and gravels mapped in the Blackburn area by Lemenstrel (1969) presumably represent these deltaic deposits. If, however, the evidence of the inferred maximum sediment surface is considered, it is apparent that some of the overburden of Champlain Sea sediments had been removed before the fluvial sands and gravels were deposited (Crawford and Eden,1965).

Below these high level fluvial sediments, a series of abandoned channels and terraces mark various stages of downcutting of the Proto-Ottawa River. East of Ottawa, a series of channels at 220 feet were cut in the clay plain leaving islands of marine clay capped by fluvial sands and gravels. A minimum date for the formation and abandonment of these channels of 7,650 years B.P. (GSC-681) has been obtained from basal peat in the deepest part of the Mer Bleue bog. This date is in broad agreement with those taken from other ancient Ottawa River channels at similar elevations (Mott and Camfield, 1968). The same stage of the Ottawa River was probably responsible for the formation of the prominant 240-foot terrace to the west of the city. This terrace has been variously described as marine by Antevs (1928) and lacustrine by Johnston (1916). Goldthwait (1933) notes, however, that the height of this terrace decreases down valley from 264 feet near Breckenridge to less than 250 feet at Deschênes. This, he reasons, is the initial slope of an expanded river rather than a slope created by subsequent upwarping of a lake strandline.

At Blackburn, two distinct terraces at 175 feet and 145 feet record the later stages of drainage evolution. These terraces are underlain by more than 30 feet of alluvial fill which indicates that erosional down-cutting was not an uninterrupted process (Lemenestrel,1969). No radiocarbon dates are available to extablish the ages of the lower terraces (i.e. below 220 feet).

In the St. Lawrence Lowlands and Lower Ottawa Valley, Macpherson (1967) has utilised radiocarbon and palynological data to correlate post-Champlain shorelines. Such data is essential because differential isostatic uplift continued well into post-Champlain time. A study of the basal pollen bearing sediments in bogs, supplemented by radiocarbon dates, reveals the stage at which the site of the bog rose above water level and sedimentation began. The elevation of the lowest bog dating from a particular pollen zone at each locality, according to Macpherson, provides the first criterion of the altitudinal limit between that zone and the later zone at a lower elevation. Physiographic evidence of former water levels and the pollen profiles from different localities allows certain pollen boundary surfaces to be regarded as deformed water planes.

Macpherson has recognized three major stages of emergence in the Lower Ottawa Valley and the St. Lawrence Lowlands which were previously discussed by Goldthwait (1933). These are: (1) Rigaud Stage (200 feet, ca. 8,500 years B.P.), (2) Montreal Stage (100 feet, ca. 7,500 years B.P.) and, (3) St. Barthèlèmi (50 feet, ca. 6,500 years B.P.). In addition, two minor water levels are to be found at 175 and 140 feet (Brown, 1962).

The Rigaud shoreline is only continuous in the Lower Ottawa Valley and the Terrebonne sand plains north of Montreal. At this time branching estuarine channels were being cut into the unconsolidated deltaic deposits of the Lower Ottawa Valley (formed at higher stages of the Champlain Sea in response to falling sea level). Macpherson conceives that the well-developed Rigaud shoreline was formed when Glacial Lake Barlow-Ojibway drained through the Ottawa Valley. This suggestion is in accord with the known duration of this Lake (9,000 to 7,500 years B.P.). The isobases constructed from the boundary elevations between pollen zones V and IV correspond closely to those of the Rigaud water plane. In fact, the boundary between pollen zone V and IV lies only 10 feet below the Rigaud plane and the tilt is approximately the same (1.5 feet per mile).

The shoreline of the succeeding Montreal stage can be traced with only a few breaks from the Lower Ottawa Valley and Richelieu Valley to Lac St. Pierre. The formation of this shoreline, which is untilted, is represented in the pollen sequence at the lower limit of zone IV giving an approximate date of 7,500 years B.P. for this stage.

The last stage of the emergence of the St. Lawrence Valley, the St. Barthèlèmi (50 feet), is recorded by a prominant terrace which can be traced from Lac St. Pierre to the Lachine rapids. According to Macpherson, during the Montreal-St. Barthèlèmi interval, the Lake of Two Mountains was separated from the estuary and the local base level for the Ottawa River became the present level of the lake at 73 feet above sea level.

In the St. Lawrence Lowlands, stratigraphic evidence for the existence of a post-Champlain lake is to be found in an exposure at St. Philomene, south of Montreal; 3 feet of fresh water sands and gravel containing the fossil <u>Lampsilis</u> rest on brackish water clays (Elson,1969a and b). Unfortunately Elson does not comment upon the water level or extent of this lake. He does, however, suggest that the St. Lawrence River had occupied its present channel by 6,800 years B.P. which establishes a minimum date for the termination of this lake phase.

Although Macpherson refers to these water bodies as stages of the Champlain Sea, there is no stratigraphic or faunal evidence to show that marine waters occupied the Lower Ottawa Valley and the Montreal area after 8,700 years B.P.(Prest,1970)

Correlation of the stages identified in the Lower Ottawa Valley with the terraces at Ottawa, or even Pembroke, is exceedingly difficult on the basis of present evidence. The present course of the Ottawa River is characterised by a series of lake-like expansions separated by rapids at hard rock barriers which act as local base levels of erosion. In the past, the downcutting and terrace development of the river were similarly controlled. Further palynological and radiocarbon data from bogs developed on terraces and in abandoned channels is required before precise correlations can be made.

A comparison and summary, based on radiocarbon dates, of the late-glacial and post-glacial histories of the study area with that of the Ottawa area and the Upper Great Lakes is given in Fig. 8, p.40.

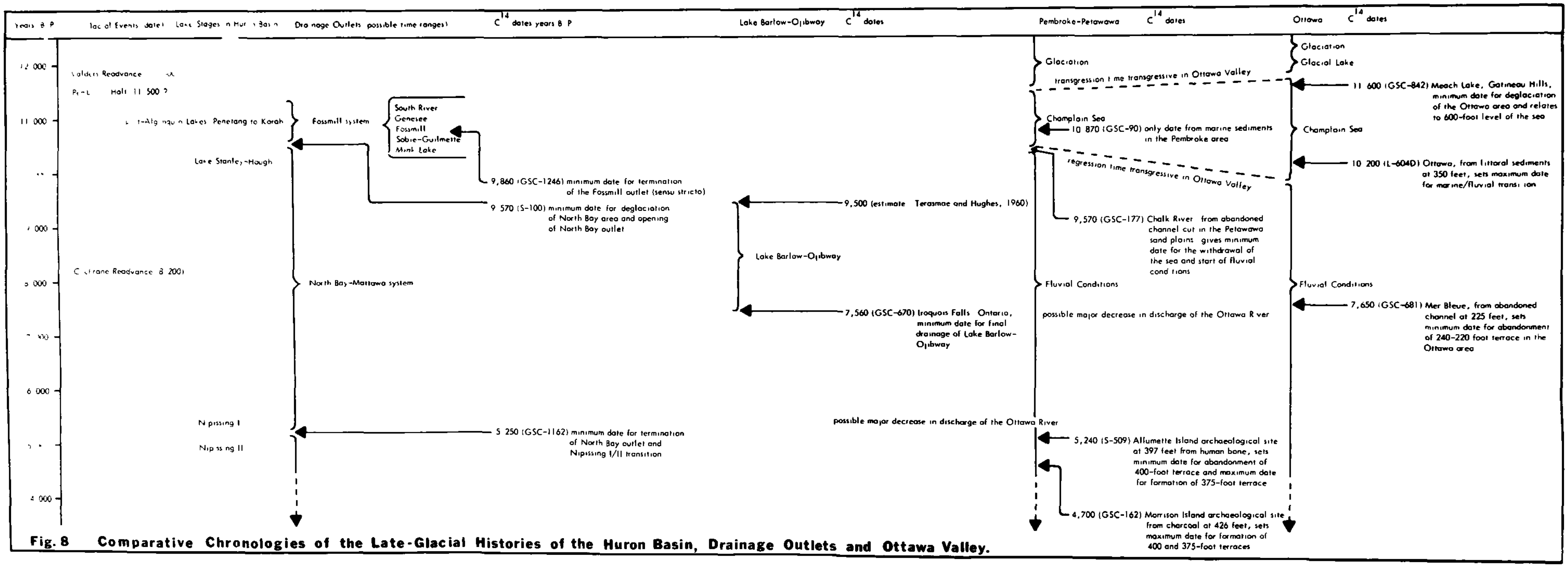


Fig. 8 **Comparative Chronologies of the Late-Glacial Histories of the Huron Basin, Drainage Outlets and Ottawa Valley.**

CHAPTER 2

THE STUDY AREA

1. The Selection and Location of the Study Area

In the Ottawa Valley, the surficial geology has only been mapped in two areas at Ottawa (Johnston, 1917; Gadd, 1961) and at Chalk River (Gadd, 1963a). These areas reflect two contrasting environments of the Champlain Sea. At Chalk River, the Champlain Sea episode is represented in the stratigraphic sequence by deltaic sands deposited in the sea by overspill waters from the Upper Great Lakes. In the Ottawa area, however, the whole range of sedimentary facies from littoral to deep water is present. Consequently, the study area may reveal the relationships between the two environments since it is located immediately to the east of Chalk River.

The area selected for mapping (Fig. 9, p.42) has not been previously mapped yet has the advantage of being adjacent to an area already mapped at Chalk River. The study area is to some degree naturally defined by physiographic features. The northern boundary of the region is demarcated by the escarpment of the Shield which rises over 700 feet above the lowland. To the south, in Renfrew County, the boundary of the study area lies between two and five miles inland from Allumette Lake and encompasses parts of Petawawa, Alice, Stafford and Pembroke Townships. This permits the investigation of the morphology of the river terraces and also the stratigraphy of the transition zone between littoral and deep water Champlain Sea sediments. The eastern boundary of the study area includes the eastern boundaries of Chichester and

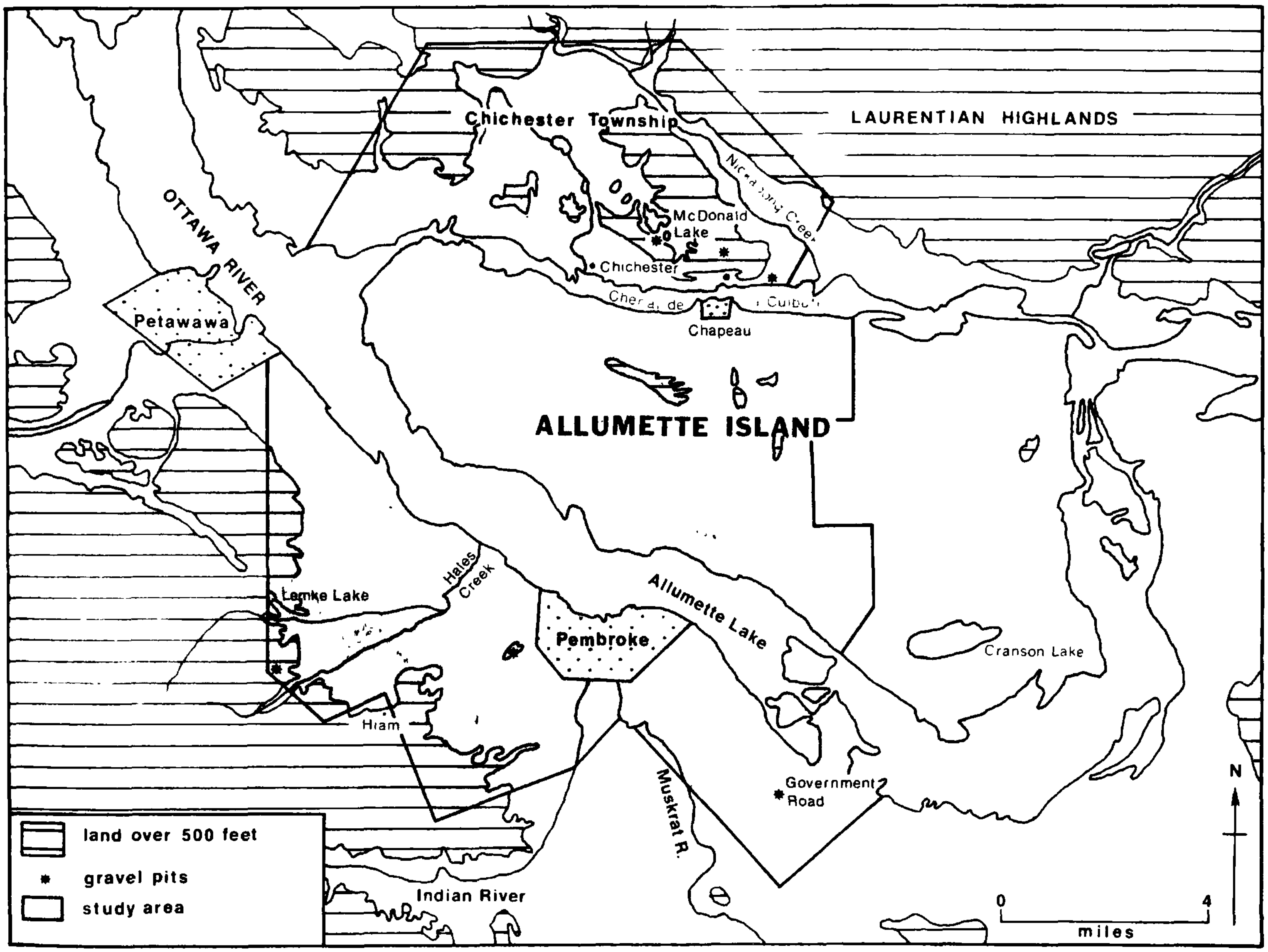


Fig. 9 Location of the Study Area.

Pembroke Townships and a north-south line drawn across Allumette Island between "The Plains" and Morrison Island. The western boundary is formed by the western boundary of Chichester Township and the western limit of the Pembroke (East) 1:50,000 map sheet.

The study area lies at the junction of two fundamentally distinct geomorphological zones. West of Chalk Bay, the Ottawa River is relatively straight and confined to a gorge-like channel whereas downstream it has several channels, bends and detours. Former stages of the Ottawa River above this junction are mainly recorded by a series of abandoned channels cut into the Petawawa sand sheets where bedrock topography was probably a major control of drainage development. To the east of Chalk Bay, bedrock control is still important but the river has been able to cut a series of broad river terraces into the (generally) thick unconsolidated deposits of the lowland.

A major reason for the selection of the study area is that it is adjacent to the outlets of the Fossmill and North Bay-Mattawa channels and as such should reveal the impact of these drainages upon sedimentation and erosion. In particular, the down valley extent of the Petawawa delta should be revealed. The complex relationships between glacial, marine, deltaic and fluvial sediments in the Ottawa Valley should probably be nowhere better demonstrated than in the Pembroke-Petawawa area.

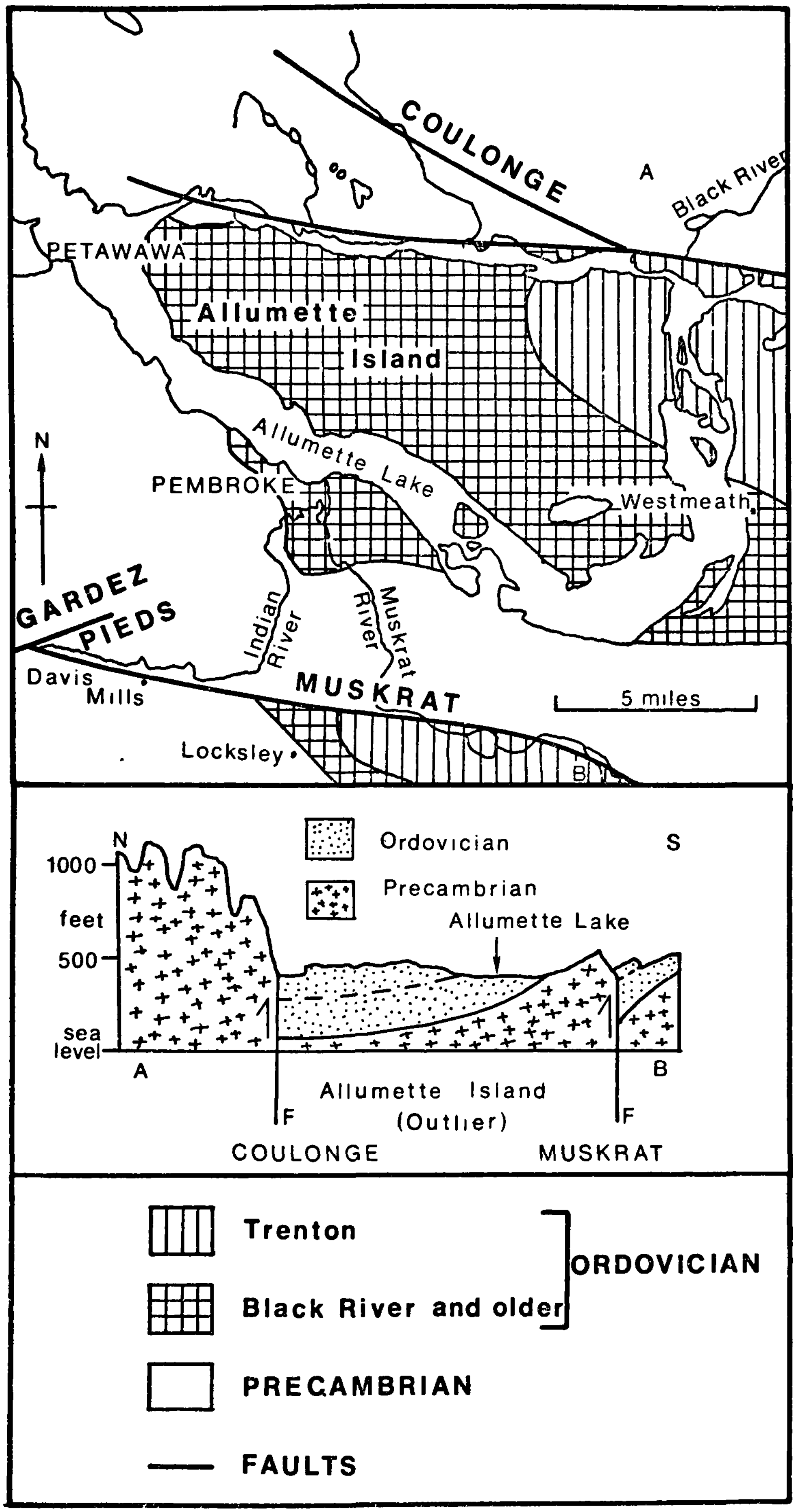
2. Bedrock Geology and Structure

Investigations of the bedrock geology and structure in or adjacent to the study area include a report and map by Ells (1907), a study of the Ottawa-Bonnechere graben by Kay (1942), a report on Renfrew and Lanark Counties by Quinn (1952), a reconnaissance along the Coulonge and Black Rivers by Retty (1932), and a description (with geology map) of the mineral occurrences in the Renfrew area by Satterly (1944). The most comprehensive studies are those of Ells and Kay.

Allumette Island, the Westmeath peninsula, western Calumet Island and a small area around Pembroke form one of the most westerly Ordovician outliers of the Ottawa-Bonnechere graben. The present distribution of the Precambrian and Ordovician bedrock in the study area is primarily the result of post-Ordovician faulting which has preserved the Ordovician sediments as downfaulted blocks on the Precambrian basement (Fig. 10, p.45).

In the study area, Precambrian crystalline rocks outcrop to the north of Chenal de la Culbute, on the northwestern tip of Allumette Island near Culbute Rapids and to the south of Allumette Lake (with the exception of the Pembroke area). The oldest Precambrian rocks of the area are hornblende gneiss and amphibolite which have been formed from basic volcanic rocks by metamorphism. Younger Precambrian rocks include crystalline limestone and dolomite (not found in the study area) and paragneisses. The latter have often been injected

Fig.10 **Bedrock Geology and Structure of the Study Area (Sources: Kay, 1942; Satterly, 1944).**



by granitic and syenitic magmas and changed into hybrid gneisses and migmatites. These two groups of rocks have been intruded by bodies of igneous rocks such as granite and syenite and by dikes of diabase and basalt. Thus the Precambrian basement rocks show varying degrees of deformation and metamorphism. It should be noted, however, that crystalline limestone, which is characteristic of the Precambrian Grenville Province north of Ottawa and east of the study area, is absent in the western parts of Renfrew and Pontiac Counties.

Resting unconformably on the Precambrian basement are several formations of Ordovician sedimentary rocks, which in the study area are restricted in outcrop to Allumette Island, Morrison Island, northwestern Cotnam Island and the area around Pembroke. From oldest to youngest these are:

Groups	Major Rock Types
Beekmantown	dolomite
Chazy	cross-laminated, quartz-rich, pebble-bearing, sandstone with some interbedded shale
Black River	calcareous shale, shaly limestone and limestone
Trenton	dolomite, calcareous shale and shaly limestone and massive coarse-textured limestone

The upper formations of the Trenton group and the younger formations of the Ordovician, which can be found in the Ottawa area, are absent on Allumette Island. The maximum thickness of Ordovician strata of approximately 300 to 400 feet is to be found beneath Allumette Island adjacent to Chenal de la Culbute (Kay, 1942).

With the exception of the northeastern part of Allumette Island, the Ordovician rocks of the study area are of Black River age or older.

In the geology maps of Kay (1942) and Satterly (1944) there is one error which has been corrected by the present study. On Cotnam Island, Ordovician sediments are restricted to a narrow area bordering Allumette Lake, opposite Morrison Island, and the rest of the island is underlain by Precambrian granite-gneiss, whereas the maps of Kay and Satterly show the whole of Cotnam Island underlain by Ordovician sediments.

Two major faults and one subsidiary fault, all normal and with a downthrow to the south, transect the Pembroke area from east to west. These are three of a series of sub-parallel faults which bound several downfaulted Palaeozoic outliers within the structurally depressed and topographically low region of the Ottawa-Bonnechere graben. The graben is approximately 35 miles wide between the Coulonge fault-line escarpment north of Chenal de la Culbute and the St. Patrick escarpment south of Calabogie Lake and Lake Clear.

The Allumette outlier comprises a shallow syncline, the axis of which trends east-west, whose northern limb is cut out by faulting. According to Kay (1942), the structural relief of the outlier is in the order of 200 feet. Between Allumette Lake and the Muskrat fault, Precambrian rock outcrops at the surface but on the south side of the fault Ordovician sediments outcrop in the form of another downfaulted outlier.

The northern boundary of the study area is formed by the Shield escarpment which is the topographic expression of the Coulonge fault (Plate 1, p.49 and Plate 2, p.49). This fault, which Kay estimates has a minimum throw of 1000 feet, is but one of a series of faults, arranged 'en echelon', which form the northern boundary of the Ottawa-Bonnechere graben between Ottawa and Petawawa. In the study area, the Coulonge fault trends southeast-northwest and probably follows the line of the Nickabong Valley. Subsidiary to the Coulonge fault is one which follows Chenal de la Culbute from the Plains to the Culbute Rapids. With reference to this fault, Kay (1944, p.162) states "That the [Allumette] outlier is principally bounded by a subsidiary fault is evidenced by the presence of a 200-foot scarp immediately north of Culbute Channel at Chapeau". This "fault-scarp" is, in fact, the undercut frontal slope of a glacial outwash delta (see p.130). Nevertheless, two observations suggest the presence of a fault along Chenal de la Culbute. First, the bedrock surface is definitely higher on the north shore of Chenal de la Culbute than on the south shore, and secondly, through much of its length the channel separates Ordovician sediments from Precambrian crystalline

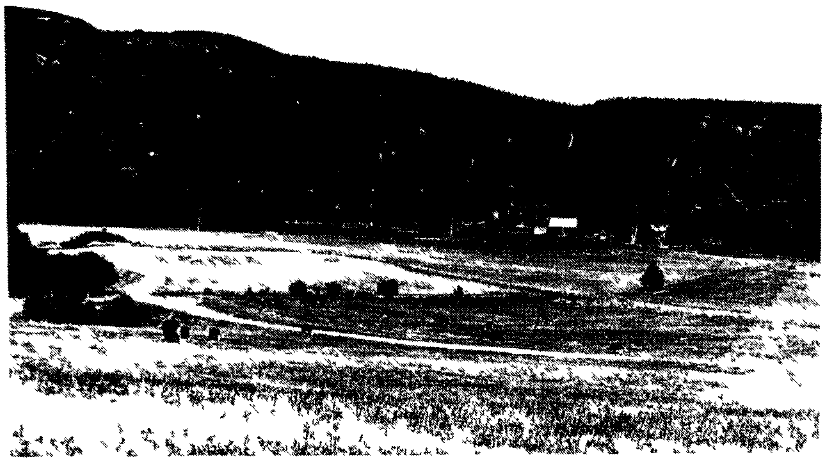


Plate 1 The Coulonge fault escarpment along the Nickabong Valley (402882).

Plate 2 The Shield escarpment and the Nickabong sand plain looking east towards Nickabong village (317930).

rocks.

To the west of the study area in the Indian River Valley, the Gardez Pieds cross-fault forms an éscarpment which rises northwest of the depression extending from Round Lake to Alice. The effect of this cross-fault is to cause a lateral displacement of the Muskrat fault westward from Mud Lake.

The distribution of bedrock and the major topographic features of the Pembroke area (the Muskrat and Coulonge escarpments) are largely the result of faulting. The Ordovician sediments of Allumette Island have been preserved, to some degree, from erosion by the fact that they form part of a downfaulted outlier. Furthermore, the bedrock surface is lower on Allumette Island than the areas to the north of Chenal de la Culbute and to the south of Allumette Lake. Consequently, Allumette Island has received the thickest overburden of late-Quaternary glacial, marine and deltaic sediments. The irregular topography of the bedrock surface has also had important effects on the morphology of the river terraces and the nature of the post-glacial drainage development of the study area (see p. 188). The distribution of Precambrian crystalline rocks and Ordovician limestone and dolomite is reflected in the composition of the glacial sediments (Burger, 1967; see p.53). Throughout much of the study area the bedrock is covered by a thick mantle of unconsolidated sediments. The area of bedrock outcrop is limited to two types of areas (Fig. 11, back pocket): (1) Above an elevation of 480 feet on the steeper slopes and (2), on the lower river terraces, generally below 400 feet, where fluvial erosion has removed the unconsolidated overburden.

3. Previous Research

Only two major studies have been devoted to the glacial and post-glacial stratigraphy of the Pembroke region. Gadd (1963a) has mapped the surficial geology of a 400 square mile area in the region of the Chalk River atomic energy establishment. More recently, an area of 1500 square miles between Petawawa and Arnprior has been investigated by Burger (1967) who has produced a series of maps which demonstrate the relationships among parent soil materials, bedrock and landforms. Other studies have been made by Antevs (1925,28) who has described several exposures of surficial materials in the Pembroke area. Additional research includes the soil maps of Renfrew and Pontiac counties by Gillespie *et al*. (1964) and Lajoie (1962) respectively, and a geological study of Renfrew County by Quinn (1951). In his treatise of the Upper Ottawa Valley, Kennedy (1971) has reported upon archaelogical sites on Allumette and Morrison Islands which may have important geomorphological implications.

4. Stratigraphy and Landforms

(a) Glaciation

According to Burger (1967), only one till is to be found in Renfrew County. The orientation of striations and ice-moulded landforms indicates a south or southeasterly movement of the ice in this part of the valley; in the Chalk River area, a general southeasterly flow has been observed (Gadd, 1963a). A series of recessional moraines, trending between east-west and northeast-southwest, mark six or seven halts during the retreat of the ice. One of these, the Indian Point moraine, has been traced by Gadd from Jorgens Lake to Petawawa and thence across the Ottawa River, where it forms a string of islands, to the Fort William boom. The moraine is composed of steeply-dipping beds of till, boulders, coarse gravels, sand and some silt. Subsequent marine and fluvial erosion has removed much of the fines and in places the moraine is formed completely of boulders. Gadd suggests that the moraine may have been responsible for the ponding of a glacial lake prior to the marine transgression; varved clays overlying till and glacial gravels have been located from borings near Perch Lake. The Indian Point moraine is in a particularly significant position since it probably marks the final location of an ice lobe blocking the Ottawa Valley (Prest, 1969,70).

A minimum date for deglaciation in the Ottawa area of 11,600 years B.P. (GSC-842) is given by marine shells taken from Champlain Sea sands at an elevation of 557 feet in the Gatineau. The only other date pertaining to the time of deglaciation north of Ottawa is 9,910 years B.P. (GSC-680) from a bog formed in a kettle hole in the Kazabazua sand plain.

The ice margin had retreated to beyond Pembroke sometime before 10,870 years B.P. (GSC-90), a date obtained from shells in Champlain Sea sands near Pembroke. At this time, a lobe of ice probably occupied part of the Ottawa Valley between Chalk River and Mattawa (Harrison, 1970; Prest, 1969,70). A reconstruction of possible ice-marginal positions (Fig. 5, p. 21) for the Wisconsin ice sheet by Prest (1969) indicates that between Ottawa and Pembroke ice retreat was probably up-valley (i.e. northwesterly). This accords with the pattern of moraines and other ice-contact features in the valley. Even with an essentially northward retreat, the valley would still be partially blocked by ice since the topographic trend is northwest-southeast. These considerations have an important bearing upon the subsequent marine transgression.

The tills of the Upper Ottawa Valley generally reflect the composition of the adjacent bedrock varying from highly calcareous on or to the lee of limestone bedrock, to a low base status in granitic areas (Burger, 1967). The typical till of the Chalk River area is sandy, grey and non-calcareous (Gadd, 1963a). There is a distinct relationship between the texture of the till and the type of bedrock; tills developed in areas of crystalline (Precambrian) rock have a higher sand fraction than those in limestone areas.

Fluvio-glacial sediments occur mainly in the form of kames, eskers, outwash and pitted outwash. An impressive north-south ridge which extends from Westmeath to Beachburg has been mapped by Burger as an esker. This feature has a fresh appearance and its flanks are cut by a marine terrace, factors which suggest that it was not completely submerged by marine waters. To the south and east, between Beachburg and Forresters Falls, Antevs (1928) has located a large outwash plain which has distinct ice-contact characteristics with numerous kettle holes. Since this feature has a maximum elevation of 560 feet, which is in accordance with similar features in the area, he considers that deposition must have occurred when the Champlain Sea was near its maximum limit (i.e. when the ice front lay in the sea). The remnants of a major esker, exposed as a series of islands in the middle of the Ottawa River, have been located by Gadd (1963a). There is a downstream gradation of materials from boulders to gravels and sand. Its position at right angles and downstream from the Indian Point moraine suggests that it was formed just prior to the moraine.

(b) The Champlain Sea

The Pembroke area lies at the northwestern limit of the Champlain Sea and, as such, the depositional environment was in many ways unique. Unlike the Ottawa area and the St. Lawrence Lowlands, the sea, even at its maximum level, was shallow. Additions of fresh water from the adjacent ice margin and later from the Great Lakes discharges ensured that the environment was, at most, brackish. The Great Lakes discharges also supplied large quantities of glacially-derived debris into the sea.

Evidence of the marine limit in this area is to be found from a variety of features rather than a series of beaches. The elevations of wave-cut terraces, lag concentrates, bedrock surfaces and washed-over and fresh glacial features reveals that the marine limit was approximately 520 feet in Renfrew County (Burger, 1967). The surface elevation of the Petawawa sand plain, which is a deltaic feature deposited in the Champlain Sea, gives an approximate height of 600 feet for the maximum marine limit north of the Petawawa River. This is in broad agreement with Gadd's observation that the till in the Chalk River area has a veneer of wave-washed rubble up to an elevation of 600 feet. The absence of a series of well-developed marine strandlines in this area is notable, and probably reflects the influence of a shifting shoreline created by deltaic sedimentation. The aerial extent of the Petawawa sand sheets, in particular their down-valley limit, is not precisely known although Ells (1901,7) has commented upon the similarity of the spreads of sands on Allumette Island to those of the Petawawa area. The Petawawa sands are horizontally-bedded and mainly fine-grained. In places, however, cross-bedded, coarse sand and gravel (channel fill deposits) are interstratified with the fine sands. Gadd considers that their relationship with the fine sands establishes contemporaneity of the two systems (i.e. the

Fossmill Channel and the Champlain Sea).

In Renfrew County, the Champlain Sea sediments are of two major types, which in many places grade into one another. Stratified clays form extensive plains in the lowland generally below 475 feet whilst stratified sands and silts occur above 475 feet and are related to the shorelines of the sea (Burger 1967; Quinn, 1951). Near the marine limit, especially where there is an abundant supply of glacial materials such as on the flanks of kames or eskers, clay beds interfinger with layers of sand and gravel. Quinn has reported thicknesses of marine clay in excess of 200 feet in the Bonnechere River Valley. Much of the Champlain Sea sediments, Quinn believes, have been derived from the erosion of glacial materials to the west and northwest. Burger has noted that the offshore deposits, calcareous fine and medium sand, are probably erosion products from granitic till areas mixed with materials eroded from highly calcareous deposits (fluvioglacial gravels and till in limestone areas).

Two radiocarbon dates relate to the Champlain Sea episode in this part of the valley. A date of 10,870 years B.P. (GSC-90) has been obtained from marine shells in stratified fine sand and silty clay at an altitude of 450 feet in a gravel pit 4 miles southeast of Pembroke. An abandoned channel cut into the Petawawa sand plain at an elevation of 500 feet near Chalk River has been dated at 9,540 years B.P. (GSC-177). This date establishes a minimum age for the withdrawal of the Champlain Sea and the fluvial dissection of the sand plain.

No data is presently available on the regressive phase of the Champlain Sea in the Petawawa-Pembroke area; no beaches below the maximum marine limit have been recorded. With the withdrawal of the sea, dissection of the deltaic and marine sediments commenced. The change in the salinity of the water accompanying this transition could not have been great because the water was never more than brackish throughout the marine episode. Essentially, the transition was from a depositional to an erosional environment. According to Gadd (1963a), the distinctive red pebbles in the terraces of Lone Creek and the Petawawa and Barron Rivers help to distinguish these channels (associated with the Fossmill system) from glacial and post-glacial gravels in channels north of the Petawawa Valley.

(c) Post-Glacial Drainage Development

Below the marine limit, the stages of drainage development are recorded by a series of terraces and abandoned channels. Research into the drainage evolution of the Ottawa Valley, and the Upper Ottawa Valley in particular, has almost been totally neglected: Macpherson (1967; as Brown, 1962) has studied the Lower Ottawa Valley, Ells (1901) has briefly discussed ancient river channels in the valley, Mackay (1949a,49b) has examined the terrace morphology of the valley between Petawawa and Montreal, and Goldthwait (1933) has investigated marine, lacustrine and fluvial strandlines.

Mackay's account is probably the most comprehensive in the regional context although it is primarily devoted to a critique of Blanchard's hypothesis of the depositional origin of the river terraces.

Paired terraces have been identified at 400 and 370 feet along Chenal Grand Calumet (Mackay, 1949a, 49b). Several large abandoned channels dissecting the Petawawa sand plains have been located by Gadd; one extends from Heart Lake to Chalk Lake via Chalk River and Corry Lake; another extends from Tee Lake, southwest of Rolphton, to Chalk Lake via Wylie Creek and Duck Lake. These are both tributary to an abandoned channel, which extends from Balmer Bay to Chalk Bay, and appear to be associated with a high level stage of the Ottawa River which cut a prominent terrace at 425 feet north of Petawawa. North of the Petawawa River, therefore, the high level stages of the Ottawa River are characterised by a series of abandoned channels rather than a sequence of terraces along the present river channel.

High-level alluvial sediments have been reported at an elevation of 450 feet in a gravel pit southeast of Pembroke (see GSC-90; in Dyck and Fyles, 1962) and at an elevation of 460 feet in a broad, shallow abandoned channel on Allumette Island between Chapeau and Demers Centre (Lajoie, 1962). Gadd (1963a) reports that for a while after the regression of the Champlain Sea the Indian Point moraine caused local ponding of the Ottawa River; the presence of red-banded silts in the terraces of several abandoned channels in the Chalk River area suggest a lower energy environment than the steeper gradients of the present river (i.e. the Indian Point moraine for a time acted as a local base level of erosion).

Two archaeological sites, investigated by Kennedy (1971), on Morrison Island (426 feet) and Allumette Island (397 feet) have been dated at 4,750 years B.P. (GSC-162; from charcoal) and 5,240 years B.P. (S-509; from human bone) respectively. These dates may provide valuable datum points for the chronology of the terrace sequence in the study area. The only other date pertaining to the drainage evolution of the area is 9,540 years B.P. (GSC-177) taken from the basal gyttja in an abandoned channel at an elevation of 500 feet near Chalk River.

5. Summary of Problems of the Study Area

Although Antevs (1928) has suggested that marine inundation and deglaciation were partly contemporaneous in the Ottawa Valley, no detailed descriptions of the stratigraphic relationships are available. This is a problem since the accordance of height of glacial features such as those described by Antevs at Beachburg and Fort Coulonge could be the result of marine planation rather than a primary sedimentary surface of glacio-marine deposition. The evidence gathered by Gadd (1963a) and Burger (1967) indicates that all but the highest glacial features were submerged by marine waters.

A second problem is related to the stages of retreat of the ice and the nature of proglacial drainage. Until the ice had retreated beyond the Petawawa River Valley, the sea could not reach its maximum extent and overspill waters via the Fossmill channel could not reach the Ottawa Valley. A possible earlier route of the Fossmill system may have utilised the Barron River Valley, as far as its elbow at Stratton Lake, and thence the Indian River Valley to Pembroke (Prest, 1967). If Antevs' Pembroke Halt is correlative of the St. Narcisse stage and the same age, a valuable datum would be provided for the time of deglaciation and the maximum marine limit (assuming the ice did not readvance into the sea). More radio-carbon dates for the Champlain Sea in the Upper Ottawa Valley are required. To further elucidate ice-marginal positions, the Indian Point moraine needs to be traced on the north shore of the Ottawa River in Pontiac County.

The precise relationship of the terrace gravels in the Fossmill system to the Petawawa sand sheets (although in places the former have been observed as channel fill deposits in the latter) has not been fully explained by Gadd. Whereas the gravels of the Fossmill system are confined to distinct channels, the sand sheets blanket considerable areas below 600 feet to the north of the Petawawa River. The fine, yellow sands, which cover much of Allumette Island and which form a relatively flat surface between 480 and 500 feet, may be part of the Petawawa delta.

Investigations of the landforms to the north of the Ottawa River in Pontiac County need to be undertaken to provide further data on the maximum marine limit in the area. Insufficient evidence is available to construct the isobases of this water plane. The increase in elevation of the Petawawa sand plains northwest from Petawawa may reflect the initial slope of the delta or subsequent differential isostatic uplift. The marine limit is definitely higher in the north of the region (600 feet: Gadd, 1963a) than to the southeast (520 feet: Burger, 1967).

The transition from marine to fluvial conditions was probably accompanied by a change from a depositional to an erosional environment. A study of the river terraces, abandoned channels and high-level alluvial deposits should permit the reconstruction of drainage development and establish a minimum elevation at which the marine/fluvial transition took place. Correlation of the river terraces may be complicated by the fact that differential isostatic uplift may have continued well into post-glacial time.

CHAPTER 3

THE SURFICIAL GEOLOGY AND LANDFORMS OF ALLUMETTE ISLAND AND THE PEMBROKE AREA

1. Introduction

The surficial materials of Allumette Island and adjacent parts of Renfrew County mask a bedrock surface of low relief composed of Precambrian crystalline rocks, mainly granite and gneiss, and of Ordovician limestone, dolomite and shale (see p. 44). Bedrock becomes important in area of outcrop in the vicinity of the Allumette Rapids, on the 375-foot terrace along Allumette Lake, and inland in Renfrew County above an elevation of 540 feet. From a consideration of the bedrock contour map of the study area (Kay, 1942), it would appear that Allumette Island is the deepest part of the late-Quarternary sedimentary basin and has consequently received the thickest covering of surficial deposits.

Allumette Island and the Pembroke area are characterised by low relative relief which is only diversified by the river terraces along Allumette Lake and the dissection of the surficial sediments by Hales Creek and the Indian and Muskrat Rivers. With the exception of some sand dunes and sand ridges, the central portion of Allumette Island is remarkably flat at an elevation of 480 feet.

In contrast to Chichester Township to the north, fluvio-glacial sediments south of Chenal de la Culbute are of only limited extent whereas marine clays and silts, which have only a small area of outcrop in Chichester Township, are second in importance to the Petawawa deltaic sands. Another contrast is that the bedrock surface is lower and more planate on Allumette Island and in the Pembroke area than in Chichester Township.

In this account, the surficial sediments are discussed in the chronological order of their deposition and are genetically classified with the exception of the last group, the Recent deposits, which comprises the youngest sediments of diverse origin. The marine sediments can be divided into three classes according to the three facies of the Champlain Sea: Deep-water, nearshore (littoral) and deltaic. By precise definition, however, the term marine may be misleading because the Champlain Sea in the study area was probably never more than brackish and as a result marine fauna is often absent in exposures of Champlain Sea age sediments.

2. <u>The Nature and Distribution of the Surficial Materials</u>

<u>Glacial Till</u>

Glacial till is only of minor importance in volume and extent south of Chenal de la Culbute. There are no thick exposures of till available for investigation and only at one locality is the relationship of till to the overlying sediments visible.

The till of eastern Allumette Island and to the southeast of Pembroke is calcareous, compact and composed of both Precambrian and Ordovician pebbles and boulders in a silty clay matrix. The larger limestone fragments tend to be tabular in shape reflecting the thin bedding of much of the limestone bedrock. Fresh exposures of till are dark brown but dark reddish brown when oxidised in the C horizon of soil profiles.

West and southwest of Pembroke and on western Allumette Island, the till is non-calcareous, sandy (with only a small silt content) and contains only Precambrian pebbles and boulders. Fresh exposures are grayish brown and compaction is generally poor.

The contrasts in composition of the two tills reflect the composition of the local bedrock, either crystalline Precambrian rocks or Ordovician limestone, although even the calcareous till developed on (or to the lee of) the limestone areas (most of Allumette Island and the city of Pembroke) contains a significant proportion of Precambrian-derived material. The latter characteristic is probably a consequence of the fact that, in the regional context, limestone bedrock is of limited extent; the Allumette Island outlier is the most westerly outcrop of Ordovician limestone in the Ottawa-Bonnechere graben.

Glacial till is restricted in outcrop to two types of areas: (1) Above an elevation of 540 feet (the marine limit in the study area) on the gentler slopes of the bedrock uplands, and (2) on the lower river terraces, generally below an elevation of 400 feet, where fluvial erosion has stripped away the overburden of later marine and deltaic sediments. In the latter areas, the fines have often been removed and the till consists of a thin veneer of boulders over bedrock (Plate 38, p. 190). Several small bedrock outcrops, which project above the marine clay plain at elevations between 480 and 530 feet, have a thin veneer of boulders which is probably the residual product of wave action on till.

With the exception of a small moraine southeast of Pembroke (ref. 378737), the till south of Chenal de la Culbute does not form any distinct landforms. A small till-cored ridge, approximately one mile long and 20 to 40 feet high, trending east-west, projects above marine sediments two miles southeast of Pembroke. The rounded form of the ridge and the presence of well-sorted sands and gravels on its flanks suggest that the moraine has been wave-washed. The unusual feature of the ridge is that rather than being formed from a variety of ice-contact materials, it is composed entirely of till similar to that found in the areas to the southeast; no concentrations of boulders or intercalated masses of fluvio-glacial sediments were found.

Fluvio-glacial sediments

On Allumette Island and in the Pembroke area, fluvio-glacial sediments are more limited in extent than till although they are important locally as a source material for the marine nearshore sands and gravels. Fluvio-glacial sediments occur as a series of isolated, indistinct features rather than an assemblage of distinct landforms and as such do not provide any valuable evidence of ice retreat in this part of the study area. Since the study area for the most part lies below the marine limit (520 to 540 feet), the fluvio-glacial landforms have either been modified by wave action or buried beneath later marine and deltaic sediments. Consequently, the stratigraphy is often confused.

The whole range of fluvio-glacial sediments, from outwash gravels in distinct foreset beds to highly-contorted ice-contact sands and gravels, and to thin clay beds (the product of local ponding), is present in the study area. Only in three localities, which are all south of Allumette Lake, are thick exposures of fluvio-glacial sediments available for study. These are located at: (1) the Government Road gravel pit (ref. 405712), (2) the Pembroke West gravel pit (ref. 326759), and (3) the Lemke Lake gravel pit, two miles southwest of Forest Lea (ref. 256758).

At Government Road, fluvio-glacial sands and gravels are found beneath marine clay (Exposure C: Fig. 12, p. 77) and nearshore sands and gravels (Exposure A: Plate 15, p. 86). One hundred feet to the northwest of Exposure A, 30 feet of gray, medium to coarse fluvio-glacial sands with several beds of gravels are to be found in essentially horizontal beds (Plate 3, p. 67). The sands are well-sorted and lack distinct bedding although secondary structures such as micro-faults and diapiric folds (upper left in Plate 3), probably the result of loading, are present. The centre of

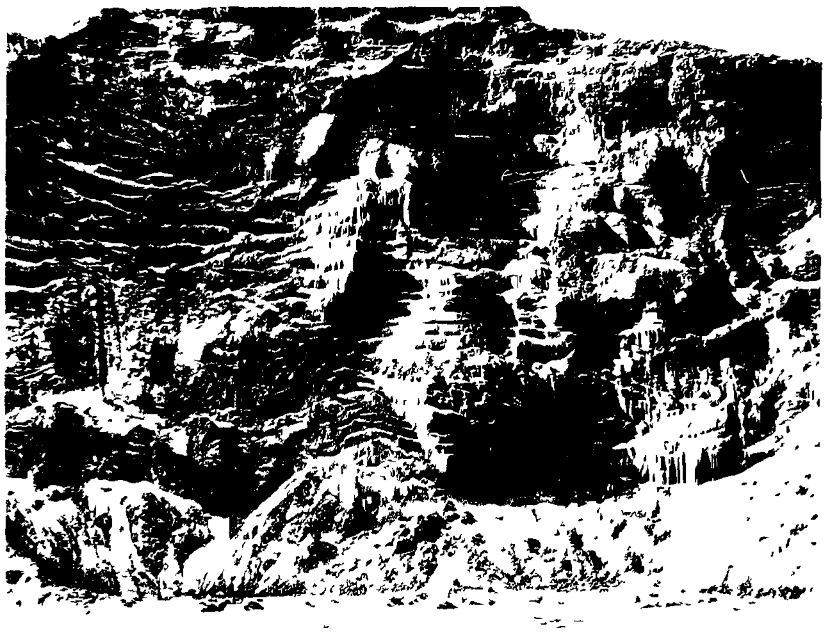


Plate 3 Fluvio-glacial sands and gravels at the Government Road gravel pit (405712).

the outcrop shows considerable distortion which may be the result of the melting of buried ice masses. Because the fluvio-glacial gravels for the most part lie beneath marine sediments, it is difficult to discern the original form of the glacial landform. The sediments form the core of a broad, faint ridge, trending northwest-southeast, which merges with a marine clay plain to the northwest and rises towards higher ground where till forms the surface material at an elevation of 475 feet. At Government Road the fluvio-glacial sands and gravels were undoubtedly the major source of sediment from which the adjacent beds of marine sands and gravels were derived by wave and current action.

Two miles southwest of the centre of Pembroke, fluvio-glacial sands and gravels outcrop in the form of a flat-topped, oval-shaped ridge which rises approximately 50 feet above a lowland underlain by marine clay and Petawawa sands. The steep northern flank of the ridge was probably truncated and undercut during a high-level stage of the Proto-Ottawa River (see p. 174). In contrast, the southern flank of the ridge consists of a narrow tongue of gravels which extends into the surrounding sand plain. A variety of fluvio-glacial materials are present in the Pembroke West gravel pit. At an elevation of 480 feet, just below the planate top surface of the ridge, thick deltaic foreset beds of coarse sands and gravels dip steeply (a maximum of 20°) to between south and southwest (Plate 4, p. 69). The pebbles are of both Precambrian

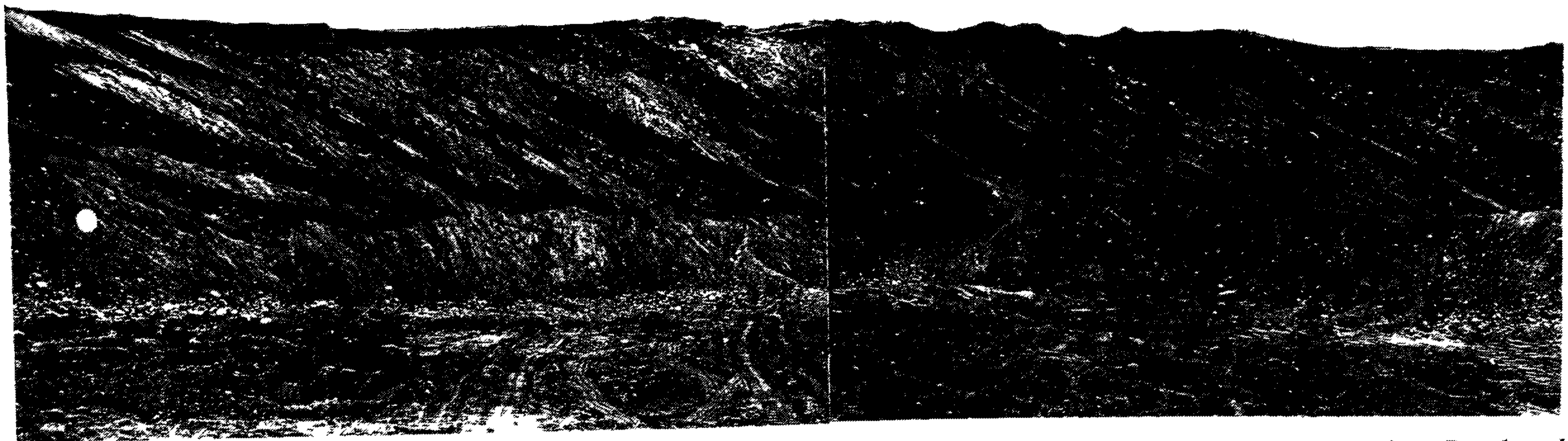


Plate 4   Fluvio-glacial sands and gravels in deltaic foreset beds at the Pembroke West gravel pit (326761).

and Ordovician origin, with the former dominant, and are moderately rounded. The dip and structure of the fluvio-glacial gravels indicate that they were deposited in a body of still water by outwash streams flowing from the north.

A different calibre of material is to be found in an excavation on the steep northern flank of the ridge at an elevation of 450 feet. Here, a strike exposure, approximately 30 feet thick, reveals gray, well-sorted, structureless, medium sands which in the upper two-thirds of the section contain lenticular masses of gravels in the form of cut-and-fill structures (Plate 5, p. 71). Well-sorted, structureless sands, which form the lower third of the exposure, are indicative of a large inflow of suspended sediment from outwash streams deposited rapidly in still water. These sands have been deformed by faulting (Plate 6, p. 71).

At a similar elevation, 200 yards to the northwest, 40 feet of gray, fine-grained fluvio-glacial sands show considerable deformation in the form of tight recumbant folds, diapiric structures and faults (Plates 7 and 8, p. 73). There are three processes which could account for this deformation. First, the sands may have been deformed by the melting of enclosed ice masses (i.e. by strict definition the sands are ice-contact deposits). Secondly, the deformation could have resulted by deposition from turbidity currents in a sub-aqueous environment. Finally, the possibility has to be considered that the deformation is the result of

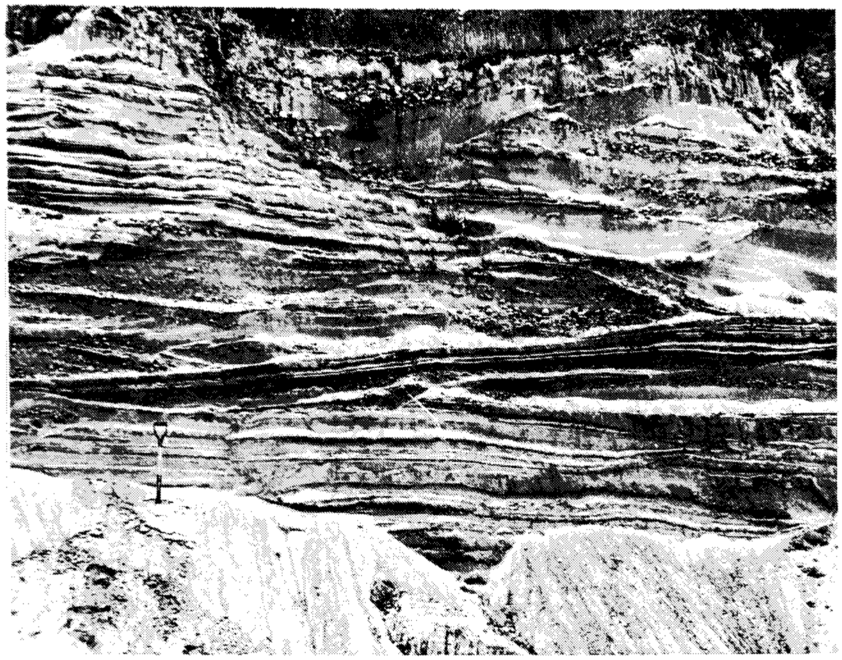


Plate 5 Fluvio-glacial sands and gravels at the Pembroke West gravel pit (329759).

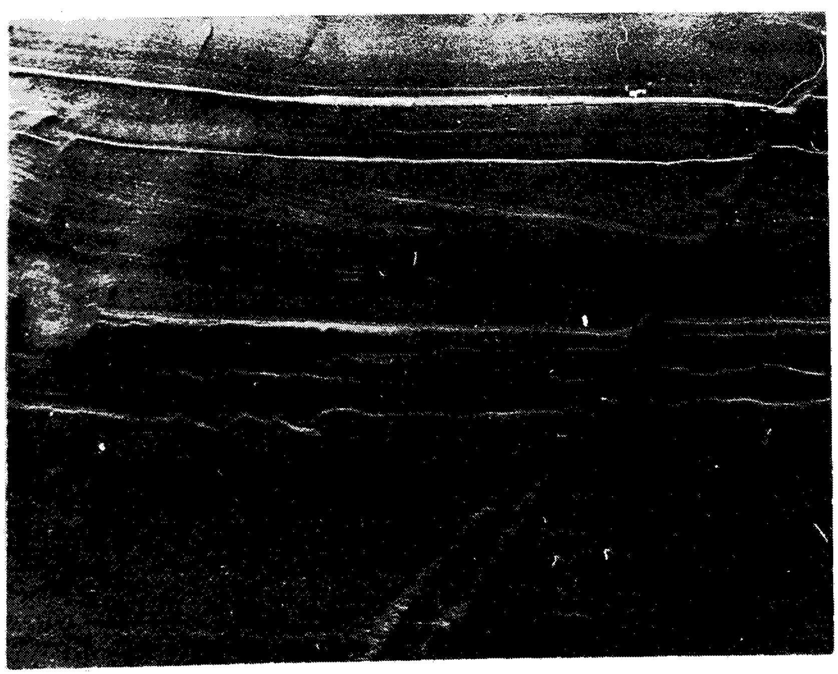


Plate 6 Fault in well-sorted, medium-grained, fluvio-glacial sands at the Pembroke West gravel pit (329759).

slumping caused by the undercutting of the northern flank of the glacial feature during a high stage of the Proto-Ottawa River.

At Pembroke West, interpretation of the fluvio-glacial sediments and the glacial feature which they form is exceedingly difficult. The remarkably planate top-surface of the feature at an elevation of 500 feet, the absence of topset beds in Exposure A, and the presence of marine nearshore sands and gravels on its flanks are proof that the glacial feature has been planed off and modified by wave action. Moreover, the steep northwestern flank has been undercut by fluvial erosion. Consequently, the original topographic expression of the fluvio-glacial gravels has been obscured. The contrasting characteristics of the sediments exposed on top of the ridge (deltaic foreset beds), and at two localities on the northern flank at a lower elevation (structureless outwash sands and highly deformed, fine sands) make it difficult to arrive at a conclusion as to the origin of the feature. Furthermore, it cannot be assumed that these various materials were all deposited during the same time.

A third major exposure of fluvio-glacial sediments is located near the marine limit two miles southwest of Forest Lea at an elevation of 530 feet. Here, 15 to 20 feet of thick, crudely stratified beds and non-stratified masses of gravels, consisting mainly of angular pebbles and cobbles, form the base of a low, flat-topped bench above a tributary of Hales Creek (Plate 19, p.100). Of particular interest is a

Plate 7 Deformed fluvio-glacial sands at the Pembroke West gravel pit (328762).

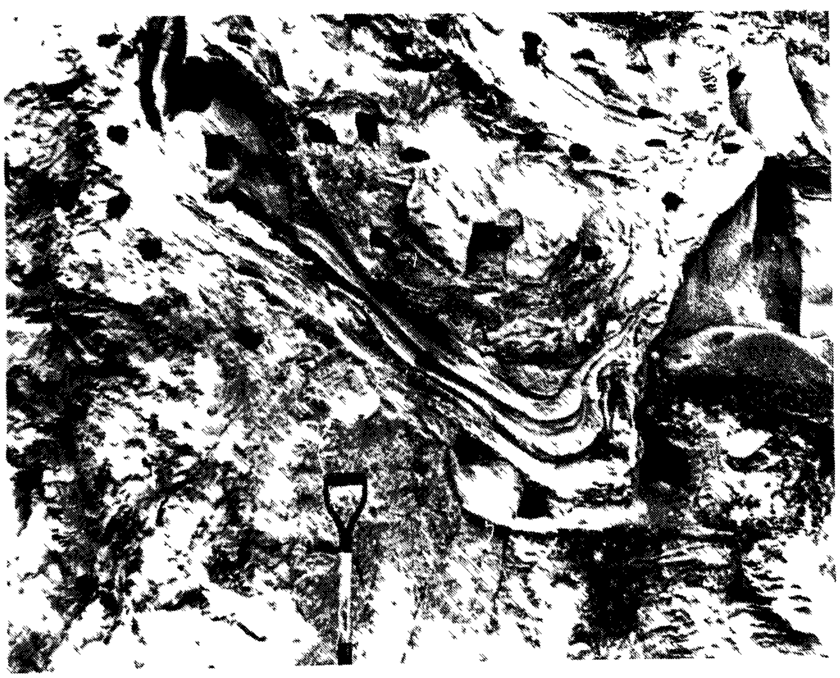


Plate 8 Folding in fluvio-glacial sands at the Pembroke West gravel pit (328762).

Plate 9 Lens of clay and sand in outwash gravels in the Lemke Lake gravel pit (256758).

lenticular bed of clay, silt and fine, cross-bedded sand approximately 8 feet thick, found within the gravels (Plate 9, p. 74). This exposure is probably an example of deposition by braided outwash streams near the ice front where local ponding (hence the clay lens), a coarse calibre of transported sediment, and rapid variations in channel directions are characteristic.

Marine Sediments

By far the most important surficial materials in terms of extent and volume are the sediments of the Champlain Sea. Although the marine episode was relatively short-lived in the study area (see p. 22 and Fig. 8, p. 40) as compared with areas to the east, the Champlain Sea has had the greatest influence on landform development. In contrast to the Lower Ottawa Valley or the St. Lawrence Lowlands, the marine limit has been particularly difficult to determine. As a result, the interpretation of the stratigraphy in some areas, especially in the absence of marine fossils, remains speculative. The marine sediments fall into three convenient classes on the basis of grain-size and mode of deposition: (a) Deep water clays and silts, (b) nearshore sands and gravels, and (c) deltaic sands.

(a) clays and silts

Silty marine clay rest unconformably on either till, fluvio-glacial gravels or bedrock. At the Government Road gravel pit, the marine clay rests unconformably upon fluvio-glacial gravels which form a faint, oval-shaped ridge. The stratigraphic relationships in this pit are reasonably characteristic of the study area in situations where marine clay rests on the flanks of glacial features.

Exposure C (Fig. 12, p. 77) consists of a thick bed (5 feet) of fossiliferous, silty marine clay filling a depression in the underlying fluvio-glacial gravels at an elevation of 415 feet. The clay is massive, dark gray and has a blocky fracture when dry. Reddish, dark brown streaks running through the clay are revealed when blocks are removed. The clay contains a rich molluscan fauna of Macoma balthica and less numerous Hiatella arctica which are often found in growth position with both valves intact. Small pebbles, which have probably been ice-rafted, are scattered randomly throughout the clay. The clay is cut by five lenses of coarse sand and gravel, which contain moderately rounded pebbles up to 3 inches in diameter.

Faintly laminated, dark gray silts rest unconformably on the massive clay; the boundary is an irregular erosion surface with a very thin basal coarse sand bed. The laminae consist of alternating bands of very fine sand and silt which, like the underlying clay, are cut by thin lenses of coarse sand and gravel.

An exposure, 50 feet to the north of Exposure C, reveals that the clay and laminated silts thicken to the north towards the marine clay plain which partially surrounds the

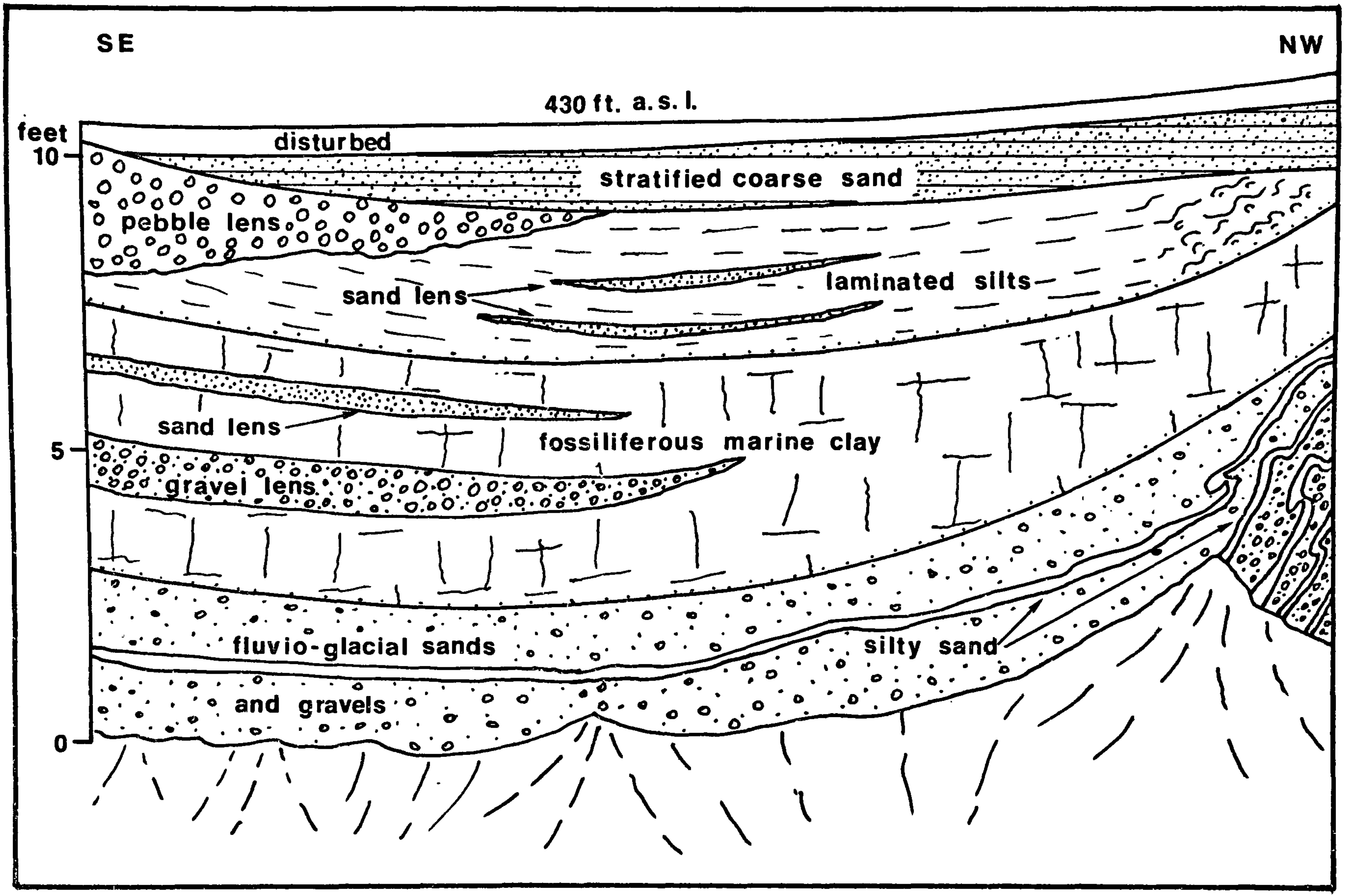


Fig.12 Exposure C at Government Road.

fluvio-glacial ridge. This exposure shows that the massive marine clay grades without an erosional break into the laminated silts. The transition from massive clay to the laminated silts is marked by 2 or 3 feet of varve-like bedding at the top of the true clay. Bands of dark gray clay (between 1 and 2 inches thick) alternate with reddish gray siltier bands of similar thickness (Plate 10, p. 79).

The exposure of marine clay at Government Road reveals two features of the clay which are characteristic of many exposures of clay in the study area. Where the upper layers have not been removed by erosion, thick exposures show that the massive, fossiliferous marine clay becomes siltier upwards and grades into laminated silts which are devoid of marine fossils. Locally, for example Exposure C of Government Road, the laminated silts rest upon an eroded surface of massive clay but elsewhere, where the materials are undisturbed, the relationship is conformable. To the north and west of Pembroke, the clay, even by visual observation, appears to become siltier and marine fauna are absent; the most westerly outcrop of fossiliferous clay in the study area is found at the Pembroke West gravel pit.

A second characteristic of the marine clay is that it interdigitates with shallow-water sands and gravels on the flanks of glacial outwash features. At the Pembroke West and Government Road gravel pits, for example, the marine clay becomes thinner and pinches out towards the higher ground where it is

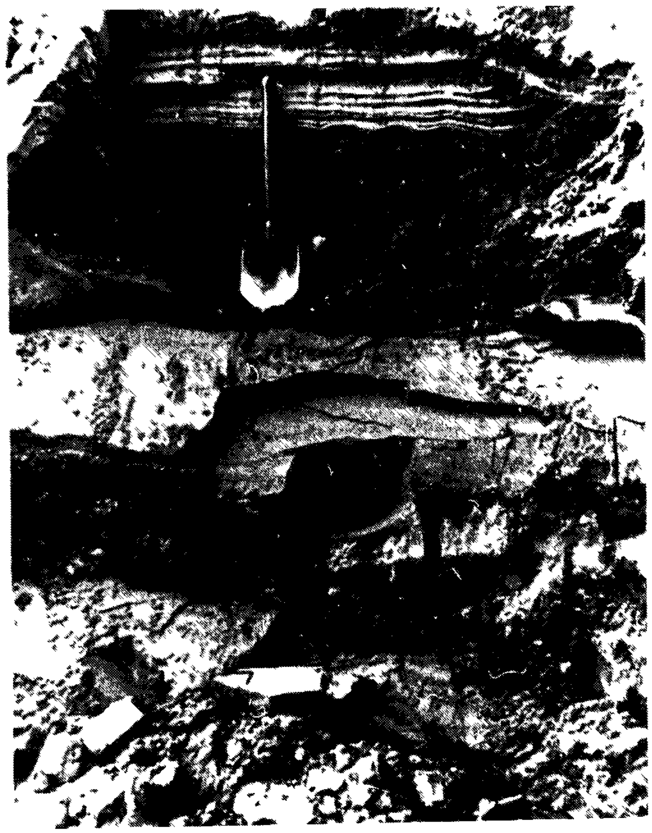


Plate 10 Fossiliferous marine clay and overlying laminated silts at the Government Road gravel pit (405713)

replaced by the nearshore sands and gravels (see p. 84). In places, the clay has become deformed on the steeper slopes, apparently as a result of sub-aqueous slumping.

South of Allumette Lake, marine clay is only exposed at the surface, with the exception of one area, below an elevation of 500 feet. The clay forms broad areas of low relief adjacent to Hales Creek, the Indian and Muskrat Rivers, and along Allumette Lake where it underlies the 375 and 400-foot terraces. On Allumette Island, the marine clay and overlying laminated silts are restricted to a small area on the 400-foot terrace north of Desjardinsville. Further east, north of Morrison Island, the clay, but not the laminated silts, is exposed beneath fine sand in the valleys of small streams cut through the terraces. Another small area of marine clay occurs on the 400-foot terrace two miles east of Chapeau. In all these localities on Allumette Island, no marine fossils were found although the clay is similar in composition and structure to that found south of Allumette Lake.

The most significant stratigraphic relationship of the marine clay to the overlying sediments is found in the terrace bluff of the 420-foot terrace northeast of Desjardinsville (ref. 376796). Here, approximately 30 feet of laminated silty clay lies unconformably beneath Petawawa sands (Plates 11 and 12, p. 81). The relationship is only unconformable in the sense that there is a distinct lithological break; the top surface of the clay does not appear to have been eroded or

Plate 11   Contact between laminated silty clay and Petawawa sands in terrace bluff on Allumette Island (376796)

Plate 12   Close-up of laminated silty clay.

weathered. A similar relationship occurs on the 400-foot terrace on the south shore of Allumette Lake between McGregor Bay (ref. 292803) and the Game Preserve and Fish Hatchery (ref. 262838) near Petawawa Point. At these localities, the terrace bluff, which is over 60 feet high, has been cut into the Petawawa sands whereas the terrace is underlain by marine clay (Plate 13, p. 83). The zone of contact coincides with the base of the 400-foot terrace bluff and, although there are no exposures where the direct superposition of the sediments can be viewed, it appears that the Petawawa sands were deposited over the clay. Direct superposition of the sediments can, however, be viewed in several tributaries of Hales Creek which have dissected much of the original Petawawa sand plain and exposed the underlying marine clay. From these observations it can be concluded that the formation of the Petawawa delta post-dates an earlier deep water phase of the Champlain Sea.

There is very little data on the thicknesses of marine clay in the Pembroke area. The altitudinal range of the clay is from the present level of the Ottawa River (365 feet) to over 500 feet inland. Thicknesses in excess of 50 feet are visible on the steep valley sides of the Indian and Muskrat Rivers near Pembroke and in Hales Creek at ref. 308777.

The present distribution of marine clay clearly reflects the pattern of post-glacial fluvial dissection of the surficial overburden. The largest co-extensive areas of

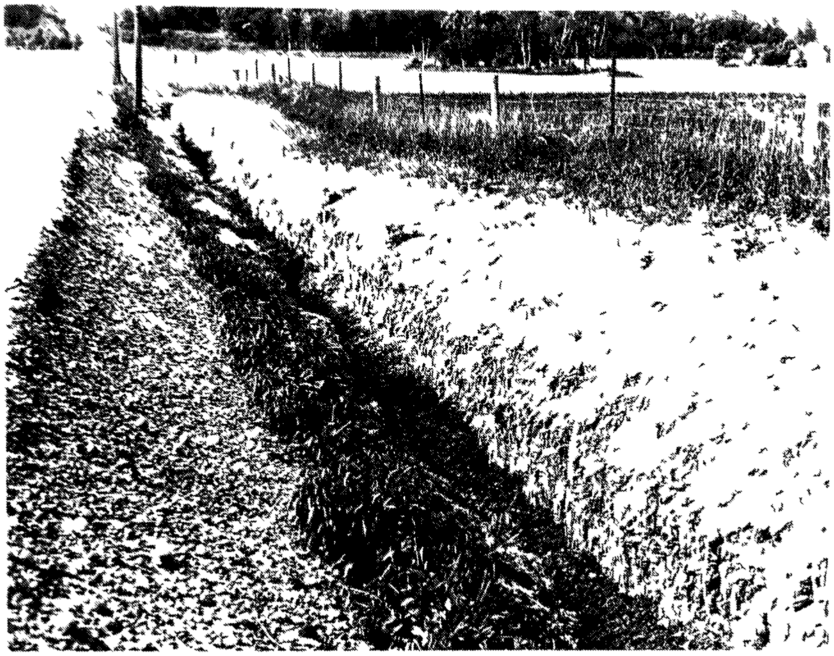


Plate 13 Silty marine clay underlying the 400-foot terrace near Petawawa Point (277818).

Plate 14 Silty marine clay in the Indian River Valley one mile west of Davis Mills (265698).

marine clay are located in the vicinity of Hales Creek and on the 400 and 375-foot terraces of Allumette Lake where the overlying Petawawa sands have been removed. An isolated tongue of silty clay, with a maximum (visible) thickness of 60 feet, outcrops in the Indian River Valley west of Davis Mills (outside the mapped area) (Plate 14, p. 83). This occurrence is unusual in that the clay outcrops to a maximum elevation of 520 feet and that in places the clay rests directly against the bedrock or till-covered valley sides. If the clay is marine (it has similar characteristics to that of the study area), it would be expected that at this elevation (near the marine limit) wave action would have been effective and the deposition of clay would not, therefore, have taken place. Presumably, in the narrow Indian Valley, wave action was dampened and relatively still water was present.

(b) nearshore sands and gravels

Nearshore sands and gravels have been derived from pre-existing till and fluvio-glacial sediments by wave and current action. They are, therefore, restricted to two areas. Below the marine limit (540-520 feet), nearshore sands and gravels occur on the flanks of fluvio-glacial ridges which rise above the general level of the marine clay plain. Between 520 and 530 feet, southwest and west of Pembroke, a narrow tongue of the nearshore sediments extends from a point two miles southwest of Forest Lea (ref. 257760) to a point one mile southeast of Hiam Station (ref. 293730).

Nearshore sediments are notably absent on Allumette Island and north of Chenal de la Culbute. South of Allumette Lake, only two thick exposures of nearshore sediments were available for study, Government Road Exposure A and Pembroke West Exposure B, and only one (Pembroke West) was identifiable as marine on the basis of fossil content alone.

Exposure A at Government Road (Plate 15, p. 86) consists of 25 feet of sands, gravels and silts in foreset beds of variable thickness. The basal 5 feet of sediments are steeply-dipping, deformed, fluvio-glacial sands and gravels which disappear beneath the surface across the exposure face. Resting unconformably on these sands and gravels are alternating beds of fossiliferous grayish-brown, medium to coarse sands and silts. The dark gray silt beds, which vary in thickness from 1/8 to 5 inches, can generally be traced down-dip across most of the exposure. Occasionally the silt beds when traced up-dip split in two or pinch out. Small, well-rounded pebbles occur in distinct horizons throughout the exposure. The apparent dip of the beds decreases progessively across the exposure face (i.e. to the east) with an average dip of 23° in the direction N 10° E. Marine shells of _Macoma balthica_ are found throughout the exposure. Single valves, often broken, predominate and only rarely are specimens present with both valves intact and none were observed in growth position. In order to ascertain the true dip of the beds, the east-facing side of Exposure A (i.e. at approximately 90° to

Plate 15 Exposure A at the Government Road gravel pit. Fossiliferous, nearshore sands and gravels of the Champlain Sea (405712).

Plate 16 Nearshore sands and gravels of the Champlain Sea at the Pembroke West gravel pit (325761).

the main face) was investigated and revealed a gentle dip of 5°, N 20° E. The true dip of exposure would appear, therefore, to be approximately northeast which indicates a sediment source from the centre of the ridge (i.e. southwest).

These marine sands and gravels have undoubtedly been derived from the pre-existing sands and gravels which outcrop in adjacent parts of the gravel pit. The sorting is generally better than that of the fluvio-glacial gravels and constituent pebbles are better rounded. The variations in grain-size (from bed to bed) and the presence of silt beds, which sometimes pinch-out up-dip, suggest a fluctuating sea-level as wave wash reworked the fluvio-glacial gravels at different elevations on the higher parts of the ridge. Fifty feet to the northeast of Exposure A, indistinctly cross-bedded fine sands, which become siltier upwards and grade into thin silt beds, enclose a large boulder of granite-gneiss weighing approximately 7 tons (Exposure B: Fig. 13, p. 85). Although the fine sands and silt are unfossiliferous, they are probably marine since they can be seen resting unconformably on deformed fluvio-glacial sands to the northwest of this particular section and the alternation of fine sand and silt is reminiscent of other exposures of nearshore marine sediments in the vicinity. The boulder, which has deformed the silty sand and silt beds beneath it, can only have been placed in such a position by ice-rafting. Above the silt bed is a thin layer of very fine, structureless

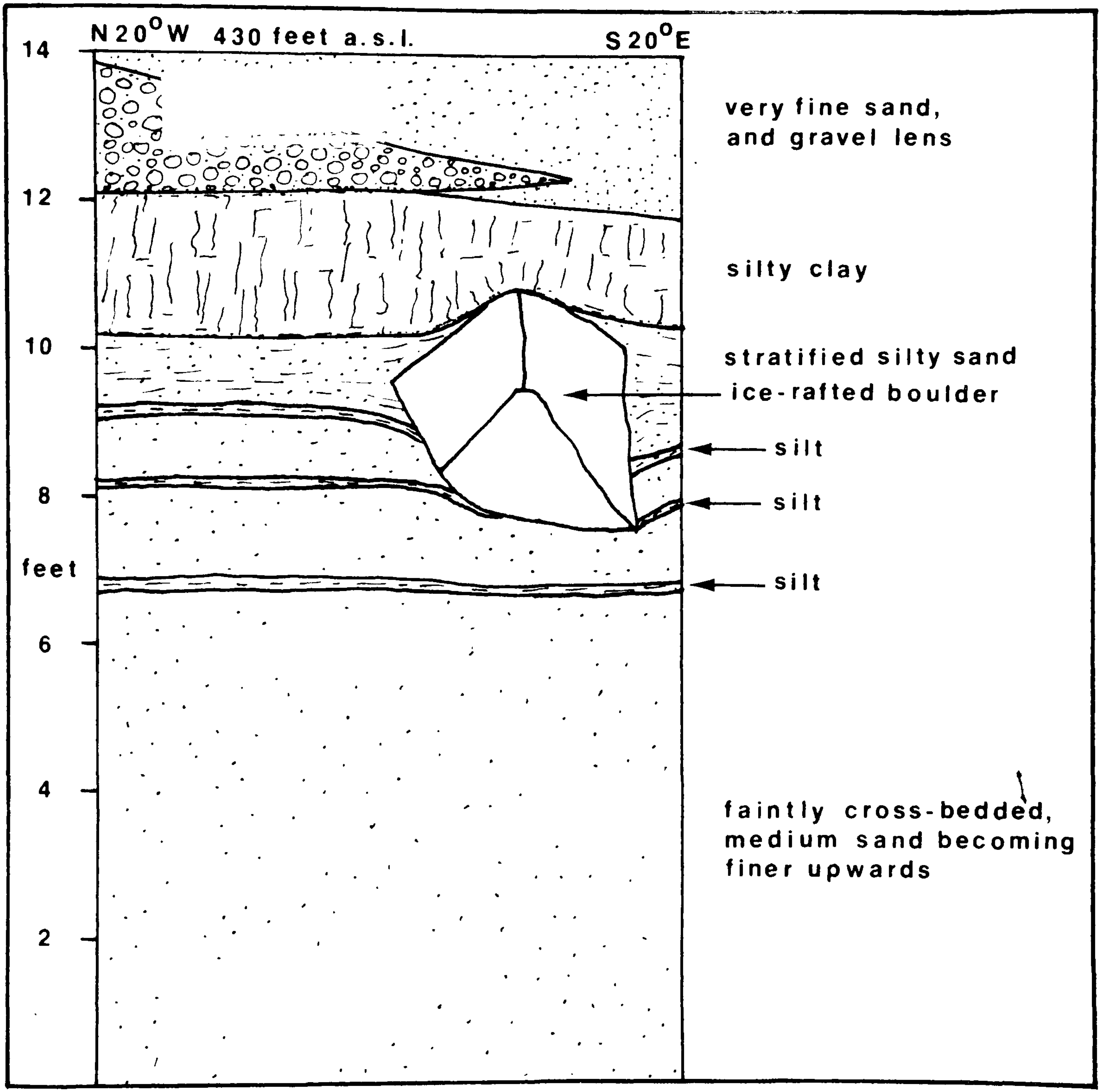


Fig. 13 Exposure B at Government Road.

sand and a gravel lens (probably fluvial) containing well-rounded pebbles. The stratigraphic relationships in the Government Road gravel pit are shown in Fig. 14, (p. 90).

The second major exposure of nearshore sands and gravels can be viewed in the Pembroke West gravel pit which has been excavated in a thick ridge of fluvio-glacial sands and gravels. On the north flank of the ridge at an elevation of 460 feet, 15 to 20 feet of alternating beds of silty clay, sands and gravels dip steeply (15 to 30^{o}) to the north (Fig. 16, p. 92 and Plate 16, p. 86). Several contrasting characteristics distinguish the nearshore sands and gravels at this location from the adjacent foreset beds of the fluvio-glacial gravels:

(i) On the northern flank of the ridge, the nearshore sands and gravels dip steeply between north and northwest, whereas the fluvio-glacial gravels have a general southwesterly dip.

(ii) The nearshore sediments contain silty clay and silt beds which pinch-out up-dip and which are absent in the fluvio-glacial gravels.

(iii) The lowermost (i.e. below 430 feet) units of the nearshore sediments are fossiliferous containing the marine mollusc Macoma balthica.

(iv) There is a greater range in grain-size of the nearshore sediments; the finest material is fine sand in contrast to the fluvio-glacial sediments in which the smallest grain-size is coarse sand. Individual beds, however, exhibit better sorting

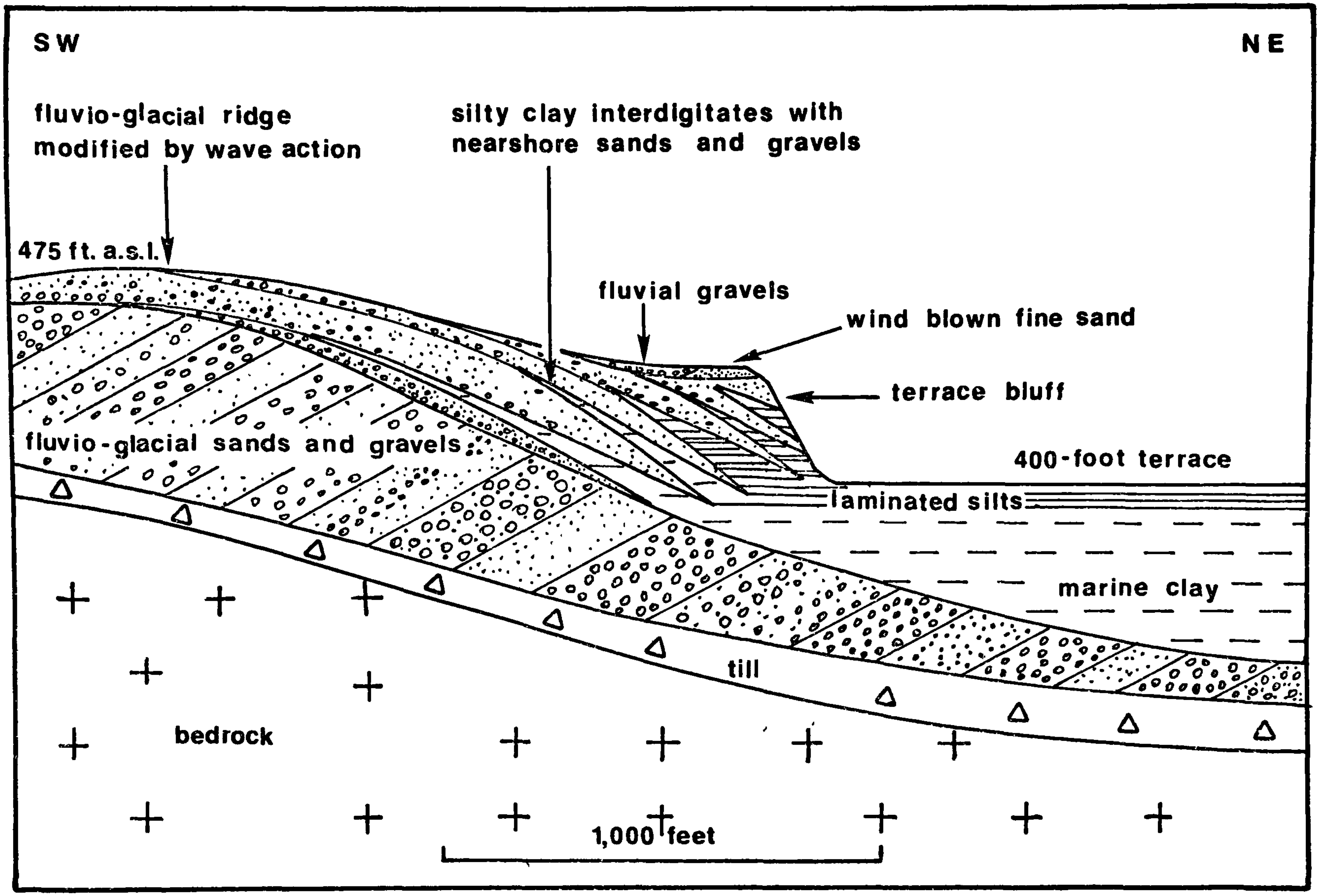


Fig. 14 Diagrammatic Cross-Section of the Surficial Materials at Government Road.

of the materials than those of the fluvio-glacial gravels.

(v) The rounding of the pebbles in the nearshore sediments is better than that of the fluvio-glacial gravels.

(vi) The dip of the beds of the nearshore sediments, though steep on the flanks of the fluvio-glacial feature, tends to decrease away from the ridge towards the lower ground. In low lying areas, the nearshore sediments are horizontally stratified.

A major characteristic of the nearshore sands and gravels in Exposure B at Pembroke West is that cobble beds when traced down-dip grade gradually into coarse and then fine sand. This would appear to demonstrate the selectivity and energy characteristics of wave wash and current action on the fluvio-glacial gravels; the materials become progressively finer away from the ridge (i.e. offshore).

The interpretation and identification of the nearshore sediments is made difficult by the general absence of marine fossils except at the Government Road and Pembroke West gravel pits, and even at the latter location molluscan shells are rare. In these localities, the identification of nearshore sediments is made easy by their juxtaposition to fluvio-glacial gravels. In the areas to the west of Pembroke, near the marine limit, however, the stratigraphic relationships are less clear. In the absence of fossils, the nearshore sediments have to be identified on the basis of lithology and structure alone. Nevertheless, the sediments exposed between Lemke Lake and Hiam Station exhibit

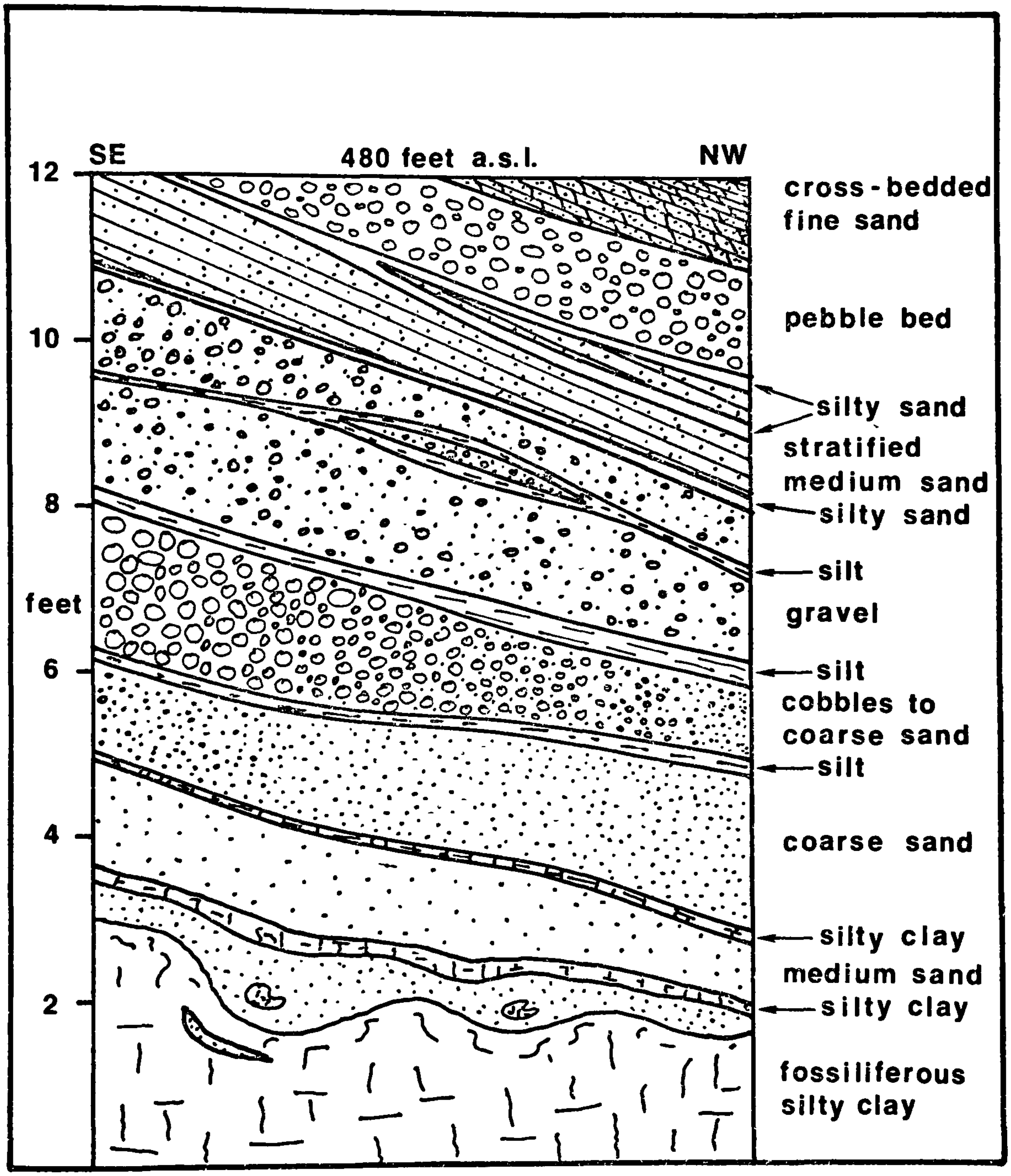


Fig. 16 Exposure B at Pembroke West.

several of the characteristics listed above and the source of material (generally fluvio-glacial gravels) can be found towards the higher ground to the west.

When traced towards the clay plain, the nearshore sediments become finer and become very difficult to distinguish from the Petawawa deltaic sands which bury the marine clay in many areas.

(c) the Petawawa deltaic sands

The most important group of sediments in terms of extent and volume are the medium to very fine-grained sands deposited in the Champlain Sea by overspill waters from the Upper Great Lakes. Large sand pits have not been excavated in these sands within the study area and, therefore, the best exposures are to be seen in road cuts and along the terrace bluffs of the Ottawa River.

Where the sands have not been dissected by post-glacial fluvial erosion, they form a distinct morphological unit (Fig. 15, back pocket) of a flat plain, diversified by sand dunes, which decreases in elevation from 520 feet near Petawawa Point to 470 feet east of Pembroke and on eastern Allumette Island. The flat, undissected portions of the sand plain are probably the original depositional surface of the delta which was deposited in the sea.

The most characteristic feature of the sands is their lithological homogeneity both over large areas and through great thicknesses. The sands are cross-bedded and horizontally stratified although in many exposures bedding structures are faint and indistinct (Plates 17 and 18 p. 95). When dry the sands are pale yellow but reddish yellow when saturated.

Many exposures show that, in the upper layers (up to 2 feet) below the soil profile, the sands are structureless and, therefore, probably wind blown. On Allumette Island one mile west of Demers Centre, for example, road cuts in the sands reveal the characteristic slip faces of dune bedding. This area of sand dunes consists of a series of linear ridges up to 30 feet high oriented west-east.

The notable absence of marine fossils in the Petawawa sands could be explained by leaching since the sands are non-calcareous and generally permeable, but a more likely explanation is that the water body in which the sands were deposited was fresh. Gadd (1963a), however, has reported the presence of broken shells of Macoma balthica and crayfish skeletons in a sand pit near Baie Cayien, four miles east of Rolphton.

The Petawawa sands overly marine clay and, locally, till or fluvio-glacial gravels. On eastern Allumette Island (ref. 419780), for example, 15 to 20 feet of Petawawa sands rest on steeply-dipping beds of fluvio-glacial gravels at an elevation of 440 feet. Although the sands have completely buried the underlying fluvio-glacial gravels, the topographic expression of the glacial feature in the form of a north-south ridge (possibly an esker) has not been totally masked. In some areas, for example Morrison Island, the sands lie

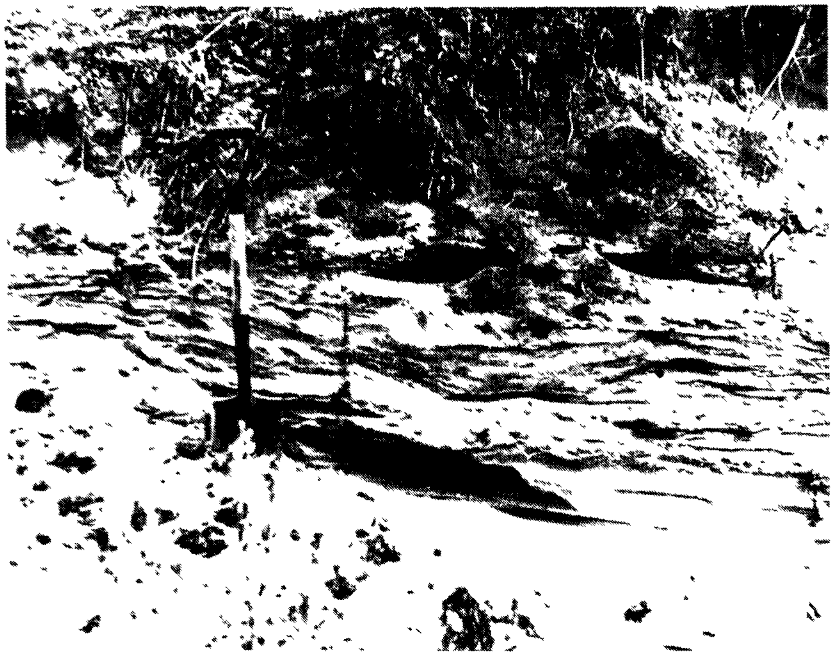


Plate 17 Petawawa sands in terrace bluff on Allumette Island (398782).

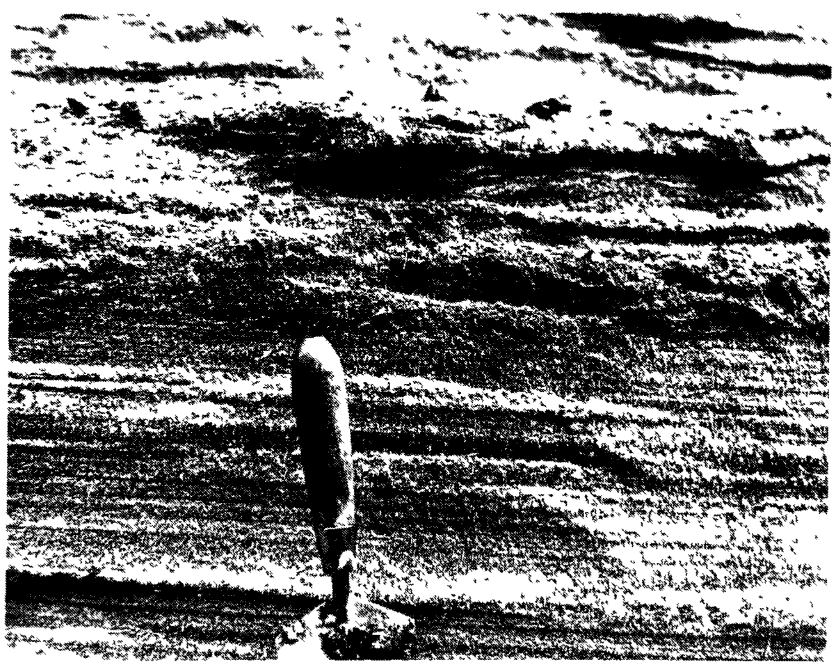


Plate 18 Close-up of Petawawa sands in terrace bluff on Allumette Island showing horizontal stratification (398782).

unconformably on till and bedrock while in others, for example on the 420-foot terrace northeast of Desjardinsville, they rest on marine clay (see p. 80). Throughout much of the study area, especially south of Allumette Lake, Petawawa sands rest directly on marine clay. In those areas where it does not, it can be assumed that either the deposition of clay was originally patchy or there was a period of erosion, possibly by submarine currents, before the deposition of the sands.

It is highly probable that not all the deltaic sands were derived from a northwesterly source (i.e. via the Petawawa and Barron River system). A large area of Petawawa-type sands located between Chichester and the Shield escarpment were probably deposited by streams from the north.

Without extensive bore-hole data, the thicknesses of the Petawawa sands are difficult to estimate. Field investigations provide an approximate estimate by using evidence from the elevations of the stratigraphic contacts between the sands and the underlying sediments and the altitudinal range of the sands. On Allumette Island and the area north of Hales Creek, this evidence suggests that the sands in these areas are over 70 and 100 feet thick respectively.

Recent sediments

The Recent sediments, which consist of peat, muck and alluvial sands, silts and gravels, are of only limited extent in the study area.

Muck, composed of dark gray silty sand and organic debris, occurs in the poorly-drained areas of the study region such as the central portion of Allumette Island and in an abandoned channel south of the Plains. No peat horizons were observed in the study area although the difficulties of terrain and vegetation prevented investigation of those areas where conditions would be favourable for its development.

In many cases, alluvial sediments were of too limited extent or thickness (less than 2 feet) to be worthy of inclusion as a mappable unit on the surficial geology map. A study of the river terraces (see Chapter 5) reveals that there was no period of alluvial in-filling during the post-glacial drainage development in this part of the Ottawa Valley. Stratified fine sands with some silt (less than 2 feet thick) form the floor of an abandoned channel on Allumette Island and 1 foot of gray, fissile silt outcrops on a terrace of the Indian River near Pembroke (ref. 337723). Another isolated outcrop of fluvial-sediments occurs at Government Road where five feet of horizontally-stratified medium sands and gravels truncate the underlying marine sands in exposure A at an elevation of 445 feet (Plate 15, p. 86). These sands are probably fluvial but their outcrop is limited and there is no morphological evidence to relate them to a high stage of the Proto-Ottawa River since they occur above the highest identifiable terrace of the area.

3. The Problems of Stratigraphy and Landform Evolution

South of Chenal de la Culbute, the most common stratigraphic sequence below an elevation of 500 feet is till - marine clay/laminated silts - deltaic sands. Locally, near the marine limit and on the flanks of the higher glacial features, beds of silty marine clay and silt interdigitate with littoral sands and gravels. The stratigraphic relationships, however, are not as clear as the above summation suggests and several problems require further elaboration.

The marine limit

The absence of any distinct strandlines or fossiliferous beach materials, which in itself is significant (see p. 101). is characteristic of the study area. Consequently the elevation of the marine limit has to be inferred from several lines of indirect evidence.

From Lemke Lake in the north to a point one mile southwest of Hiam Station in the south, there is a narrow area between 520 and 540 feet where nearshore fine to coarse sands, and gravels outcrop. Although these sediments are unfossiliferous, their lithological characteristics and stratigraphical relationships point to a shallow water marine origin (see p. 89). The nearshore sediments bear a distinct relationship to areas of glacial outwash at slightly higher elevations which have undoubtedly been the source material for the nearshore sediments. Where till outcrops near the marine limit or on bedrock 'highs' in the marine clay plains at lower elevations, there is often a veneer of boulders which is probably the product of wave wash on till. Since all these features occur within a narrow altitudinal range, the marine limit can be tentatively placed at a maximum elevation of 540 feet to the west and southwest of Pembroke. The only distinct bluff of possible marine origin near this elevation is located at an altitude of 530 feet two miles southwest of Forest Lea (ref. 255756), (Plate 14, p.100). Here, a northeast-southwest trending bluff, approximately 15 feet high, has been cut into a small area of outwash gravels and nearshore sands and gravels (derived from the adjacent fluvioglacial materials). This strandline may not record the maximum marine limit in the area because the top surface of the outwash appears to have been truncated by wave action at an elevation of 540 feet. Nevertheless, the presence of nearshore sediments which outcrop in this strandline is highly suggestive of a marine origin.

Further indirect evidence of the marine limit is given by the top surface elevations of the Petawawa sand plain northwest of Hales Creek and its extensions on Allumette Island and in the Pembroke area. Northwest of Hales Creek, the Petawawa sand plain declines in elevation from 540 feet south of the Petawawa River to 500 feet near Lemke Lake. Another relatively undissected area of the sand plain occurs to the north of the Indian River Valley between 500

Plate 19 Possible strandline of the Champlain Sea two miles south-west of Forest Lea (262756).

and 520 feet. On Allumette Island, the sand plain forms a remarkably flat area, only diversified by sand dunes, at an elevation of 480 feet. East of Demers Centre, however, stream erosion has destroyed much of the original depositional surface. If these portions of the original depositional surface of the Petawawa delta were deposited near the sea level of the time, a sea level of at least 530 feet is indicated. Of course, there is no way of knowing the depth of water in which the sands were deposited but this elevation (530 feet) is in agreement with other evidence discussed above. There appears to be a southeasterly decrease in elevation of the delta which could either be the original slope of the depositinnal surface or, more probably, the result of differential isostatic uplift. The latter suggestion is supported by a study of the subsequent drainage evolution of the study area which provided evidence that isostatic uplift continued well into post-glacial time (see p. 193). The deposition of the Petawawa deltaic sands may have occurred when the Champlain Sea had passed its maximum transgression (elevation) because in Chichester Township there is evidence that an outwash delta was deposited in the sea at an elevation of 590 feet and Petawawa-type sands can be found on the flanks of this feature up to an elevation of 522 feet (see p.126 and p. 134).

The absence of well-developed marine strandlines in the study area can probably be explained by several factors. The sea in this part of the Ottawa Valley formed a narrow embayment, approximately 12 miles wide from northeast to southwest, in which wave action would have been considerably less effective than in the more open parts of the valley to the east. A second factor is that the Champlain Sea episode in the Pembroke area was relatively short-lived compared to the Ottawa region and the St. Lawrence Lowlands and less time would be available, therefore, for the construction of shoreline features (see p. 22). Finally, the later stages of the Champlain Sea episode in the study area were characterised by a shifting shoreline of deltaic sedimentation. In Chichester Township, the stratigraphical and morphological evidence indicates that for a time the ice front lay in the sea and thus there would be no evidence of the maximum marine limit (in the form of strandlines or beach materials) north of Chenal de la Culbute (see p. 130).

Glacial landforms

On Allumette Island and south of the Ottawa River, there are no glacial landforms which have not been modified by wave action or dissected by fluvial erosion. Furthermore, the glacial sediments have generally been buried beneath a thick overburden of marine sediments. Consequently, the stratigraphy is often confused and a genetic identification of a particular body of outwash or till is exceedingly difficult.

There is no evidence that the ice margin lay in the Champlain Sea for a period of time. These observations contrast with the evidence from Chichester Township where the glacial landforms are fresh and where the ice front may have formed the northern shoreline during the early stage of the Champlain Sea.

Environmental changes during the Champlain Sea Episode

Marine clay generally outcrops at the surface where subsequent fluvial erosion has stripped away the overlying Petawawa sands. A major characteristic of the marine clay is that it grades upwards into laminated silts which are devoid of fossils. This reflects an important environmental change during the Champlain Sea episode in this part of the valley. An increase in the calibre of sediment reaching the marine basin and a freshening of the water are indicated. The latter change would account for the extinction of the marine fauna and would also explain why the environment was no longer favourable for the flocculation of clay particles

The mechanism by which such a change was accomplished was not a shallowing of the sea but rather the introduction of fresh, sediment-laden water into the marine basin accompanying the opening of the Fossmill channels. The radiocarbon dates pertaining to this event indicate at least partial contemporaneity with the Champlain Sea episode (Harrison, 1970; Prest, 1970).

The most significant stratigraphical relationship is found where marine clay is overlain by deltaic sands. A study of the distribution of the marine clay, which outcrops to within one mile of Petawawa Point, indicates that it is far more extensive than its present outcrop. It would appear that the deposition of marine clay was abruptly terminated by the influx of large volumes of fine sands and that the formation of the Petawawa delta, therefore, post-dates an earlier deepwater phase of the Champlain Sea. This is in accord with the evidence of decreasing salinity suggested by the transition from massive marine clay to laminated silts.

Even before the opening of the Fossmill outlet and the formation of the delta, the salinity of the Champlain Sea in the study area was very low. In a study of Champlain Sea fauna, Goldring (1922) suggested that in the Ottawa Valley the salinity of the sea decreased northwestwards to essentially fresh water west of Renfrew. There is evidence that the salinity of the sea varied spatially in the study area. The only two fossiliferous exposures of marine sediments observed occur at the Government Road gravel pit (two species: Hiatella arctica and Macoma balthica) and the Pembroke West gravel pit (one species; Macoma balthica). Northwest and west of the latter locality, no fossil-bearing marine sediments were found. This contrasts with the rich and varied marine fauna characteristic of the Champlain Sea sediments of the Ottawa area. The absence of marine fossils near the marine limit west of Pembroke and in the massive marine clay northwest of the city probably reflects the decreasing salinity of the sea water towards these areas. Meltwater streams draining from the Algonquin Highlands and the Shield no doubt diluted the sea water in these areas but with decreasing effect towards the areas of deeper water southeast of Pembroke.

Another important characteristic of the Champlain Sea in the study area is that it must have been shallow even at its maximum transgression. The elevation of the maximum marine limit (520 to 540 feet) and the altitude of the bedrock floor (300 feet a.s.l. beneath central Allumette Island; see Kay, 1942) indicate that the sea had a maximum depth of approximately 240 feet (possibly less allowing for an unknown thickness of glacial sediments). South of Allumette Lake, the sea must have become shallower since the bedrock floor increases in elevation inland.

Contrasts among fluvio-glacial, nearshore and deltaic sediments

A major characteristic which differentiates the Petawawa deltaic sands and the nearshore sands and gravels is their provenance, (Burger, 1967). The former are non-calcareous having been derived from granitic areas to the north and west by streams draining into the Champlain Sea. The latter are moderately calcareous where they have been derived from till or fluvio-glacial sediments with a higher carbonate content such as at the Pembroke West exposure. The nearshore sands and gravels west of Pembroke, however, are non-calcareous since the parent materials, generally fluvio-glacial gravels, are composed of Precambrian derived materials.

The nearshore sands and gravels were deposited at a time when wave action was effective, but it is unlikely that such would be the case when the Petawawa delta gradually encroached on the marine embayment. The stratigraphic relationships between the nearshore sediments and the Petawawa sands is obscure. It appears, however, that the nearshore sediments in some areas were buried beneath the Petawawa sands.

4. Conclusion

The stratigraphy of the study area south of Chenal de la Culbute reveals that the Champlain Sea rose to its maximum elevation rapidly since marine clay covers large areas of till, fluvio-glacial sediments and bedrock. No exposures revealed a transition from varved lacustrine clay to marine clay as has been reported from the Ottawa and Cornwall areas (Gadd, 1961, 63b; Terasmae, 1965).

Littoral sediments of the Champlain Sea are of limited extent and there is no offlap relationship where littoral sediments would have progressively blanketed marine clay as the marine embayment retracted. This is because, at the time when the Champlain Sea was still near its maximum transgression, the sedimentary environment rapidly changed as large volumes of sediment-laden water entered the marine basin and built a large delta of fine sands. North of Petawawa River, however, no exposures of marine clay have been reported and it is highly probable, therefore, that deglaciation in that area was not yet complete. There is evidence that at an early stage of the Champlain Sea ice still occupied part of the study area while marine sediments were being deposited elsewhere. It is to this problem that the next chapter is, in part, devoted.

CHAPTER 4

THE SURFICIAL GEOLOGY AND LANDFORMS OF CHICHESTER TOWNSHIP

1. Introduction

North of Chenal de la Culbute, the study area is demarcated by the east and west boundaries of Chichester Township and in the north by the Shield escarpment. In contrast to Allumette Island and the Pembroke region, the topography is characterised by high relative relief. This is primarily the result of the irregularity of the bedrock surface which, southeast of Nickabong, rises to an elevation of 725 feet in the form of an outlier trending northwest-southeast. McDonald and Isabel Lakes to the west of this bedrock outcrop, however, are developed in the surficial materials and have bottom elevations well below the water level of Chenal de la Culbute (echo soundings taken by the author and a field party from the Geological Survey of Canada). There are three areas where the surficial materials are particularly thick (over 100 feet): (1) The area surrounding Dennie, Ranger and Pupore Lakes, herein designated as the "Nickabong Sand Plain", (2) the Nickabong stream valley, and (3) the area on the north shore of Chenal de la Culbute opposite Chapeau where there is a thick body of outwash gravels. Bedrock becomes important in controlling landforms in the areas west of Chichester and below an elevation of 450 feet the terrace sequence is fragmentary and the surficial overburden has been removed by fluvial erosion.

Unlike the areas to the south, fluvio-glacial sediments are second only in importance in volume and extent to the Petawawa deltaic sands. The landscape of Chichester Township is dominated by a large outwash delta which covers an area of nearly 2 square miles north of Chapeau. This glacial feature presents special problems of interpretation and as such features prominently in this account.

In this discussion, the nature and distribution of each group of sediments are considered briefly in their stratigraphic order. The second part of the account is devoted to a review of the major problems of stratigraphy and landform evolution.

2. The Nature and Distribution of the Surficial Materials

Glacial Till

Sandy non-calcareous till derived from Precambrian bedrock is restricted to a few small areas above 450 feet along the Nickabong stream valley and a larger area (approximately 1 square mile) to the west of Dennie Lake. Elsewhere, the till has either been buried beneath younger sediments or has been removed by fluvial erosion along Chenal de la Culbute. The non-calcareous till of Chichester Township is similar in composition to that described in areas to the south on Allumette Island and in Renfrew County (see p.63).

To the west of Dennie Lake, above an elevation of 625 feet, the till has been moulded into three small southeast-trending ridges each of which has a bedrock core. These ridges, the largest of which is 1/3 mile long and 200 yards wide, have a streamlined form and resemble drumlins but do not conform to the ideal drumlinoid shape. Since bedrock is near the surface, the bedrock topography appears to have dictated the pattern of till deposition. The largest ridge is somewhat flattened on top and the highest point is on the down-ice side (i.e. southeast). The survival of this area of till can be explained by the fact that it lies above the elevation of the depositional surface of the Petawawa sand plains and the marine limit of the area. Below 625-feet contour, the till is surrounded by (and probably buried beneath) fluvio-glacial gravels deposited in the form of an outwash delta between the shield escarpment and the till upland.

It is doubtful if these till ridges are true drumlins, although their orientation (northwest-southeast) conforms to the general direction of ice-movement in this part of the valley but so also does the structural trend of the Precambrian bedrock which forms the core of the ridges.

Fluvio-glacial Sediments

Two large areas of fluvio-glacial sands and gravels outcrop in Chichester Township. North of Chapeau, an outwash delta containing numerous kettle holes is located between McDonald Lake in the west, Nickabong Creek in the east and the outlier of Precambrian bedrock in the north (Plate 20, p. 111). Fluvio-glacial gravels related to this feature are

Plate 20 Outwash delta north of Chapeau looking east from Chichester (348878).

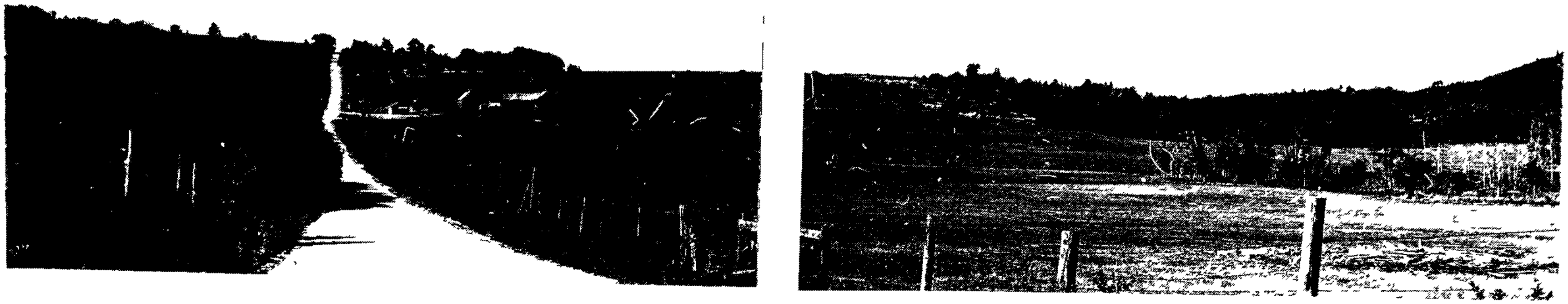


Plate 21   Outwash delta two miles west of Nickabong village (324927).

Plate 22 Top surface of outwash delta two miles west of Nickabong looking north towards the Shield escarpment (315927).

probably more extensive than their present outcrop because below an elevation of 500 feet they have been buried beneath younger sediments. The second large area of fluvio-glacial gravels occurs in the northwest part of the township 2 miles west of Nickabong. Here, the outwash forms a flat-topped divide between the Shield escarpment and an area of till and bedrock to the south (Plate 21,p.112; Plate 22, p.113).

Several large exposures of fluvio-glacial gravels and sands in the area north of Chapeau were available for study. Their locations and designations are as follows: (1) Northeast Chapeau gravel pit (ref. 410868), (2) North Chapeau gravel pit (ref. 394875), (3) McDonald Lake gravel pit (ref. 374883), and (4) North Chichester gravel pit (ref. 359891).

The petrographic and structural characteristics of the fluvio-glacial materials are similar in each of these gravel pits and one exposure, therefore, can serve as an example. Northeast of Chapeau, on the eastern flank of the outwash delta, a maximum of 90 feet of fluvio-glacial gravels and coarse sands are exposed between elevations of 390 and 480 feet. At the north end of the gravel pit, facing south, east and west, 90 feet of gravels in thick beds dip steeply to the south (Fig. 17, p.115 and Plate 23, p.118). The material is characterised by wide variations in grain-size, sorting and rounding. Rapid variations in grain-size, from coarse sand to cobbles, occur both horizontally (with the dip) and vertically (between beds). Stratification, in the

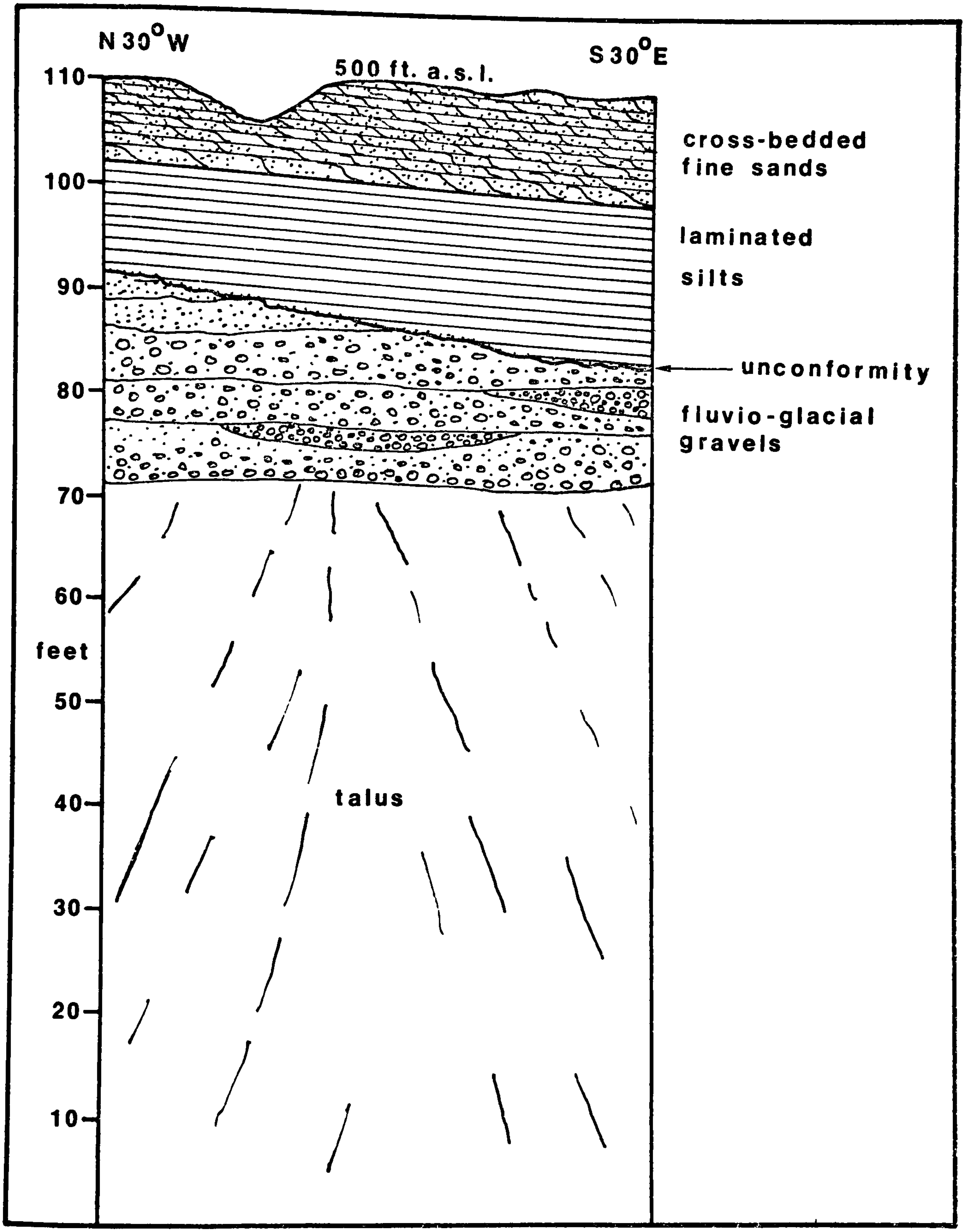


Fig. 17 Exposure A at Northeast Chapeau.

form of thick foreset beds (generally in excess of 2 feet), is well-developed in the finer materials (coarse sand) but is crude or absent in the pebble and cobble beds which tend to thicken up dip. Cut-and-fill structures, in the form of lenticular masses of cobbles and pebbles, are common. The pebbles and cobbles, which are of Precambrian igneous and metamorphic origin, are poorly to moderately rounded and this, coupled with poor-sorting, is indicative of rapid (torrential) deposition by glacial outwash streams.

Rapid variation in orientation and angle of dip between the beds is characteristic although the general direction of maximum dip (20 to 30°) is to the south. Up to 15% of the pebbles are chemically rotted especially along lines of subsurface seepage.

Other exposures on the frontal slope of the outwash along Chenal de la Culbute show a general southerly dip, indicating deposition by streams from the north. Whereas the finest materials in the Northeast Chapeau gravel pit are very coarse, brown sands, exposures on the frontal slope elsewhere exhibit the whole range of grain-size and sorting from uniform, fine-gray sands to chaotic cobble beds with little or no stratification. In places, the beds have become considerably contorted and faulted as a result of either the melting of enclosed ice masses or subsequent undercutting of the slope by Chenal de la Culbute.

An exposure of gravels in a pit located on the planate top surface of the feature reveals only a gentle (less than 10^{o}) southerly dip of the beds. These beds are probably the topset beds of the outwash delta (Plate 24, p. 118).

The relationship between the topset and foreset beds of the outwash can be observed in the McDonald Lake gravel pit located at an elevation of 515 feet (base of the lowermost exposure) on the south shore of McDonald Lake (a kettle complex). The lower 20 feet of materials are brown gravels with two thick (2 feet) lenticular cobble beds (channel fill deposits) in steeply-dipping foreset beds with a maximum dip of 30^{o} in the direction S40^{o}W. Above the lower unit are 30 feet of pale brown, coarse sands and gravels in horizontal but indistinct beds. The contact between the two units is not an unconformity but rather a distinct change in dip of the materials in a short vertical distance.

On the western flank of the outwash delta, between 520 and 480 feet, a change occurs in the surface materials from fluvio-glacial gravels to fine sands or laminated silts. West of McDonald Lake, fluvio-glacial gravels outcrop in the southeast-trending ridge between Poupore and Isabel Lakes. A small area of fluvio-glacial gravels, overlain by Petawawa sand, outcrops in the bluff of the 450-foot terrace on Payne's farm northwest of Chichester (ref 348886).

Plate 23 Fluvio-glacial gravels in thick foreset beds at the Northeast Chapeau gravel pit (409869).

Plate 24 Fluvio-glacial gravels in gently-dipping topset beds on the top surface of the outwash delta north of Chapeau (394875).

Marine Sediments

On the basis of fossil content, no stratigraphic unit north of Chenal de la Culbute could be identified as marine. However, the similar petrographic characteristics and stratigraphic relationships of certain sediments in Chichester Township to those of Allumette Island and the Pembroke area, suggests that some of the sediments of Chichester Township are marine, or at least of Champlain Sea age. Three stratigraphic units of this group of sediments can be distinguished: (a) marine clays and silts, (b) high-level clays and silts, and (c) Petawawa deltaic sands. These materials rest upon the basal materials of either till, fluvio-glacial gravels or bedrock.

(a) Marine clays and silts

The surface outcrop of silty clays or silts with similar characteristics to those in areas to the south is very limited. An exposure of between 8 and 15 feet of dark gray, laminated silty clay can be observed along the banks of Nickabong Creek at ref. 411883 at an elevation of 365 feet (Plate 25, p.120). The silty clay is compact and fissile. The laminae vary in thickness from 3/4 inch at the base of the exposures to less than 1/4 inch at the top. At this locality the clay is overlain unconformably by approximately 70 feet of fine and medium current-bedded sands which fill the major portion of Nickabong stream valley. Since the silty clays

Plate 25 Laminated silty clay in Nickabong Creek (411883).

have only been exposed by the recent undercutting of Nickabong Creek, they are not mapped as a unit on the surficial geology map.

West of Chichester in the vicinity of Payne's farm (ref. 345883), silty clay and laminated silts can be found between 415 and 450 feet. The massive dark gray, silty clay grades into olive gray, laminated silt which splits along 1/2 to 1 inch very fine sandy partings. Only at the base of the lowest exposures can the massive silty clay be observed. These clays and silts outcrop in an abandoned channel at 400 feet and on the 420 and 450-foot terraces. That the clays and silts are not alluvial fill related to the abandoned channel and terraces, is proven by the fact that they can be traced along a small stream valley which dissects the 420 and 450-foot terraces. Also, in places the clay is overlain by the fine sands of the Nickabong sand plain.

A small area of laminated silty clay resting unconformably on till and bedrock is exposed on the 420-foot terrace north of Culbute Look. If this material is a Champlain Sea sediment, then it is, along with the clay near Petawawa Point, the most westerly visible outcrop of "marine" clay of the Champlain Sea.

(b) High-level silts and clays

Because of their topographic position and/or elevation, there are several bodies of silts and clays which do not appear to be related to those described above. The "marine" clays and silts are exposed today because fluvial erosion has removed the overburden of Petawawa deltaic sands as is evidenced by their outcrop on the river terraces along Chenal de la Culbute. The high-level clays and silts, however, are related to the outwash delta and rest unconformably upon fluvio-glacial gravels.

Exposure A (Fig. 17, p. 115) in the Northeast Chapeau gravel pit reveals 10 feet of laminated silts resting unconformably upon 90 feet of fluvio-glacial gravels at an elevation of 480 feet. The contact is irregular and it appears that the silts have been deposited upon an undulating surface of gravel filling in the voids and hollows. Beneath the unconformity, the gravels contain a high percentage of rotted pebbles (15 to 20%) and the coarse sandy matrix has been oxidised. This may indicate either a period of sub-aerial weathering of the gravels, or a line of ground water seepage. The silt is massive, dark gray and has an irregular fracture with oxidised partings but becomes gradually laminated towards the top of the outcrop.

There is a gradual transition upwards from laminated silts to fine sand with silty partings, to fine, pale yellow current-bedded sands which form the top 9 feet of the exposure. The small-scale current beds, though variable in orientation, indicate deposition by currents from the northeast. These sands form a flat surface between 480 and 550 feet above the gravel pit to the north and west.

A similar stratigraphic sequence is to be found in the east facing exposure (Exposure B: Fig. 18, p. 125) of the Northeast Chapeau gravel pit between 395 and 445 feet. The laminated silts, which rest unconformably on fluvio-glacial gravèls, form a 22-foot thick concave-upward bed (Plate 26, p. 124). On the northern limb of the outcrop, the silts become sandier and interfinger with thin beds of fine, stratified sand. Small-scale faulting and other deformation structures are present in the silt bed. Resting upon the silts, but not grading into them, is a 2-foot bed of structureless, very fine sand (possible wind blown) which in turn is overlain by a 2-foot gravel lens containing small, moderately-rounded pebbles in a coarse sand matrix. The top 5 feet of the exposure is composed of fine, pale yellow current-bedded sands similar to those exposed at the top of Exposure A.

Several problems are posed by the stratigraphic relationships in this gravel pit (see p. 144). The laminated silts and overlying current-bedded sands are restricted to the south and east-facing exposures of the pit (A and B) and they do not form the surface materials in adjacent areas to the east. Moreover, these materials outcrop at different elevations in Exposures A and B and cannot be traced laterally into one another. The laminated silts and current-bedded sands represent a drastic, though probably local, change

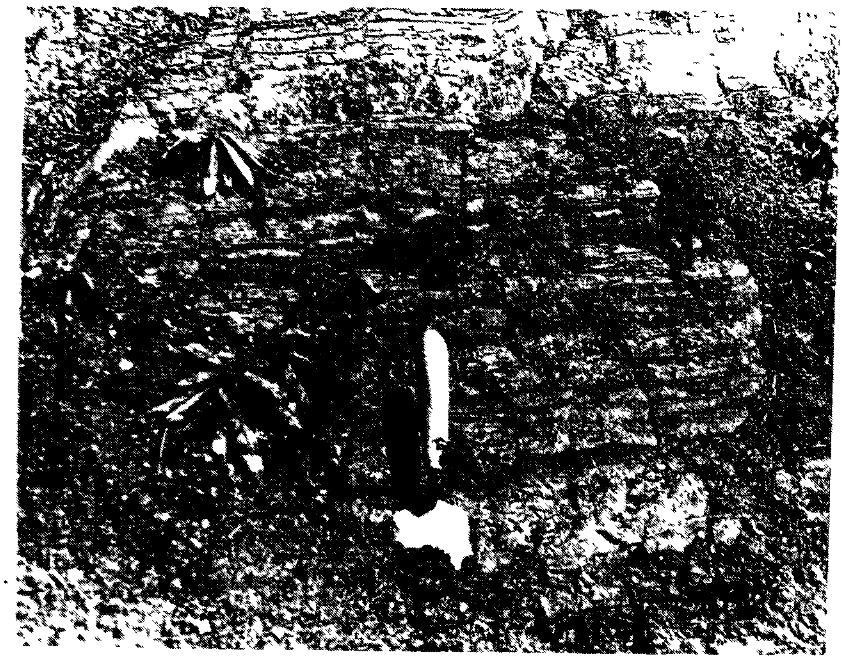


Plate 26 Close-up of the laminated silts in Exposure B at the Northeast Chapeau gravel pit (409869).

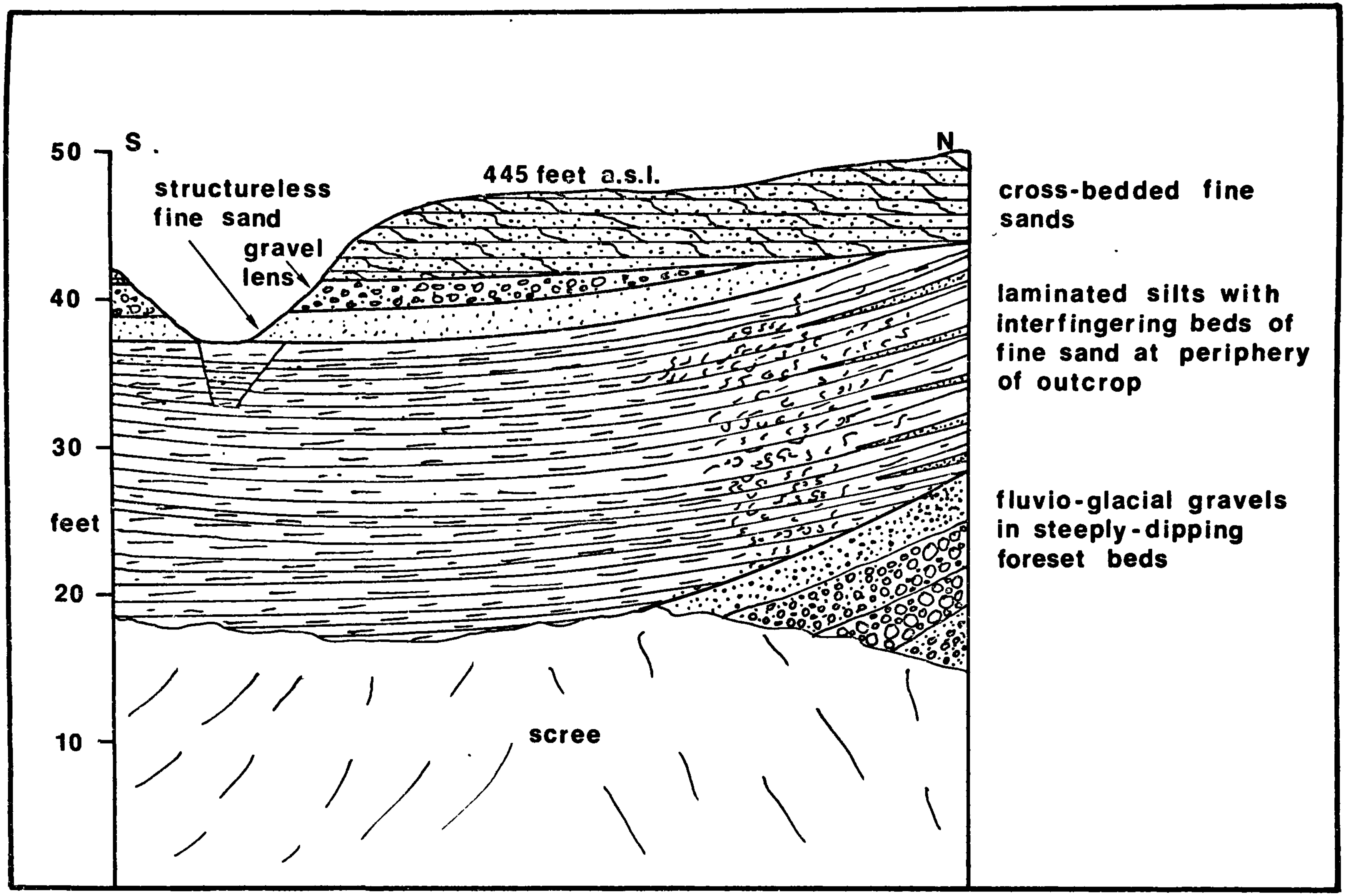


Fig.18 Exposure B at Northeast Chapeau.

in the sedimentary environment from that in which the underlying fluvio-glacial gravels were deposited.

A third small area of laminated silts, 40 feet thick, partly encloses the kettle complex east of McDonald Lake (ref. 384883) and forms a relatively flat surface at an elevation of 550 feet about 40 feet below the top surface of the outwash. The junction between the laminated silts and the fluvio-glacial gravels in the east is marked by a distinct break of slope trending north-south. The dark gray laminated silts have in places been greatly deformed and exhibit well-developed flame structures (Fig. 19, p.127). Since the silts outcrop on the side of a kettle, it is probable that they were deposited before the ice melted and that when the ice did melt, slumping caused the deformation (see p. 139).

These silts, though thick, are of only local occurrence; they are not present in the McDonald Lake gravel pit at an elevation of 515 feet on the south side of McDonald Lake and the surface materials to the northwest between the bedrock upland and McDonald Lake are fine sands.

In a stream channel east of McDonald Lake (ref. 383889), at an elevation of 510 feet, 10 feet of gray, massive clay with a small silt content are overlain unconformably by fine, compact light gray sands. The clay has a blocky fracture and contains occasional oxidised streaks. This outcrop is unusual because no similar clay is found locally and no clay is found at the same elevation in Chichester Township.

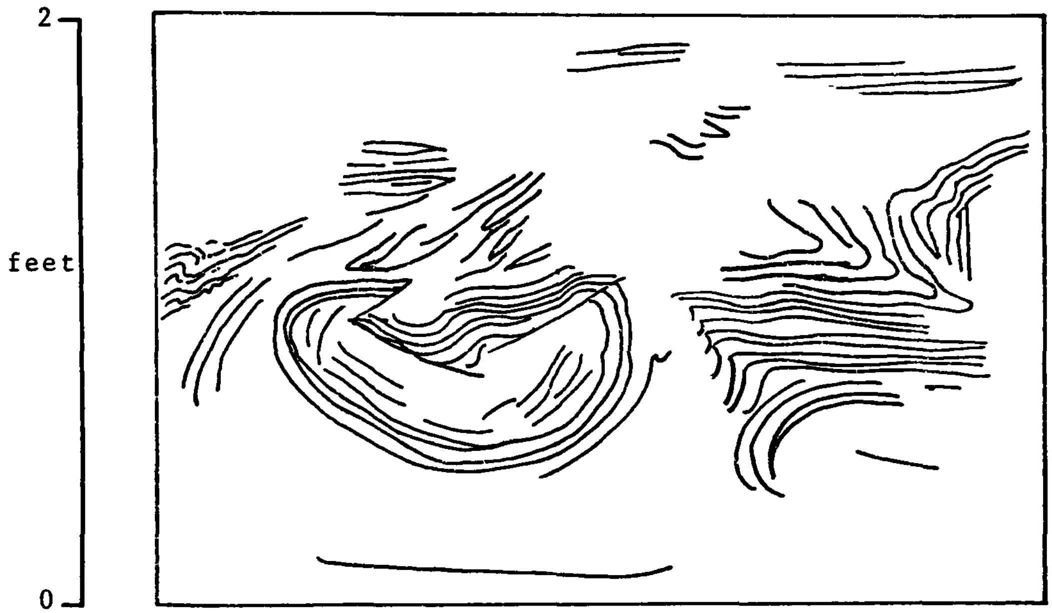


Fig. 19 Deformation Structures in Laminated Silts near McDonald Lake.

(c) Petawawa deltaic sands

In terms of area and volume, Petawawa-type fine and medium sands form the most important stratigraphic unit of Chichester Township. The sands can be found at the surface at all elevations between 370 and 520 feet. They are replaced at higher elevations by bedrock, till or fluvioglacial gravels and at lower elevations, notably on the terraces west of Chichester, they have been removed by fluvial erosion.

The sands are uniform in texture and composition throughout the township. Most exposures reveal pale yellow to yellowish brown, delicately cross-bedded fine to medium sands (Plate 27, p.129). In many areas, the top 3 or 4 feet of material is structureless (probably wind blown), very fine sands. Occasionally, thin beds (generally less than 1 foot) of coarse, reddish brown stratified sands are to be found, containing small, well-rounded pebbles, and are probably local channel-fill deposits.

These sands, which in Chichester Township form the uppermost stratigraphic unit except for recent deposits, are undoubtedly part of the Petawawa delta. In the vicinity of Nickabong village, the sands form a distinct physiographic unit of a remarkably flat plain, occasionally diversified by small dunes, at an elevation of 480 feet (Plate 28, p.129). Over 100 feet of fine and medium sands of similar composition fill the valley of Nickabong Creek up to an elevation of 480

Plate 27 Cross-bedded Petawawa sands near Ranger Lake (342911).

Plate 28 Small dunes on the Nickabong sand plain (345916).

feet.

The Petawawa sands overlie marine clay in Nickabong Creek, fluvio-glacial gravels south and west of McDonald Lake, and till north of Culbute Look.

3. Stratigraphy and Landforms

The key to the late-glacial history of the study area lies with the correct interpretation of the fluvio-glacial landforms north of Chapeau and the relationship of the fluvio-glacial sediments to the other surficial materials. Fluvio-glacial sediments are rare on Allumette Island (within the limits of the mapped area) and have been wave-washed or buried below an elevation of 530 feet in Renfrew County. The stratigraphic relationships and morphology of the fluvio-glacial features in these areas indicate that they were formed before the Champlain Sea transgression. The outwash delta north of Chapeau, however, is a remarkably fresh land-form and is one of the largest features of its kind in the Upper Ottawa Valley.

, The Origin of the Glacial Outwash North of Chapeau

The fluvio-glacial materials described from several gravel pits north of Chapeau are characterised by rapid variations in grain-size, poor-rounding and poor-sorting in steeply-dipping foreset beds (see p.114). The materials vary in texture from medium-grained sands to cobbles. Stratification is distinct in the sands but is crude and occasionally absent in the pebble and cobble beds. The general direction of maximum dip in the foreset beds indicates deposition by outwash streams from north to northwest. This is reflected in the provenance of the pebbles and cobbles which are all of Precambrian origin; Precambrian rocks in this area only outcrop north of Chenal de la Culbute.

The top surface of the outwash is remarkably flat with a gentle slope from 600 feet in the north to 580 feet in the south (see Plate 20, p. 111). At the McDonald Lake and North Chapeau gravel pits, which have been excavated in the top surface, the uppermost units are horizontally-stratified topset beds (Plate 24, p.118). This contrasts with the steeply-dipping (20-30°) foreset beds observed on the frontal slope of the outwash along Chenal de la Culbute (Plate 23, p.118). On the south shore of Chenal de la Culbute, in the vicinity of Chapeau, fluvio-glacial gravels are notably absent except for a thin veneer exposed locally on the 365-foot terrace east of the village. It is doubtful if the outwash gravels were deposited to the south of Chapeau because, at Chapeau, Petawawa sands rest directly upon till and further east in the Plains upon marine clay (Fig. 11, back pocket).

The southern flank of the outwash takes the form of a steep escarpment rising over 200 feet above Chenal de la Culbute. This escarpment is diversified by several kettles linked by a dry valley which trends parallel to the contours (see p.139). The presence of foreset beds, and topset beds forming the planate top surface of the outwash, suggest that the fluvio-glacial gravels were deposited in a body of relatively still water as an outwash delta. Such an arrangement would not be expected to occur if the materials were deposited sub-aerially in the form of an outwash fan. Although exposures along the escarpment reveal that the dip of the foreset beds approximates the escarpment slope, it is doubtful if the frontal slope is the original depositional surface of the foreset beds because the escarpment face has probably retreated since its formation as a result of undercutting by stream action during one of the early (high) stages of Chenal de la Culbute. Morphological evidence (see p. 178) suggests that at one point in time the outwash body acted as a barrier to the river and diverted the waters to the south across Allumette Island.

The flat top surface of the outwash could be a primary depositional feature or it could be the result of marine planation by the Champlain Sea. There is, however, no evidence of wave wash such as lag concentrates or beach ridges at this elevation to support the latter hypothesis. Nor are there any marine sediments overlying the gravels above 520 feet despite the availability of a large volume of unconsolidated materials for reworking. This does not preclude the hypothesis, proposed here, that the outwash delta was deposited _in_ the Champlain Sea. Evidence of marine planation and deposition of marine sediments upon the gravels implies that the outwash feature was formed before the Champlain Sea transgression. Since the top surface elevation of the outwash (590 feet) compares favourably with the known marine limit of the area (600 feet north of the Petawawa River; Gadd, 1963a), it is highly probable that the outwash delta was deposited during the maximum stand of the sea in the area. On the eastern flank of the outwash delta, above the Northeast Chapeau gravel pit, a distinct bluff, approximately 15 feet high, has been cut into the fluvio-glacial gravels and overlying fine sand (the upper unit in the Northeast Chapeau gravel pit) at an elevation of 515 feet. This strandline could either be marine, related to the Champlain Sea, or fluvial, related to a high-level stage of Nickabong Creek. The evidence is enigmatic; the bluff is considerably higher than the highest fluvial terraces of the area yet there is no stratigraphic evidence such as beach materials or boulder concentrates to suggest a marine origin.

It could be argued that the water body in which the delta was deposited was a glacial lake. Although evidence for a glacial lake phase consequent upon the retreat of the ice in the Ottawa Valley is sparse, it has been suggested that a glacial lake occupied the Ottawa Valley east of Arnprior immediately prior to the Champlain Sea episode (Antevs, 1928; Goldthwait, 1933; Prest, 1970). East of a line drawn from Arnprior to Quyon, varved clays intervene between the till or bedrock floor and marine clay, but west of this line the varved clays are absent and marine clay rests directly upon till or bedrock. The stratigraphic relationships in the study area to the south of Chenal de la Culbute certainly support the latter observation (see p. 75). Consequently, ice retreat must have taken place in marine waters and, there fore, the hypothesis of a glacio-marine origin for the outwash delta appears to be the most plausible explanation.

Ice Retreat

The large volume of fluvio-glacial gravels, in the form of the outwash delta, probably represents a marked halt in ice retreat in the Upper Ottawa Valley when the ice front lay in marine waters. On the basis of the available evidence, however, it is not possible to relate this local thickening in the drift cover to other glacial features in the study area. The absence of fluvio-glacial gravels in Nickabong Creek to the east and Allumette Island to the south, for example, is puzzling. The top surface elevation of the fluvio-glacial gravels declines towards the northwest and below 520 feet the gravels have been buried beneath the Petawawa sands. In the McDonald Lake gravel pit, at an elevation of 522 feet, pale yellow current-bedded fine sands of the Petawawa sand plain rest unconformably on the fluvio-glacial gravels. These sands, though thin in this exposure (2 feet 6 inches), become thicker towards the northeast where they form the surface materials.

At the time the outwash delta was being deposited, the ice lobe was probably hinged between the Shield escarpment and the present north shore of Allumette Island. This is very difficult to substantiate from field evidence because, with the exception of a small moraine on western Allumette Island, there are no visible glacial features on Allumette Island which could permit the recontruction of the pattern of ice retreat in the study area. However, the distribution of thick deposits of till and outwash gravels in Chichester Township suggests the pattern shown in Fig. 20A (p. 136). The moraine on western Allumette Island has no topographic expression and consists of a linear concentration, less than 200 feet wide, of exceptionally large boulders which can be traced for one half mile in a north-south direction from ref. 334868. This feature is in a direct line with, and has a similar orientation to, the second body of outwash, approximately 100 feet thick two miles west of Nickabong Village, which probably marks a second halt in the ice sheet after its retreat (or stagnation) from the vicinity of Chapeau. The outwash, which contains a large kettle, has a flat top at an elevation of 580 feet and a steep eastern slope. To the south, the fluvio-glacial gravels surround a series of small till ridges which were deposited before the gravels.

A further retreat brought the ice front to the Indian Point position. Although Sheen Township is outside the study area, the northern portion of the Indian Point moraine was investigated in order to place the glacial landforms of Chichester Township in their regional context. The Indian

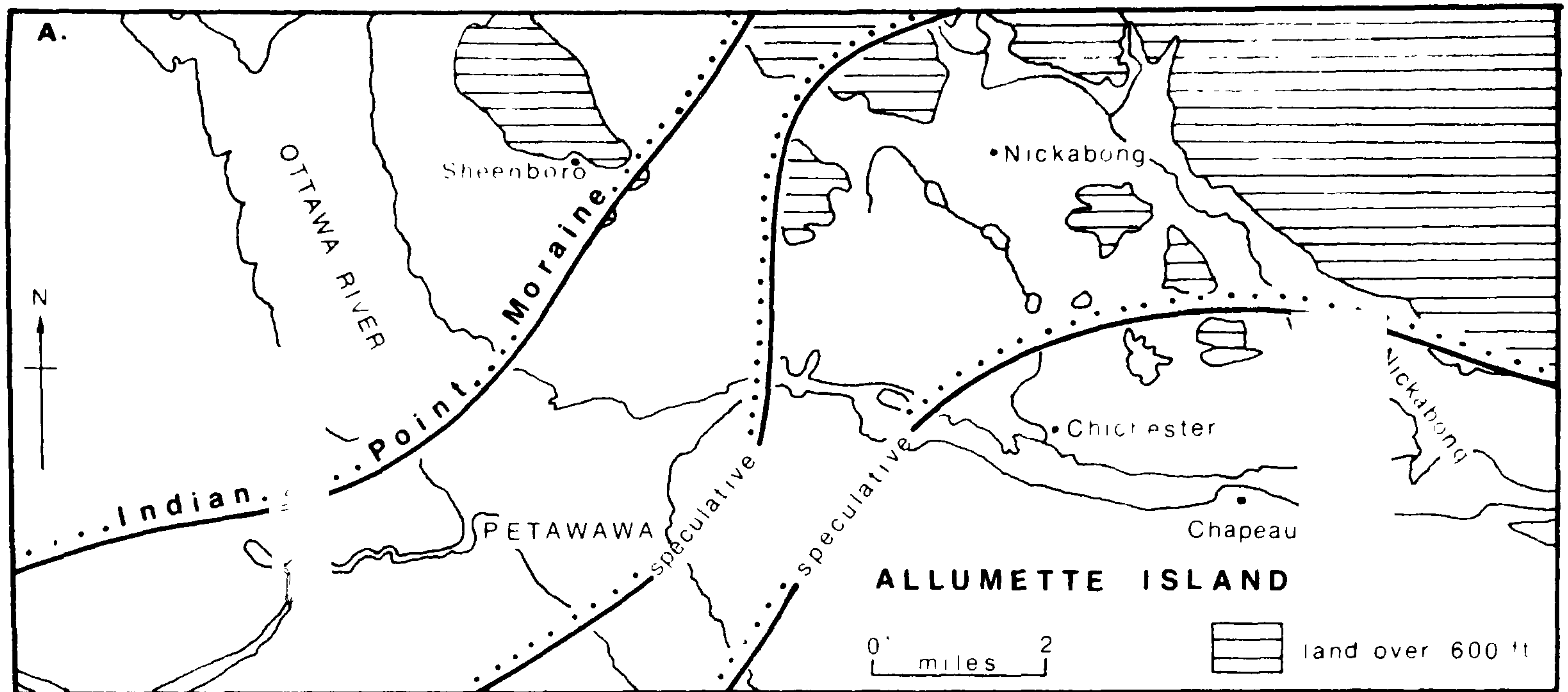
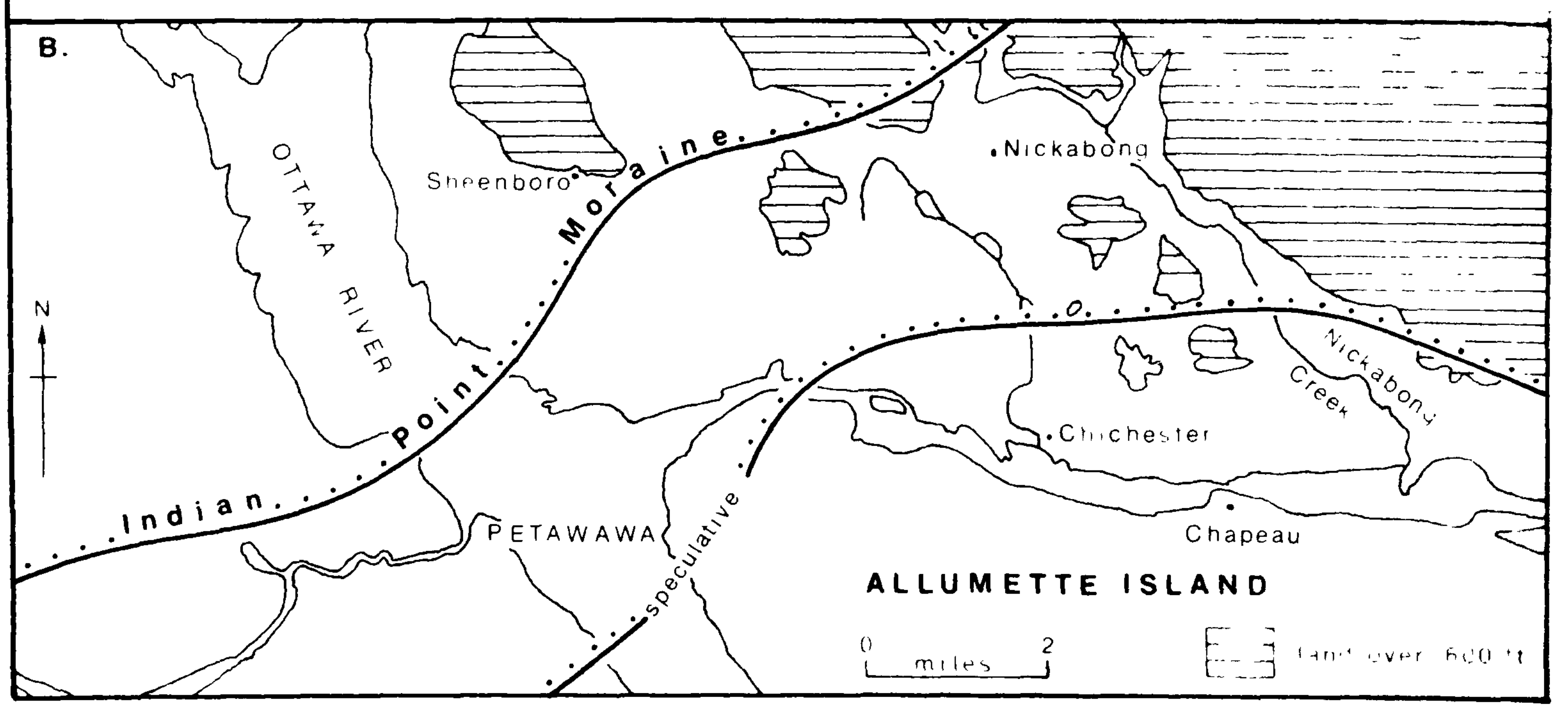


Fig. 20 Speculative Ice-Marginal Positions in Parts of Allumette, Chichester, Sheen and Petawawa Townships.



Point moraine trends southwest-northeast and can be traced with only a few breaks from the Fort William boom, north of Lorelei Island, to a point one mile east of Sheenboro. Northeast of Sheenboro, the moraine is probably buried beneath the Petawawa sands. Above 580 feet, in the vicinity of Sheenboro, the moraine has a fresh appearance and is composed of bouldery till with intercolated masses of fluvio-glacial gravels. Below 580 feet, the moraine has either been buried by younger sediments, or wave-washed leaving a concentration of boulders. Between the Fort William boom and the Fort William road (refs. 256889 and 266908), for example, the moraine is composed totally of large boulders in a ridge approximately 30 feet high and 50 to 100 yards wide. These observations are in accord with those of Gadd (1963a) who has investigated the moraine on the south shore of the Ottawa River. It is also a possibility that the outwash body west of Nickabong Village represents the northern part of the Indian Point moraine but again the field evidence is insufficient to prove this conclusively. This is because the northern (visible) limit of the Indian Point moraine is near Sheenboro and thus several miles from the large area of outwash. Consequently the only link between the two has to be extrapolated (Fig. 20B, p. 136).

A major contrast between the Indian Point moraine and the outwash delta north of Chapeau is that the former is composed mainly of till while the latter is composed totally of outwash gravels. If the ice margin did not extend much further south than Chenal de la Culbute when the outwash delta was formed, then it is highly probable that a lobe of ice occupied Chichester Township when the Ottawa Valley was ice free to the south. The presence of numerous kettles and possible ice-ponded sediments, north of Chenal de la Culbute, suggests that, rather than active ice retreat to the Indian Point position after the formation of the outwash delta, the ice lobe became separated from the main ice sheet and stagnated in the lowland between the channel and the Shield escarpment.

Kettles

The outwash gravels north of Chapeau are characterised by numerous kettles varying in diameter from 25 to 200 feet and depth from 50 to 175 feet with steep side slopes in the order of 30° (Plate 29, p.140). In the top surface of the outwash, the kettles are connected to each other by a series of deep, narrow-walled and flat-bottomed dry valleys which, southeast of McDonald Lake, radiate from a central kettle complex. Unlike stream valleys, these valleys have a barely perceptible longitudinal slope and they terminate abruptly at steep head walls. A series of kettles are also developed on the steep frontal flank of the delta and again they are connected by narrow dry valleys. Investigation of the gravels enclosing the kettles for signs of deformation proved impossible due to the dense foreset cover and the absence of exposures. Laminated silts which outcrop on the sides of several kettles southeast of McDonald Lake, however, show considerable deformation in the form of well-developed flame structures.

The most unusual features of the kettle complex are the dry valleys. If the stagnant ice blocks were not completely buried by fluvio-glacial gravels, the valleys could be overspill channels from one ponded water body to another. However, not all the valleys link one kettle to another. Alternatively, the valleys could be collapse features created by the cave-in of subsurface drainage tunnels which were formed when enclosed blocks of ice melted and the melt-water drained to lower elevations at a time when the water table was higher than at present. Unfortunately, there is no stratigraphic evidence to elucidate this problem.

Six Lakes, from Dennie Lake in the northwest to McDonald Lake in the southeast, probably occupy a series of aligned kettles (Plate 30, p. 140). McDonald Lake and the small lakes to the southeast are exceptions in that they are partially or wholly enclosed by fluvioglacial sediments which form steep side slopes above the lake level. Echo-soundings reveal that McDonald Lake, in fact, occupies three or more kettles, the adjoining walls of which are now submerged.

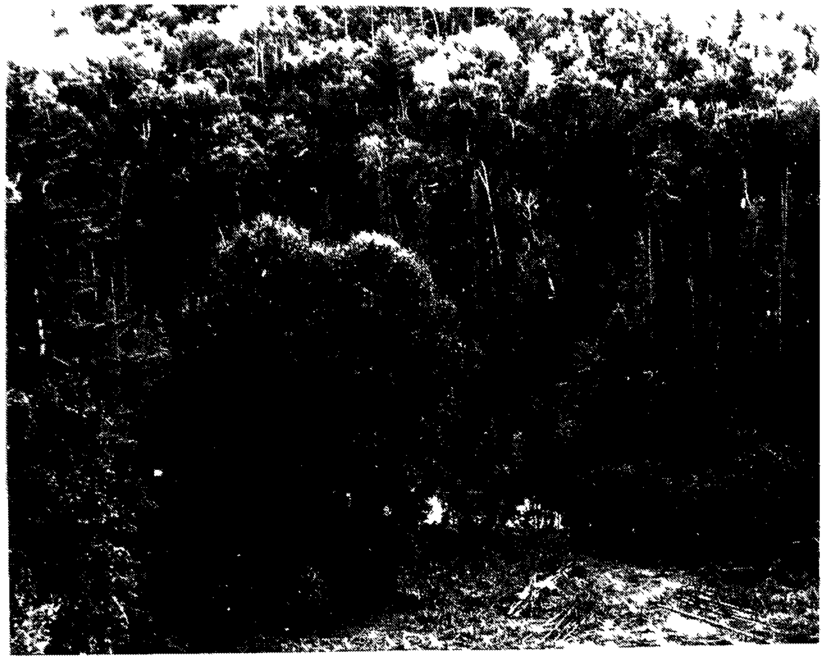


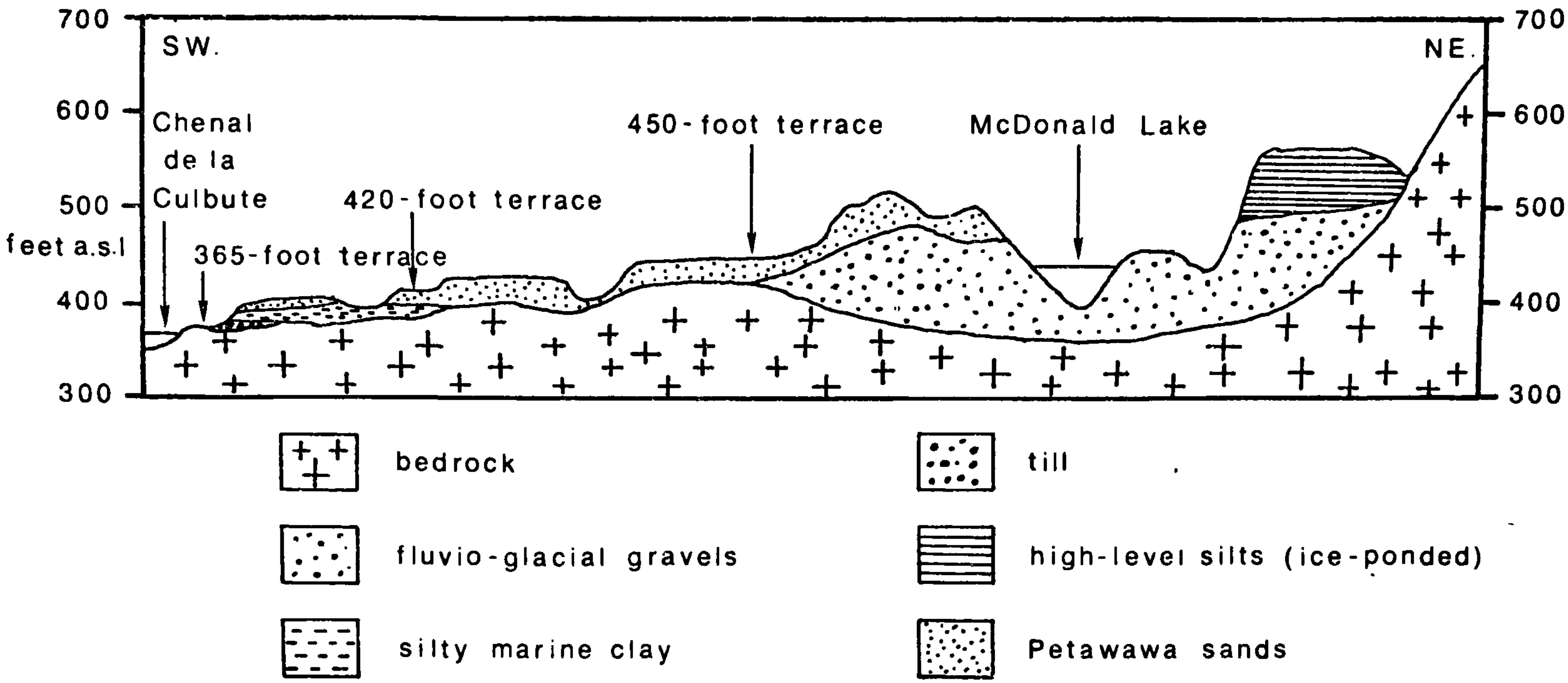
Plate 29 Kettle depression near McDonald Lake (383883).

Plate 30 Panger Lake occupying a possible kettle (342912).

There is no direct proof that the lake basins to the northwest of McDonald Lake are kettles since the surrounding sediments (i.e. those visible at the surface) are not of fluvio-glacial origin. These lakes occupy part of the Nickabong sand plain which is an extension of the Petawawa sand plain. Depth recordings of Isabel Lake revealed an exceptional depth (maximum 110 feet) and steep sides, both characteristic of a kettle. The absence of limestone bedrock in the area precludes the possibility of these features being solution depressions. If these lakes do occupy kettles, then stagnant ice must still have been present in the area when the Petawawa sands were deposited over the fluvio-glacial gravels. The key to this problem can be found in the stratigraphy around McDonald Lake. At the McDonald Lake gravel pit and in areas to the west, the Petawawa sands rest unconformably on fluvio-glacial gravels which together form the side walls of the kettle complex. Such an arrangement could only be expected to occur if the ice was still present when the Petawawa sands were deposited. Furthermore, any pre-existing glacial lakes could not be expected to have survived the deposition of great thicknesses of deltaic sands.

Stratigraphic Problems (Fig. 21, p. 142)

Foremost of the stratigraphic problems of Chichester Township is the relationship of the laminated silts found at the Northeast Chapeau gravel pit and east of McDonald Lake



Horizontal Scale 1.25 inches to 1 mile Vertical Scale 1 inch to 200 feet
Vertical Exaggeration x 20.8

Note: Sediment thicknesses and bedrock topography are speculative.

Fig. 21 **Stratigraphic Cross-Section from Chichester to McDonald Lake (ref. 343877 to 387888).**

to the outwash delta and the clays and silts found at lower elevations. Although the laminated silts of these two areas are similar in composition, they are topographically isolated from each other and, as such, are discussed separately.

The laminated silts observed in exposures A and B (Fig. 17 and 18, p.115 and p.125 resp.) at the Northeast Chapeau gravel pit must have been deposited in a still (fresh) water body. The gradation from silts through laminated silts, to fine, cross-bedded sands indicates an increase in the grain-size of sediment supply. The question arises as to what water body formed the basin in which the silts and laminated silts were deposited. Local ponding in an ice-dammed lake or in a depression in the fluvio-glacial gravels is not plausible given the present-day disposition of topography. Fluvial erosion has probably removed evidence of the southerly extension of the outwash delta across Chenal de la Culbute so local ponding may have occurred under different topographic conditions.

If this is not the case, however, a more extensive water body occupying this part of the Ottawa Valley has to be invoked. The transition from massive silt to laminated silt is reminiscent of other exposures in the area (e.g. Payne's farm) which are probably of Champlain Sea age. This is not altogether clear, however, since the outcrops of possible marine clay and silt in the vicinity of the Northeast Chapeau gravel pit occur at considerably lower elevations

(365 feet in Nickabong Creek and 400 feet on the Plains) than the laminated silts observed near McDonaldLake and at the Northeast Chapeau gravel pit. In the former areas, erosion could have removed some of the clay before the overlying Petawawa sands were laid down but this is difficult to prove. Furthermore, if the high-level laminated silts were deposited in a large water body (the Champlain Sea), the stratigraphic relationships in the Northeast Chapeau gravel pit are not consistent with other exposures to the south of Chenal de la Culbute where marine clays and silts interdigitate with sands and gravels on the flanks of outwash bodies. At Northeast Chapeau there is no horizontal gradation from laminated silts to sands and gravels despite the availability of large volumes of fluvio-glacial gravels for reworking by wave action. If the outwash delta was deposited during the maximum stand of the Champlain Sea in the area, then the deposition of the silts must post-date this event during a time of falling sea level. In exposure A at Northeast Chapeau, the gradation to fine, current-bedded sands above may reflect this change as wave-action began to rework the gravels at successively lower elevations. The local extent of laminated silts at Northeast Chapeau and their absence elsewhere at similar elevations reflect the difficulties involved in the correlation and interpretation of the stratigraphic units in Chichester Township.

The laminated silts east of McDonald Lake, however, do not present any difficulties in interpretation. Since they outcrop on the side of a kettle complex and show signs of considerable deformation, they are undoubtedly ice-contact sediments, the product of local ponding. From a consideration of the topography on the western flank of the outwash delta, it can be envisaged that a block or blocks of stagnant ice impounded a small water body between McDonald Lake and the top surface of the outwash and that when the ice melted, the silts became deformed.

At the time the outwash delta was deposited, the areas to the south were probably ice free and marine clays were being deposited. North of Chenal de la Culbute, as the ice retreated or stagnated, conditions became locally favourable for the deposition of marine clay. The distribution of marine clay in Chichester Township is patchy and probably reflects both subsequent erosion and the disposition of depressions in the generally irregular bedrock topography.

The next major event was the deposition of the Petawawa sands which buried the older sediments below an elevation of 520 feet. The sands rest unconformably on till, fluvio-glacial gravels, bedrock and locally marine clay. It is apparent, however, that not all the sands were derived from the same source (i.e. from the west via the Fossmill system). The Nickabong Valley is topographically isolated from the Nickabong sand plain by the outlier of Precambrian rock and the fluvio-glacial outwash north of Chapeau. Over 100 feet of fine and medium, current-bedded and stratified sands fill the valley and the most likely source for this sediment would be from the north (i.e. the Shield) (Plate 1, p. 49). Outwash streams from ice still present on the Shield undoubtedly supplied large volumes of sediment into the Champlain Sea in addition to that from the Fossmill system. A re-entrant in the shield escarpment, from which one of the tributaries of Nickabong Creek issues, demonstrates these relationships (ref. 376933). The upper part of the re-entrant is underlain by fluvio-glacial gravels and the lower portion (below 550 feet) by fine and medium sands of similar characteristics to those found in the Nickabong Valley.

These sediments were probably deposited in the form of a delta or fan at the base of the Shield escarpment. The fine sands, which overlie the gravels, were deposited somewhat later than the gravels when the ice had retreated further north and the sediment calibre reaching the valley had correspondingly decreased. A similar stratigraphic sequence is to be found in another re-entrant in the Shield escarpment 2 miles to the west (ref. 345946).

The later stages of landscape evolution in Chichester Township are recorded by a series of river terraces along Chenal de la Culbute. During a high-level stage of Chenal de la Culbute, the upper portion of Nickabong Creek drained into Ranger Lake south of Nickabong village. This former course of Nickabong Creek, which has since been captured, is marked by a shallow abandoned channel at an elevation of 440 feet. The presence of a distinct bluff, between 10 and 25 feet high at an elevation of 450 feet, surrounding Dennie, Ranger, Poupore, Venne and Isabel Lakes suggests that these lakes were formerly more extensive and probably co-extensive when Nickabong Creek drained into Ranger Lake. It is unlikely that such distinct and high bluffs were formed in the still water of an enlarged lake. They were probably cut by through-flowing water during a time of higher run-off when major streams issuing from the Shield drained across the Nickabong sand plain (Fig. 15, back pocket).

4. Conclusion

The morphology and stratigraphy of the fluvio-glacial gravels north of Chapeau suggest deposition in the form of an outwash delta during a high-level stage of the Champlain Sea. Large blocks of ice became lodged or buried in the outwash causing the local ponding of small lakes in which the laminated silts were deposited and, upon melting, the formation of kettles and dry valleys.

If the outwash delta is of Champlain Sea age, the late-glacial events in Chichester are compressed into a (geologically) short period of time. Immediately after the retreat of the ice to the Indian Point position, marine clays and silts were deposited. The sedimentary environment rapidly changed, however, and the deposition of clay and silt was terminated when large volumes of fine sand were transported into the area from the Fossmill system. The preservation of deep lakes and the presence of Petawawa-type sands overlying fluvio-glacial gravels in the vicinity of McDonald Lake can only be explained by the survival of stagnant ice blocks when the Petawawa delta was formed. The level of the Champlain Sea had probably fallen somewhat by the time of the formation of the Petawawa delta because the maximum altitude of the sands is lower than the top surface of the outwash delta. The absence of strandlines and littoral sediments related to the Champlain Sea in Chichester Township can be explained by the fact that the marine transgression occurred while ice still occupied the area and that the later stages of the Champlain Sea were dominated by deltaic sedimentation.

CHAPTER 5

RIVER TERRACES AND DRAINAGE DEVELOPMENT

1. Introduction

À series of river terraces and abandoned channels with associated alluvial deposits record several stages of the emergence and dissection of Allumette Island following the withdrawal of the Champlain Sea. Well-developed river terraces, which are characteristic of the Ottawa Valley, can provide valuable evidence of environmental changes such as isostatic uplift and discharge fluctuations during post-glacial time.

Downstream from Chalk River, the Ottawa River emerges from a narrow, bedrock-confined channel into the broad, structural depression of the Ottawa-Bonnechere graben with its thick covering of unconsolidated Quarternary sediments. Near Petawawa, the Ottawa River bifurcates into Chenal de la Culbute in the north and Allumette Lake in the south eventually rejoining at the eastern end of Allumette Island. This pattern not only provides the study of four sets of terraces instead of two (as in the case of one channel) but also a north-south distance of eight miles between the two channels such that the effects of any isostatic warping of the terraces may be observed. In addition, the study area is of sufficient width (15 miles, southeast to northwest) to obtain elevation data for the longitudinal slope of the terraces.

The study of the terraces involved an analysis of their morphology and stratigraphy which, in the study area, were supplemented by the chronological evidence of several radiocarbon dates. The purpose of this part of the study was threefold: (a) to elucidate the various stages of the drainage evolution; (b) to relate this history to that of adjacent areas; and (c) to assess the relative importance of various environmental conditions upon terrace morphology.

2. Methodology

The most important quantitative descriptions of terraces are provided by their longitudinal profiles and the heights and top surface elevations of their bluffs. This data was obtained by a series of traverses using a Wallace and Tiernan barometer with 5-foot calibrations permitting visual estimation of altitude on the scale to within 3 feet. Four east to west traverses were conducted: (1) along the south shore of Allumette Lake between Government Road and Petawawa Point; (2) along the north shore of Allumette Lake from Morrison Island to the westernmost point of Allumette Island; (3) along the south shore of Chenal de la Culbute from "the Plains" to the westernmost point of Allumette Island; and (4) along the north shore of Chenal de la Culbute from the eastern boundary of Chichester Township to Culbute Rapids. The elevations of two north-south trending abandoned channels on Allumette Island were also established. Where possible, on each traverse, altitudes were determined at half-mile intervals for the base and top of the terrace bluffs along each identifiable terrace. The altitudinal data obtained does not correspond ideally to a regular longitudinal interval of one-half mile because of the difficulties of accessibility dictated by the nature of the terrain and vegetation and the absence of well-developed terraces in some areas. The usual precautions and corrections (of data) for a barometric survey, as described by Sparks (1953), were performed.

The elevations at the base of each terrace bluff provide the first criteria for identifying the various terraces (and thus drainage stages) because they are a well-defined point on the terrace and they should show an approximate uniformity and progression in declination when traced downstream. The top surface elevations of the bluffs, however, give a general indication of the actual water levels related to the formation of the various terraces and, when there is a higher terrace above, the distal elevations of the terrace treads. As an indication of former water levels, these elevations have to be treated with caution since the morphology and height of the bluffs depend upon such factors as local conditions of bedrock and surficial geology, the initial slope of the landsurface and the loci of stream erosion.

In the selection of sites for altitude measurements, care was taken to avoid portions of the terraces which had been dissected by streams or which had become degraded by slumping. Difficulties were also encountered in establishing the exact location of the base of the bluff in areas where bedrock or bouldery till outcropped at the surface. Furthermore, the precise position of the break of slope even at the base of well-developed bluffs was not always easy to determine and in such circumstances height readings were taken away from the bluff where there was a pronounced flattening of the terrace tread (Plate 31, p.153). In the absence of suitable sites or distinct bluffs, the elevations of marked breaks of slope were determined if they conformed with the general trend of the terrace bluffs. At each site selected the following factors were noted:

(1) the elevation at the base of terrace bluff;

(2) the elevation at the top of the terrace bluff;

(3) the orientation of the terrace bluff;

(4) the degree of degradation of the terrace bluff;

(5) the surficial materials and bedrock exposed on the terrace bluff; and

(6) the approximate width of the terrace.

To enable the completion of a comprehensive terrace map of the study area, (Fig. 26, p.163) the field mapping of the terraces was supplemented by mapping using aerial photographs.

The longitudinal terrace profiles were drawn for each terrace indentified on each of the four traverses when a sufficient number of control points were available and the base of bluff elevations (y axis) were plotted against distance (x axis) on graph paper. Morphological evidence was used to classify each altitude reading according to the terrace level to which it belongs. Since there is a scatter of elevation points on each graph, straight-line regressions for

Plate 31 400-foot terrace bluff one mile northeast of Morrison Island showing the difficulty in determining the base of the bluff for altitude measurement (436765).

one variable (elevation) were constructed for each group of altitude data. Such a statistical analysis assumes that in this case there is a uniform and constant increase in terrace elevation per unit distance. The straight-line regressions provide an estimate of the longitudinal terrace slope and permit a comparison of profiles between each different terrace in the same area and the same terrace in different areas. In order that the profiles should be directly comparable for distance, the distance scale is given in miles downstream from a line drawn at right angles to the Ottawa River at Petawawa Point.

3. Longitudinal Profiles and Terrace Morphology

Before the regression lines for the longitudinal terrace profiles can be analysed, it is necessary to discuss the limitations of this statistical representation as applied to the study area. Because of the fragmentary development of some of the terraces, the number of altitude observations is below the minimum for statistical significance (Gregory,1963) and considerable extrapolation is required to correlate widely separated portions of the same terrace. However, the construction of regression lines is the only method by which this data can be represented, although a minimum of eight observations was deemed necessary to permit a reasonably accurate construction of the profiles. The elevation data is limited by the degree to which the surveying barometer can be read accurately, 3 to

4 feet, which is less than the maximum longitudinal slope per mile of any of the terraces. Finally, the effects of bedrock control upon terrace morphology are such that any measurements of altitude taken in areas where bedrock outcrops at or near the surface may not be comparable to those taken where the terrace has been cut in thick surficial materials. Where measurements have been obtained for a particular terrace on the downstream side of a hard rock barrier, as for example near Morrison Island or Chapeau, such readings may tend to steepen the regression line for that terrace profile. When all these factors are considered, however, there appears to be a more than reasonable correlation of terrace levels based on their profiles for each of the four areas studied (Fig.22, p.156; Fig. 23, p.157; Fig.24, p.158; Fig.25, p.159).

Although four terrace levels have been identified in the study area (designated as Low, Main, Upper and High Level Terraces), only on the north shore of Allumette Lake are all four terraces developed to a greater or lesser degree. The Main Terrace (400-foot) is generally absent on Chenal de la Culbute and the High Level Terrace (450-foot) is absent on the south shore of Allumette Lake.

<u>The Low Terrace ca. 365 and 375 feet</u>

(Fig.22, p.156; Fig.23, p.157; Fig.24, p.158; Fig.33, p.187)

The Low Terrace can be traced throughout much of the length of Allumette Lake and the south shore of Chenal de la Culbute. In the former area, the terrace is often over 200 yards in width, tending to narrow in the vicinity of Pembroke

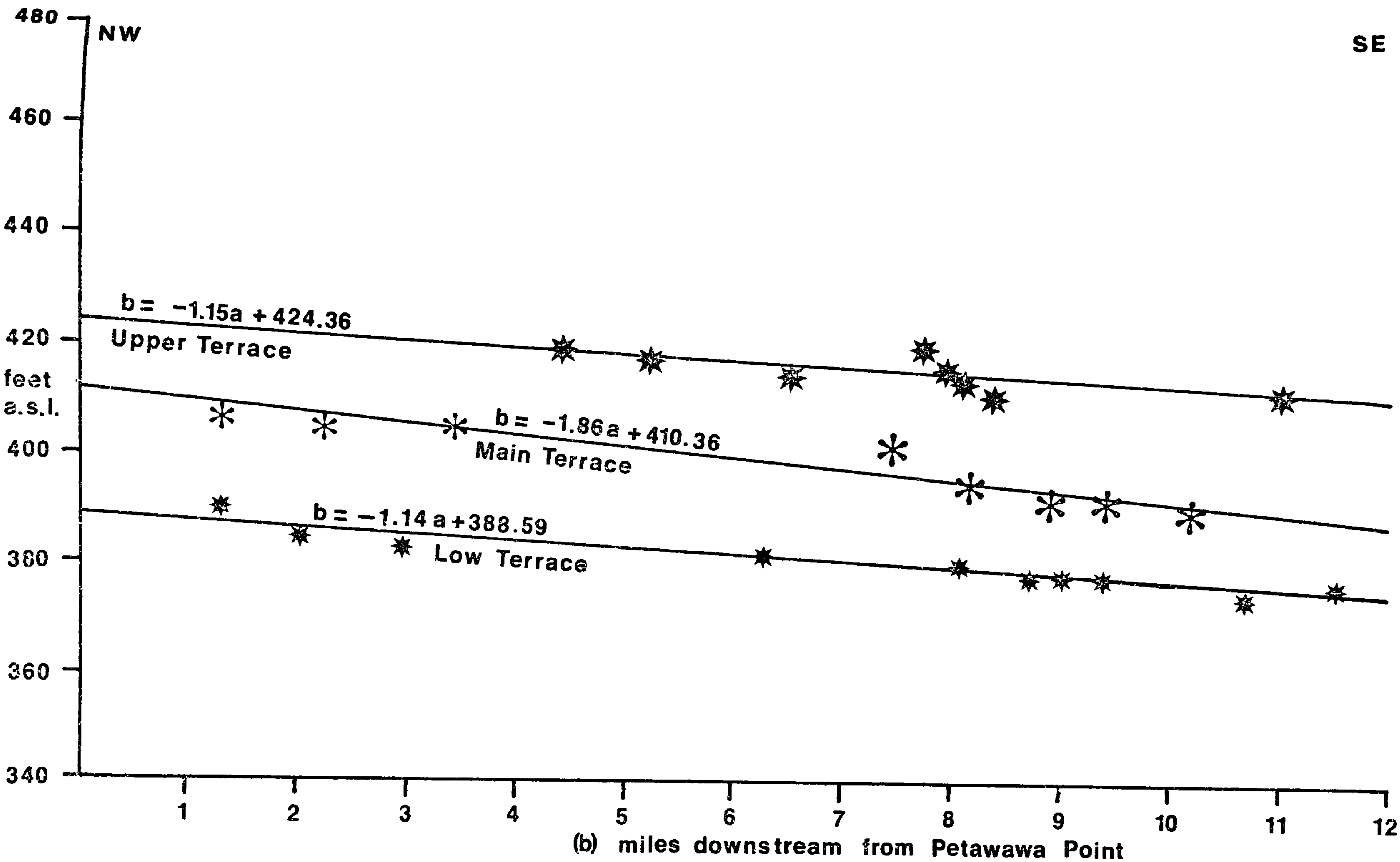


Fig.22 Longitudinal Terrace Profiles of the South Shore of Allumette Lake.

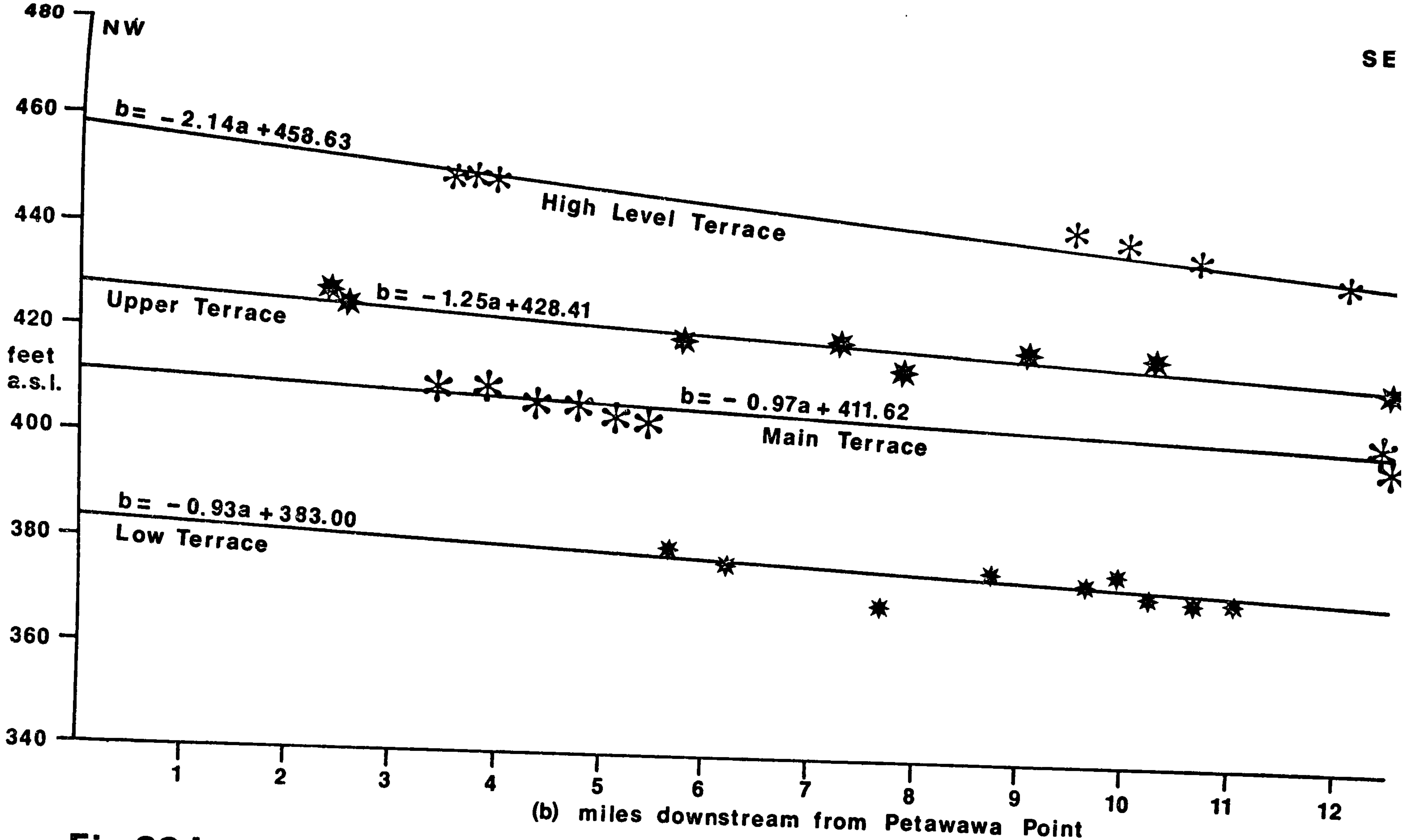


Fig.23 Longitudinal Terrace Profiles of the North Shore of Allumette Lake.

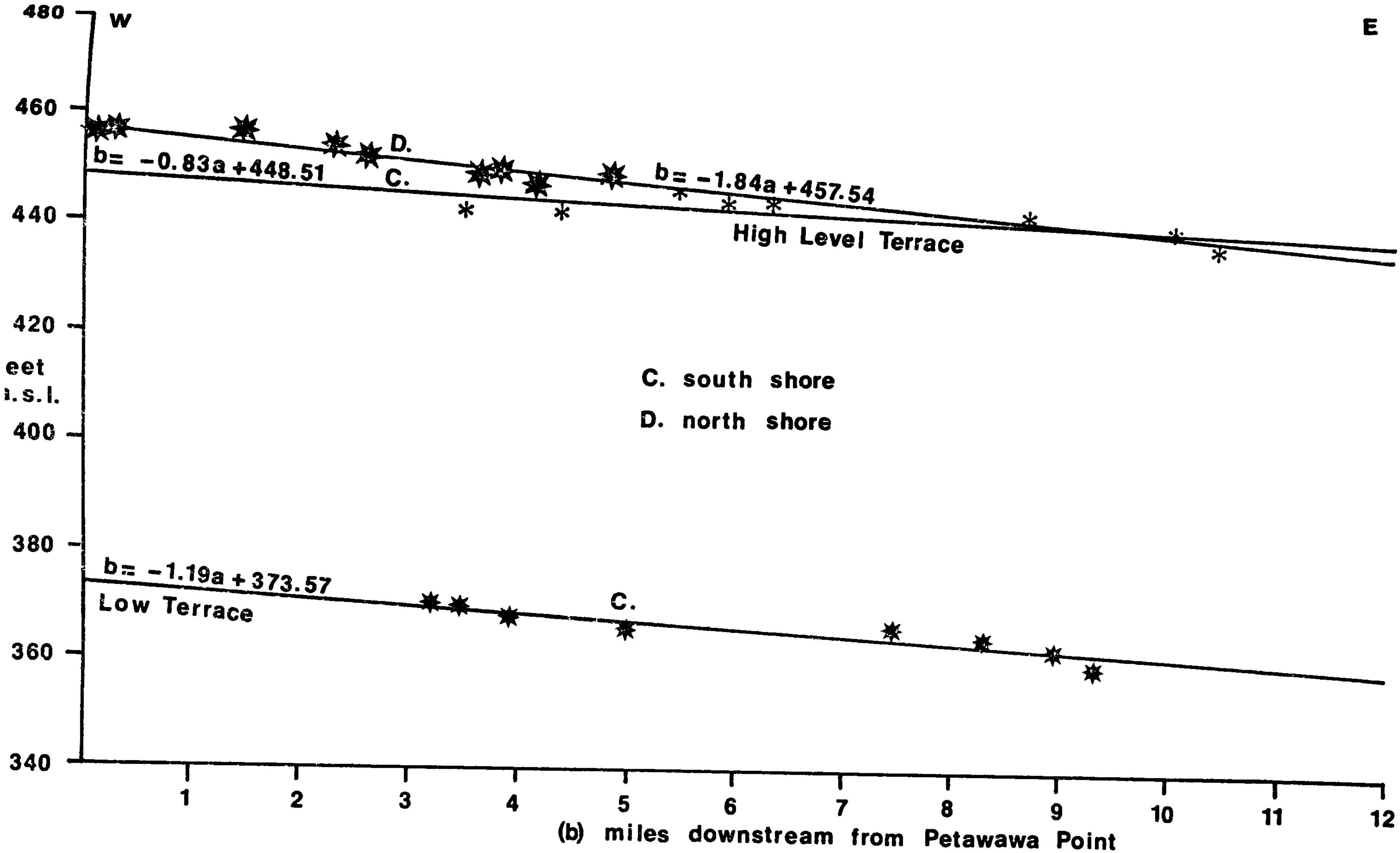


Fig.24 Longitudinal Terrace Profiles of Chenal de la Culbute.

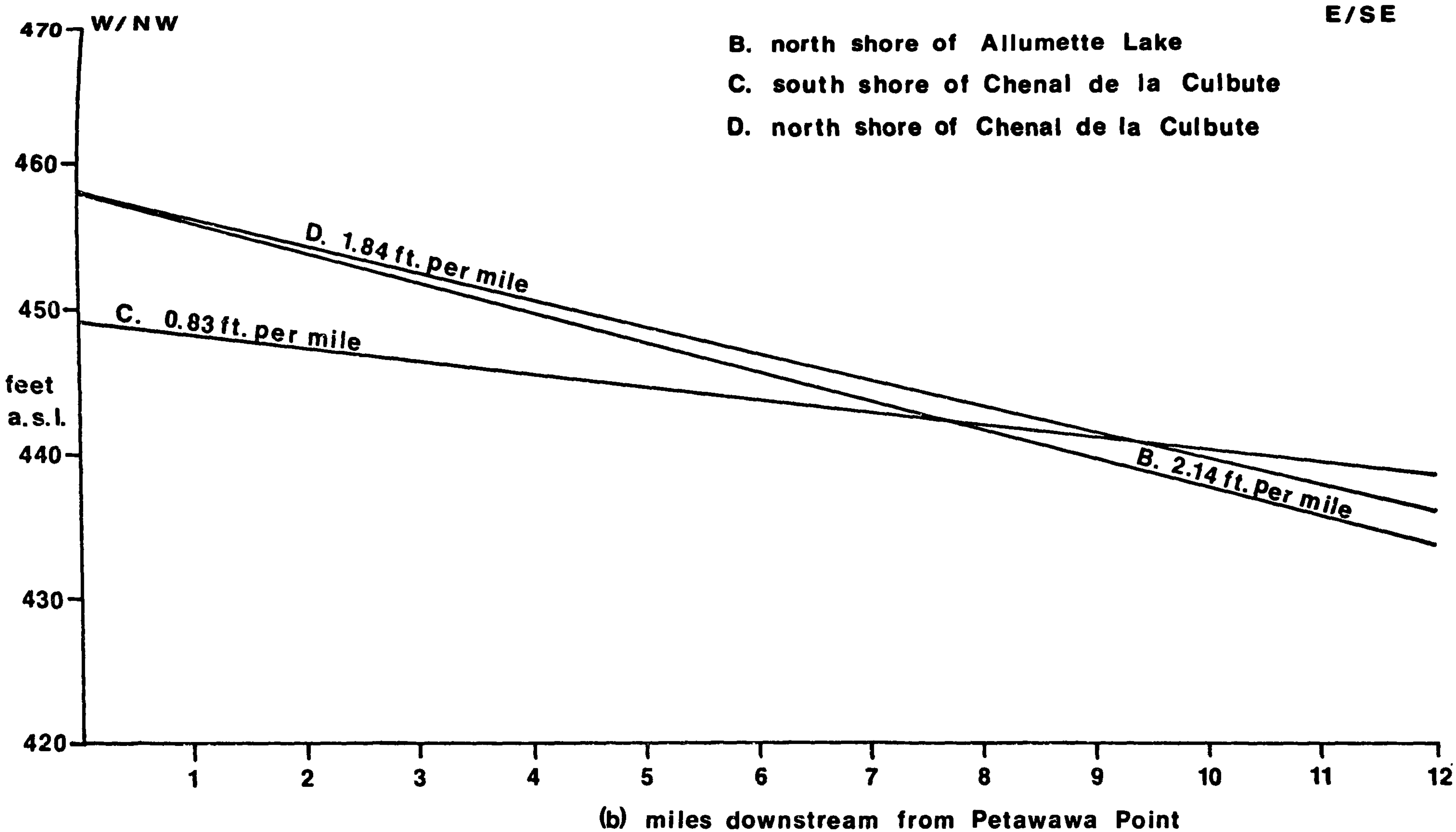


Fig.25 Comparison of Longitudinal Profiles of the High Level Terrace.

and Dejardinsville, whereas in the latter it is generally less than 50 yards in width. Northwest of Hales Creek and southeast of Cotnam Island on the south shore of Allumette Lake, however, the bluff of the Low Terrace is discontinuous and indistinct due to the influence of bedrock which outcrops at or near the surface at this elevation (Plate 32, p.161). On the north shore of Chenal de la Culbute, the terrace is only poorly-developed, a reflection of the fact that the bedrock surface is higher here than on the south shore.

The Low Terrace on Allumette Lake has an average elevation of 375 feet in contrast to that on Chenal de la Culbute where it is 365 feet. Rather than representing separate drainage stages, this difference in elevation can be explained by the location of Allumette and Culbute/Islet Rapids in relation to the 375 and 365-foot terraces respectively. The major (present-day) fall in water level along Chenal de la Culbute (approximately 15 feet) is accomplished at the Culbute and Islet Rapids at the western end of the channel, whereas along Allumette Lake there is no comparable fall until the Allumette Rapids some 11 miles further east. Since an abandoned channel related to the 365-foot terrace south of the Culbute Rapids is partially floored by bedrock, it can be envisaged that the presence of rapids in the past was the cause of the differences in elevation of the Low Terrace.

The profiles of the Low Terrace on the north and south shores of Allumette Lake show a close agreement in both average

Plate 32 Indistinct bluff of the Low Terrace (375-foot) near Petawawa Point with bedrock near the surface (279819).

elevation (375 and 380 feet, respectively) and longitudinal slope (0.93 and 1.14 feet per mile, respectively) (Fig.22, p.156; Fig.23, p.157). The small difference in elevation is probably due in part to observational error rather than an actual height contrast since the majority of observations on the south shore were made in the built-up area of Pembroke. A further contrast which may partly account for the difference is that the terrace is generally narrower with a steeped transverse slope on the south shore. Downstream of Pembroke, on both sides of the river, the Low Terrace abruptly ends in the vicinity of Morrison and Cotnam Islands where it is replaced by a broad, bedrock platform which extends to the bluff of the Main Terrace.

Although the profile of the Low Terrace on Chenal de la Culbute (Fig.24, p.158) is nearly parallel to those of Allumette Lake (Fig.22, p.156; Fig.23, p.157), the longitudinal slope is probably slightly less in reality because the regression line is steepened by the observation points downstream of the bedrock constriction at Chapeau where the terrace slope locally increases. There is no evidence from the profiles to suggest any tilting of the Low Terrace.

<u>The Main Terrace ca. 400 feet</u>
(Fig.22, p. 156; Fig.23, p.157; Fig.32, p.184)

The major contrast in the terrace sequence between Allumette Lake and Chenal de la Culbute is the presence of a well-developed 400-foot terrace in the former area and its

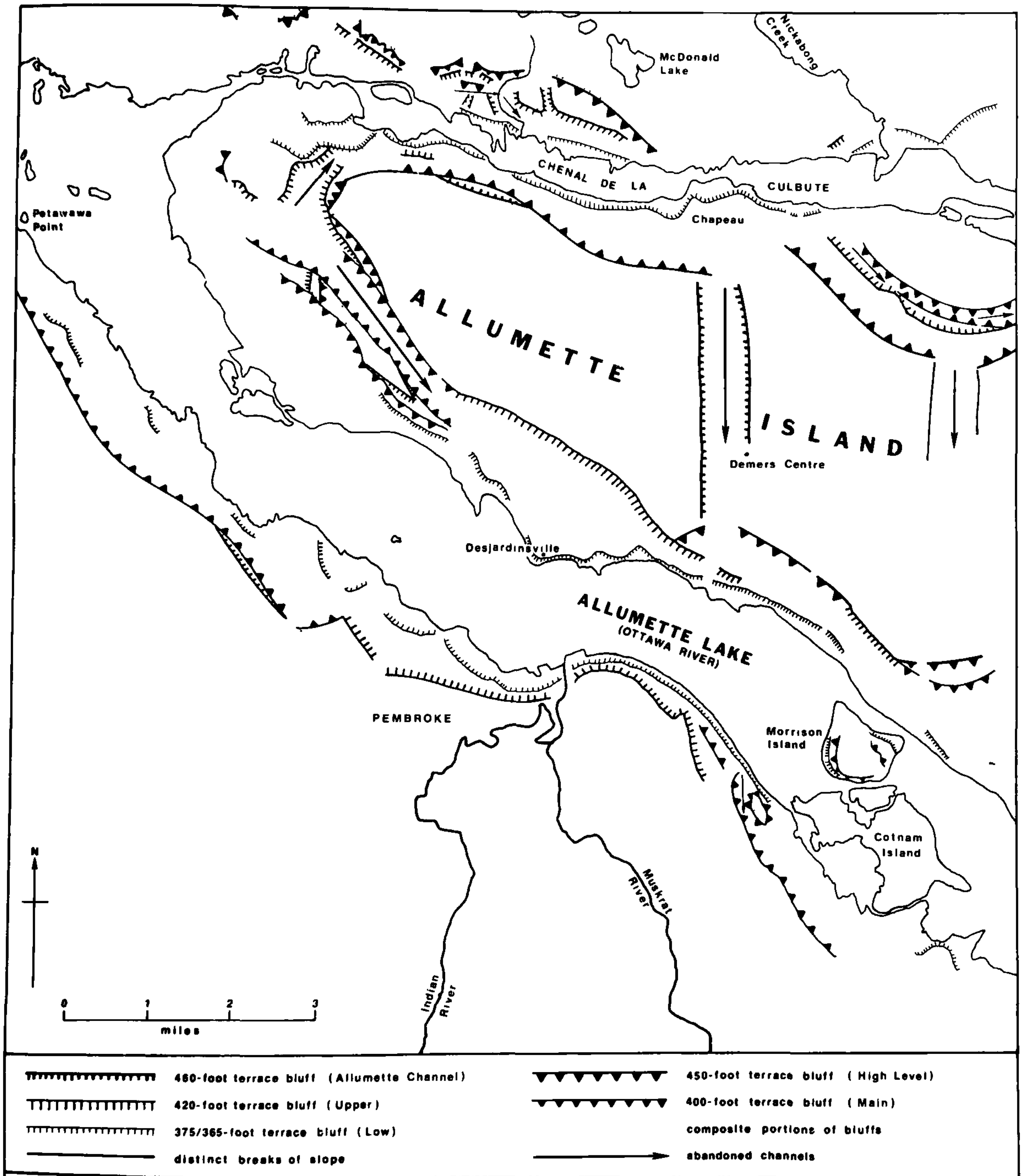


Fig.26 River Terraces of the Study Area.

absence in the latter. With the exception of a small abandoned channel west of Chichester at an elevation of 408 feet and another at 380 feet south of the Plains, the terrace sequence on the south shore west of Chapeau is characteristised by a steep, high (60 to 80 feet) bluff separating the narrow 365-foot terrace from the High Level, and locally Upper, Terraces. On the north shore, bedrock becomes important in area of outcrop at this elevation (400 feet).

A combination of several factors probably explains the absence of the Main Terrace on Chenal de la Culbute. It may have been at this stage in the drainage development that the rock barrier at Culbute began to exert an influence on water levels in Chenal de la Culbute. The appearance of the rock barrier would act as a local base level in Chenal de la Culbute. As a result, the river in Chenal de la Culbute would undergo a phase of incision unrelated to the base level of the main stream in Allumette Lake. Evidence for the separation of drainage development at this stage and not earlier, related to different base levels, is provided by a comparison of the longitudinal profiles of the terraces above 400 feet which are comparable in elevation and slope for both Allumette Lake and Chenal de la Culbute. Alternatively, the 400-foot terrace could have been destroyed by undercutting during the subsequent 365-foot stage, a process more likely to occur where the channel is constricted as in the case of Chenal de la Culbute.

The Main Terrace on Allumette Lake is by far the most distinct topographical feature of the area. Over one mile in width on western Allumette Island and near Petawawa Point, the terrace is backed by a 50 to 70-foot high bluff cut into the Petawawa sand plain (Plates 33 and 34, p.166). This bluff, in fact, may not be related to the 400-foot terrace alone because remnants of higher terrace levels are found above the major bluff. Although the major bluff was formed by downcutting during several (lowering) water levels, the river channel shifted locally abandoning portions of the bluff. This is illustrated in Fig.27 (p.167) where a small area of the High Level Terrace (450-foot) is preserved above the Main (400-foot) and Upper (420-foot) terraces. The 50-foot high bluff divides and then rejoins again downstream.

On the north shore of Allumette Lake southeast of Demers Centre, the 400-foot terrace is replaced by a gently-shelving platform of Ordovician Limestone and the terrace, as defined by a distinct bluff, does not re-appear until a point near Highway 8 north of Morrison Island.

In the vicinity of Pembroke, the major bluff above the Low Terrace is that of an earlier 420-foot terrace although the outer edge of this terrace has an elevation of approximately 400 feet. This arrangement suggests that locally the river shifted laterally while it was downcutting and did not, therefore, erode a distinct bluff. East of the Indian River at Pembroke, however, the highest bluff was formed during the

Plate 33 Bluff of the Main Terrace (400-foot) at Petawawa Point (249855: Petawawa sheet).

Plate 34 Main Terrace (400 foot) near Petawawa Point (277818).

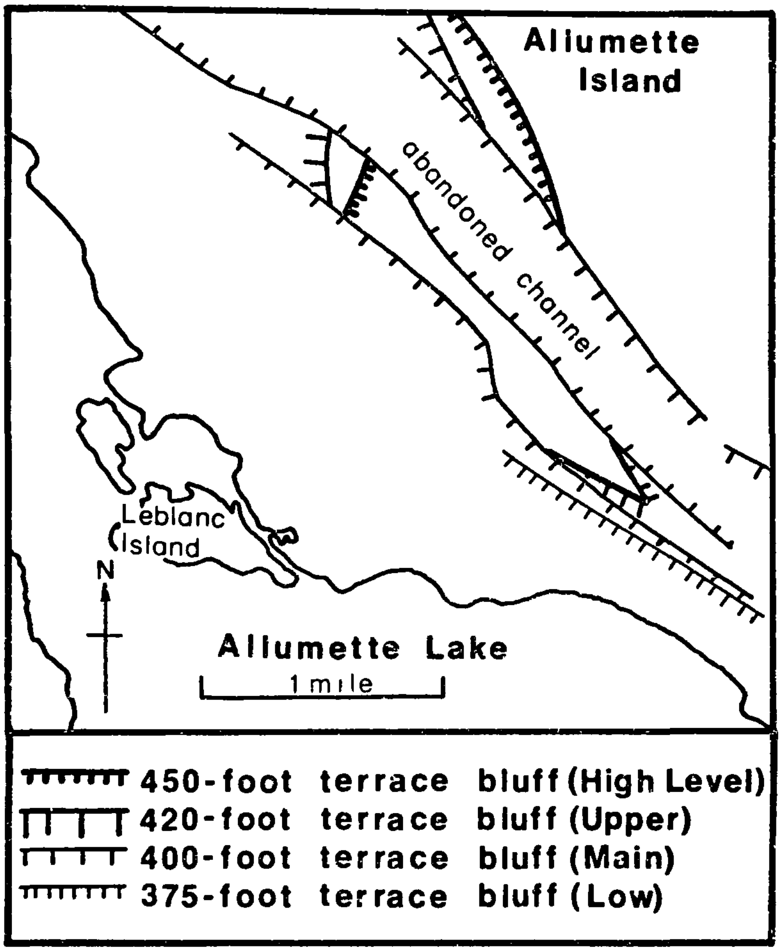


Fig. 27 Terrace Bluff Patterns on Western Allumette Island.

420-foot stage and further downcutting at the same site occurred during the subsequent 400-foot stage. Several miles further east, this bluff divides separating the 400-foot terrace from the 420-foot terrace.

A comparison of the regression lines for the 400-foot terrace on the north and south shores of Allumette Lake reveals no apparent relationship; the longitudinal slope of the terrace on the north shore is only one half of that on the south shore (0.97 vs. 1.86 feet per mile) and the total difference in elevation at the eastern end of the profile is 15 feet. To account for this anomaly, it is necessary to comment on the validity of the data. The regression line for the south shore profile was constructed from the minimum number (8) of observations, many of which were taken in the urban areas of Pembroke. Nevertheless, if the pattern of terraces and bluffs near Cotnam Island is closely studied, an adequate explanation of this problem is forthcoming (Fig.28, p.169).

In this area, the inner edge of the 400-foot terrace is represented by an indistinct bluff, less than 10 feet high, which trends parallel to Highway 17 and separates a narrow segment of the 400-foot terrace from the 420-foot terrace (above) and the 375-foot terrace (below). Near Cotnam Island, the bluffs of the 400-foot and 420-foot terraces are replaced by another bluff locally trending at 45 degrees to the Ottawa River. The elevations obtained at the base of

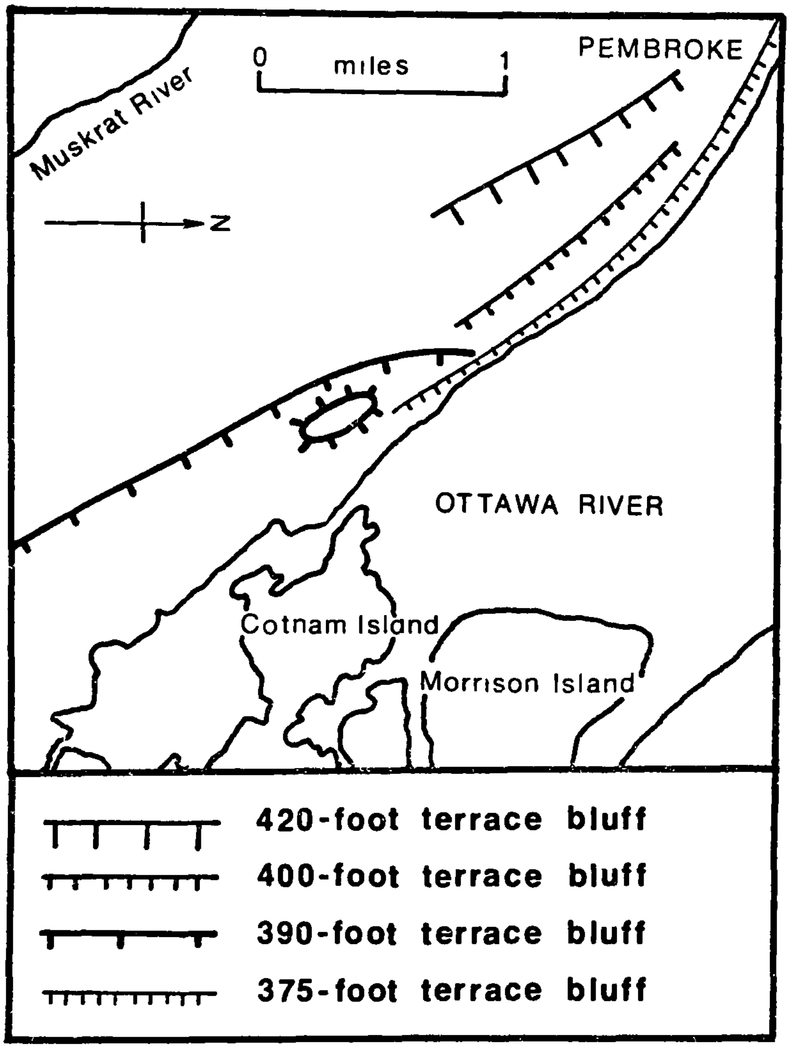


Fig.28 Terrace Bluff Patterns Near Cotnam Island.

this bluff, which can be traced for several miles to the southeast, vary between 395 and 390 feet. It would appear that this is a separate terrace which was formed when the river shifted laterally from the 400-foot level west of Cotnam Island but which re-curved inland a few miles to the southeast. The bluff presently demarkating the Low Terrace in this area was first eroded during this higher 390-foot stage. Thus, if the elevations taken from the terrace downstream of Cotnam Island are ignored, the profile of the 400-foot terrace would not be so steep and would approximate that of the same terrace on the north shore of Allumette Lake. Unfortunately, there is no evidence of a 390-foot terrace elsewhere in the study area.

The Upper Terrace ca. 420 feet

(Fig.22, p.156; Fig.23, p.157; Fig.31, p.181)

In contrast to the Low and Main Terraces, the Upper Terrace is only locally developed along Allumette Lake and Chenal de la Culbute. On the south shore of Allumette Lake, the terrace is generally narrow, less than 300 yards in width, and located above the 400-foot terrace near Hales Creek and in Pembroke west of Indian River. Elsewhere, the evidence of this terrace has been removed by undercutting during the subsequent 400-foot stage. The same process accounts for its poor development on the north shore of Allumette Lake where it is often difficult to distinguish between this terrace level and the 400-foot terrace. Northeast of Dejardinsville, for example, the base of bluff elevations are approximately 420 feet but the terrace slopes transversely from this elevation to 400 feet at its outer edge at the top of the 375-foot terrace bluff. Further west, however, portions of the 420-foot terrace are preserved on the flanks of an abandoned island and are separated from the 400-foot terrace by a distinct bluff, (Fig.27, p.167).

The 420-foot terrace is particularly significant since it provides the only link between the drainage evolution of Chenal de la Culbute and Allumette Lake. One mile south of Culbute Look, an abandoned channel at an elevation of 420 feet, which joins western Allumette Island with Chenal de la Culbute, can be traced into the 420-foot terrace on the south shore of Chenal de la Culbute. The abandonment of this channel and the separation of the drainage development of Chenal de la Culbute and Allumette Lake occurred at this stage when bedrock became exposed at the surface; the abandoned channel is floored by bedrock with a thin veneer of bouldery till.

The longitudinal profiles for the 420-foot terrace on the north and south shores of Allumette Lake compare favourably (Fig.22, p.156, Fig.23, p.157). The terrace on the north shore is slightly higher and is marginally steeper in long profile.

This may indicate a slight amount of warping from north to south or northeast to southwest. In this respect, the terraces on either side of Allumette Lake are sufficiently far apart (up to 3 miles) to reflect any isostatic uplift. With the accuracy of the present data, especially the limited number of observation points, such a conclusion has to be treated with caution although the trends of the regression lines, which tend to "iron out" anomalies, are highly suggestive.

<u>The High Level Terrace ca. 450 feet</u>

(Fig.23, p.157; Fig.24, p.158; Fig.25, p.159; Fig.30, p.179)

The High Level Terrace is particularly well-developed along Chenal de la Culbute where it is backed by a steep bluff up to 50 feet high cut into the Petawawa sand plain (Plate 35). On the north shore of Allumette Lake, however, much of this terrace was destroyed by undercutting during the later stages of the drainage development. The only significant portion of the terrace to survive is located southwest and southeast of Demers Centre where the bluff, though parallel to that of the 420 and 400-foot terraces, is offset approximately one half mile inland; this factor may account for its preservation. Further west, the same contiguous bluff may represent the shoreline of this stage (i.e. downcutting continued without a change in the location of the river channel) or the bluff may be the result of later undercutting after the channel had changed its location. In either case, the end product is the same; a steep, high bluff with a terrace of varying elevation at its base. The remarkable planate surface of an abandoned island at an elevation of 450 feet west of Desjardinsville is an isolated remnant of this terrace,

Plate 35 High Level Terrace (450-foot) on the south shore of Chenal de la Culbute one mile west of Chapeau (377854).

(Plate 36, p.185).

The absence of an equivalent of the 450-foot terrace on the south shore of Allumette Lake poses a particular problem. It is possible that the terrace has been destroyed by later erosion; the top surface elevations of the 400 and 420-foot terrace bluffs west of Hales Creek, which are remarkably uniform at 470 feet, indicate that the river at this high-level stage did not flow further inland and that the bluff may have been initially formed during the 450-foot stage. Further east, near Pembroke, the morphological evidence, though obscure, suggests that, at the 450-foot stage, the Proto-Ottawa River took a course to the south via the Muskrat River Valley. Two pieces of evidence concur with this suggestion. First, above the 420-foot terrace southwest of Pembroke, the northern flank of a prominent kame has been sharply truncated, an indication that it has been undercut by fluvial erosion. Secondly, the present-day Muskrat River is a misfit stream in a broad, flat valley which, in places, is marked by a distinct bluff at an elevation of 430 feet. The elevation of this valley is in reasonable agreement with that of the 450-foot terrace north of Allumette Lake at a similar distance downstream

The longitudinal profiles of the 450-foot terrace compare favourably in the case of the north shore of Allumette Lake and the north shore of Chenal de la Culbute but not in the case of the south shore of Chenal de la Culbute (Fig.25, p.154), A consultation of Fig.24 (p.158) reveals that the profile on the south of Chenal de la Culbute is flattened by two observations at the upper end of the regression line. If these two points, which were taken from an isolated terrace remnant of a possible meander scar formed at a slightly lower water level, are ignored then the regression line would be steepened sufficiently to be comparable with the other profiles. The profiles for Allumette Lake (north shore) and Chenal de la Culbute (north shore) are particularly interesting in that they diverge in a downstream direction. This reflects the fact that the terraces themselves become farther apart downstream such that the effect of isostatic uplift, which appears to be indicated by the profiles, is increasingly felt as the distance between the two terraces increases.

There are remnants of a higher terrace at 460 feet on the south shore of Chenal de la Culbute which is related to a north-south abandoned channel on Allumette Island (Fig. 26, p. 163). As there are no traces of a higher terrace on the north shore of Chenal de la Culbute, it can be assumed that either the evidence has been removed by erosion or, more likely, that downcutting was uninterrupted until the 450-foot terrace was abandoned (i.e. the bluff of the 450-foot stage on the north shore is composite in nature).

4. <u>The Stages of Drainage Development</u>

The height of a particular terrace only gives the elevation to which downcutting was effective in response to a given base level. It does not provide an accurate indication of the actual water level at the time the terrace was being formed. The top surface elevations of the terrace bluff which show a reasonable continuity in altitude and orientation provide a more accurate estimate of the water level. A step-like arrangement of terraces, however, provides the best information but such a single pattern is to be found at only a few localities in the study area.

The correlation of terrace remnants, extrapolation of the trends of terrace bluffs and the use of generalised contours permit the compilation of a series of maps for the major stages of drainage development in the study area. Each stage is defined according to the elevation of the terrace to which it is related.

<u>460-foot Stage</u> (Fig.29, p.177)

Fluvial erosion commenced when the top surface of Allumette Island appeared above sea level (at this time approximately 475 feet). At this time a broad, shallow channel was cut through the centre of Allumette Island trending north-south between Chapeau and Demers Centre. This (now) abandoned channel is floored with a thin layer of stratified, alluvial sand and silty sand which rests upon an eroded surface of Petawawa sand. The confining bluffs of the channel are low (less than 15 feet high) and indistinct having been modified by wind erosion. Remnants of a terrace at an elevation of 460 feet on the south shore of Chenal de la Culbute are probably related to this channel (Fig.26, p.163). On the

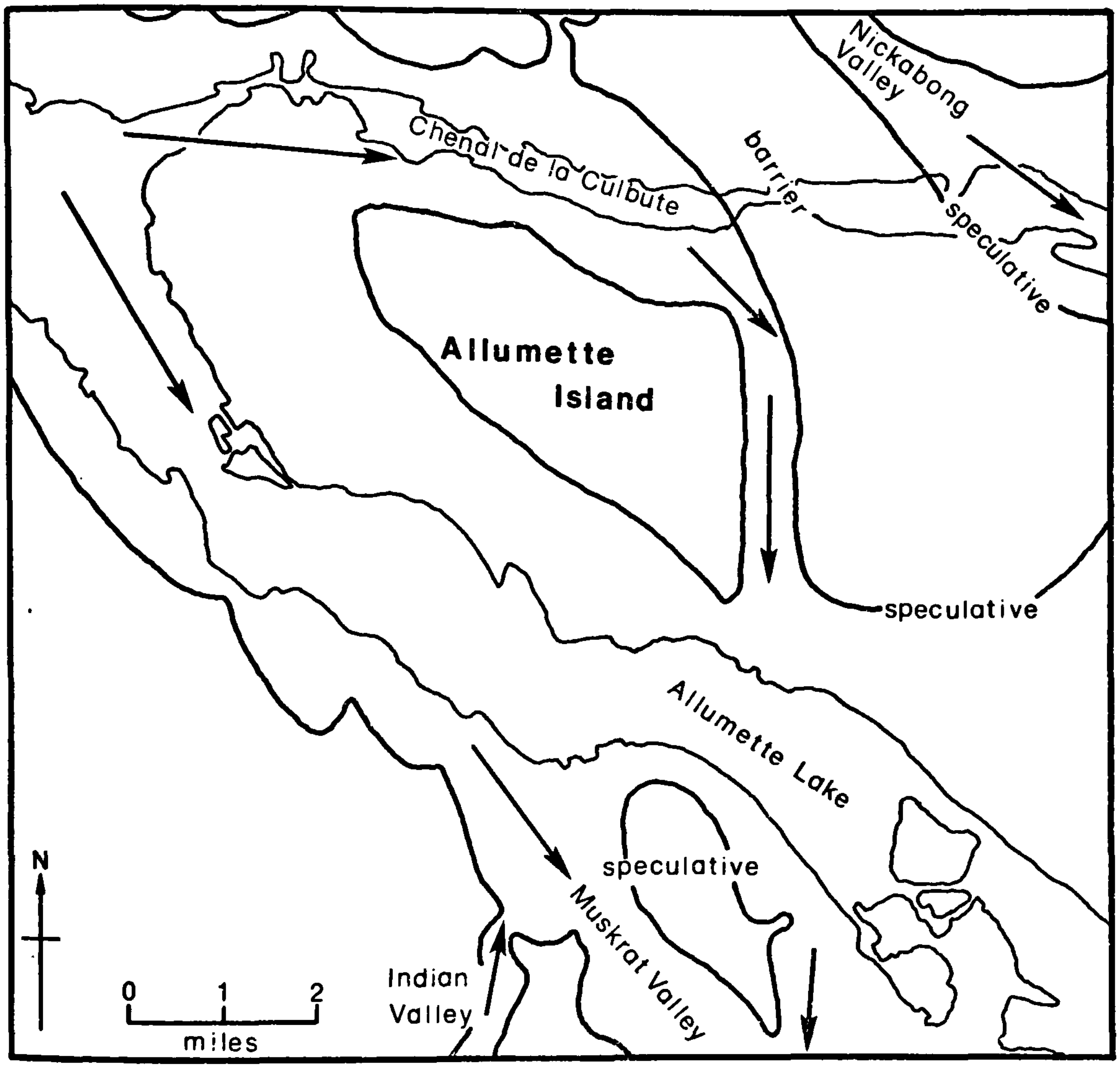


Fig. 29 460-Foot Stage (Allumette Channel).

north shore of Chenal de la Culbute, the upper portion of the 75-foot high bluff, which trends northwest-southwest from Chichester towards Chapeau, was probably eroded at this stage.

The orientations of this bluff and the abandoned channel on Allumette Island suggest that water flowing down Chenal de la Culbute was deflected southwards at Chapeau to join the mainstream opposite Pembroke. The barrier at Chapeau was probably created by a thick body of fluvial glacial gravels deposited in the form of an outwash delta. The presence of similar gravels on the south shore of Chenal de la Culbute suggests that the body was more extensive such that it could cause deflection of the river at this time.

The precise extent of Allumette Island at this stage is not known because, with the exception of the above evidence, distinct terraces and bluffs above 450 feet are absent. Consequently, the shoreline of this stage has been drawn just above, and parallel with, the present-day 475-foot contour, which includes some stretches, but not the total length, of the top surface of the highest bluff of Allumette Island. The course of the river on the south shore of Allumette is highly speculative because of considerable subsequent erosion by Hales Creek and the Indian and Muskrat Rivers.

<u>450-foot Stage</u> (Fig. 30, p. 179)

With only a small amount of downcutting (approximately 10 feet), the barrier north of Chapeau was breached and the channel on Allumette Island was abandoned. Although a broad

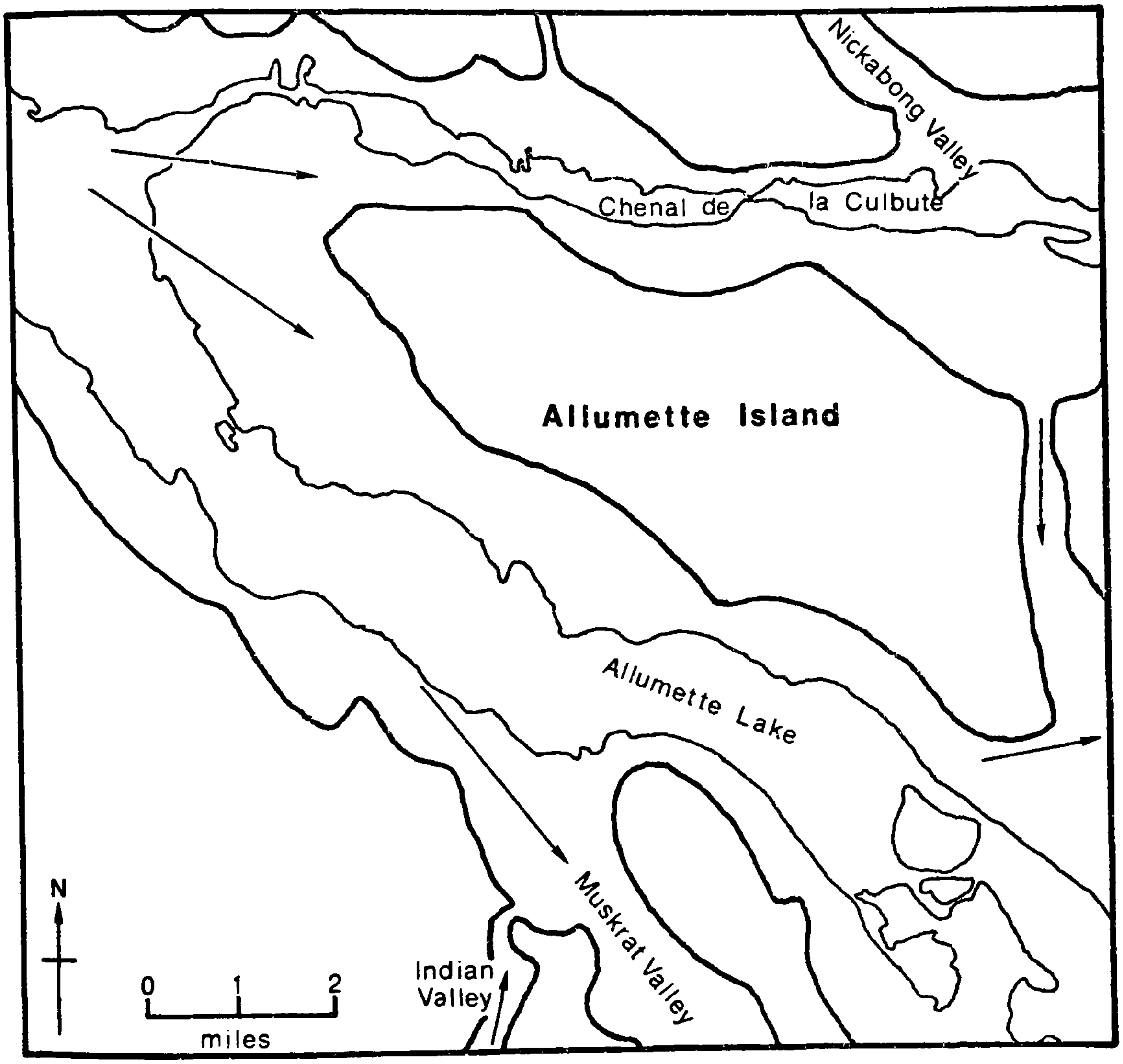


Fig.30 450-Foot Stage (High Level Terrace).

terrace (450-foot) was cut south and west of Chapeau, on the north shore opposite the village no terrace is present and it appears that the frontal edge of the outwash feature was only steepened. East of Chapeau, the river followed a course to the south of the Plains and for a time was diverted towards the mainstream east of Morrison Island. This abandoned channel lies 10 feet above the 450-foot terrace in this area and is marked by two distinct breaks of slope, rather than by well-developed bluffs.

During the 450-foot stage the major confining bluff of Allumette Island was eroded (Fig.26, p.163). This bluff, which lies between one-half and one mile inland from the present shore, varies in height from 20 - 65 feet. The terrace at its base, however, was formed during several different water levels and only small segments of the 450-foot terrace remain.

The course of the Proto-Ottawa River on the south shore of Allumette Lake is again speculative although the Muskrat River valley was the most likely route for the river at this stage (see p.174). It can be seen that at this stage the Ottawa River was over three miles wide in places with a discharge probably in excess of 10 times that of the present river.

<u>420-foot Stage</u> (Fig.31, p.181)

The shoreline during the formation of the Upper Terrace was not significantly different from that of the preceeding 450-foot stage. There was no significant lateral movement of the river channel on the north shore of Allumette Lake

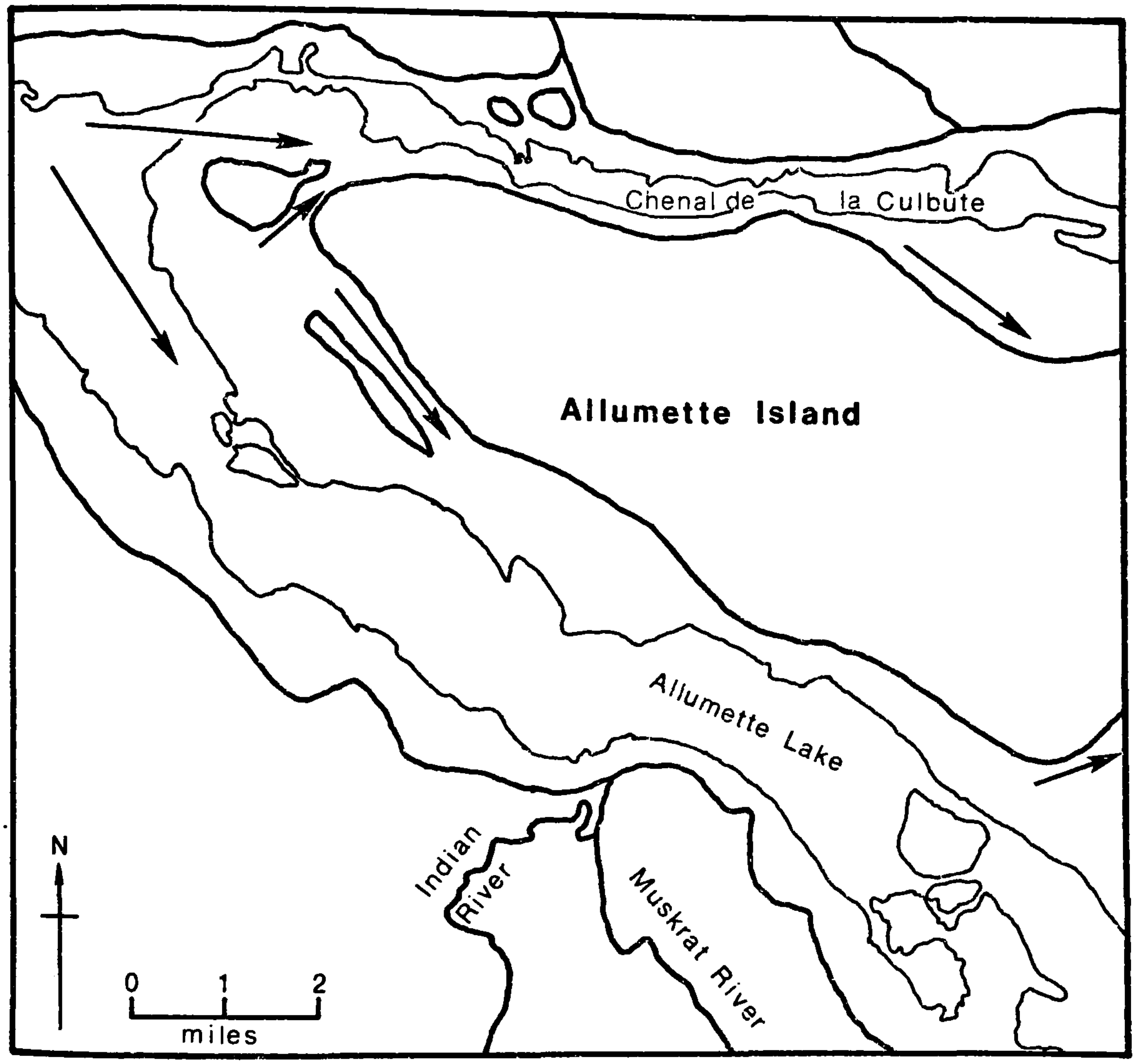


Fig. 31 420-Foot Stage (Upper Terrace).

except locally southeast of Demers Centre where the bluff of the High Level Terrace was abandoned. Further west, however, the same contiguous bluff was not abandoned and downcutting proceeded at the same site as the earlier 450-foot shoreline thus forming a composite bluff. On the south shore of Allumette Lake, the Muskrat Valley route was abandoned and a distinct bluff was cut parallel to the present river in the vicinity of Pembroke. Further east, near Cotnam Island a prominent bluff, which trends parallel to Highway 17 for several miles, was initially eroded at this time although the terrace at its base was not abandoned until the water level had dropped below 400 feet.

On western Allumette Island, two small islands appeared which are now separated from the central portion of the island by two abandoned channels. One of these islands, which joined the mainstream to Chenal de la Culbute, was abandoned before the formation of the subsequent Main Terrace because bedrock appeared at the surface at this elevation and did not permit further downcutting.

There is a distinct contrast in the morphology of the Upper Terrace between the south and north shores of Chenal de la Culbute. On the north shore, between Chapeau and Chichester, the terrace forms a distinct flat between the High Level Terrace (above) and the Low Terrace (below). West of Chapeau, on the south shore, however, the bluff of the 365-foot terrace probably marks the shoreline of the 420-foot stage because the bluff is composite and over 60 feet high in places (see p. 192). To the east of Chapeau, the river was again diverted to the south of the Plains and an arcuate bluff, parallel to that of the High Level Terrace, was formed.

400-foot stage (Fig.32, p. 184)

Further downcutting of the order of 10 to 20 feet caused the abandonment of the channel joining western Allumette Island and Chenal de la Culbute. It is probable that at this time the Culbute and Islet rapids first appeared causing the separate development of the drainage of Chenal de la Culbute and the main stream of the Proto-Ottawa River (see p.164).

Along Allumette Lake portions of the 420-foot terrace bluff were abandoned as the river channel shifted laterally but without cutting a new bluff related to the lower water level. On both sides of the river northwest of MacGregor Bay, however, a broad terrace was eroded without any significant lateral shift in the channel and the island on western Allumette Island became larger (Plates 36 and 37, p.185).

Northeast of Morrison Island the river took an oblique course across southeastern Allumette Island (outside the study area) via a channel (now abandoned), a route similar to that followed by the river during the 420 and 450-foot stages.

The course of the river in Chenal de la Culbute is speculative because of the general absence of the 400-foot terrace. Here, it would appear that downcutting was uninterrupted from the 420 to 365-foot stages, whilst a broad terrace was cut along

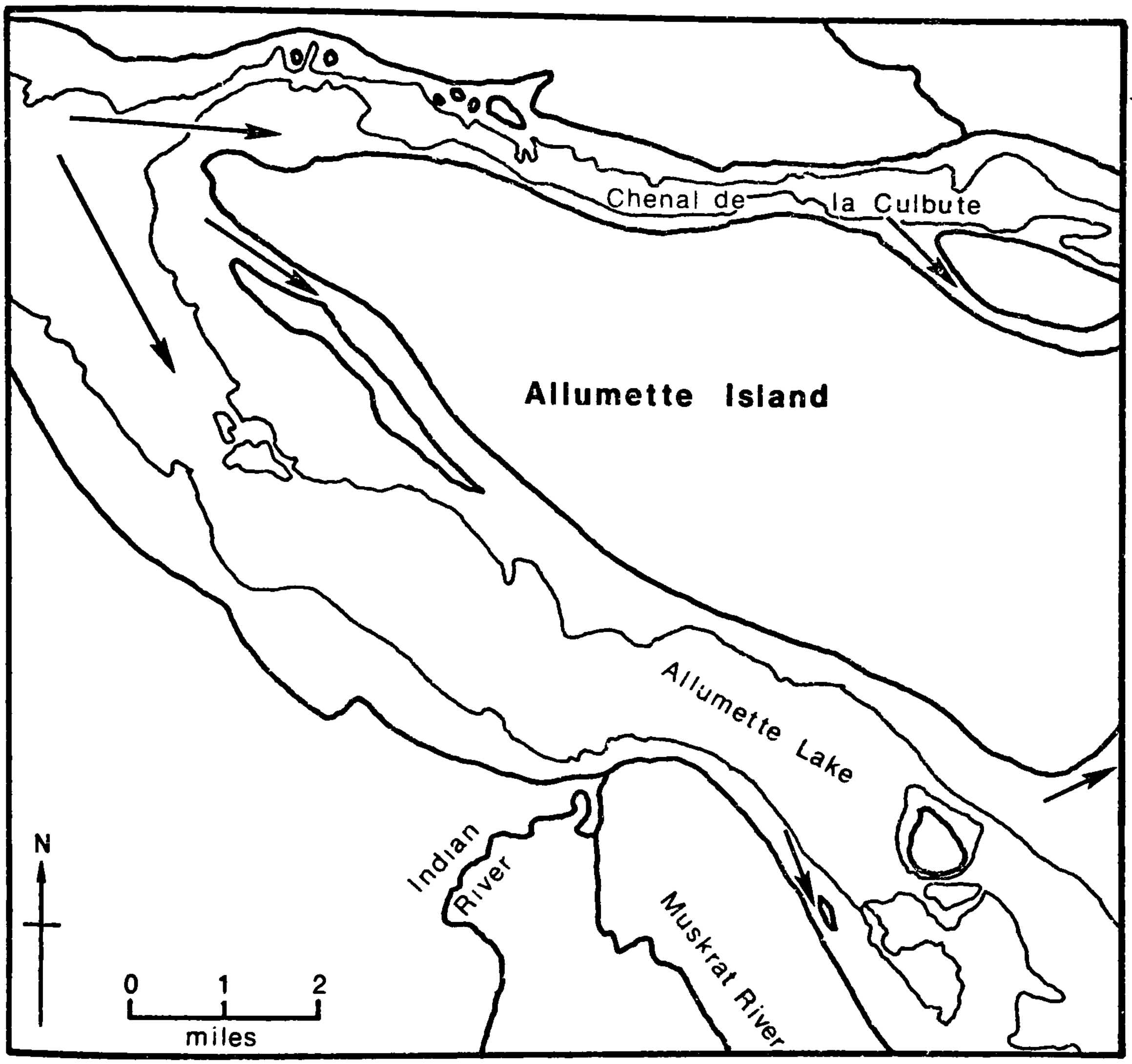


Fig. 32 400-Foot Stage (Main Terrace).

Plate 36 Bluff of the Main Terrace (400-foot) with remnant of High Level Terrace (450-foot) above on western Allumette Island (319633).

Plate 37 Abandoned channel of Main Terrace (400-foot) on western Allumette Island (330823).

parts of Allumette Lake. The irregular bedrock surface on the north shore of Chenal de la Culbute created a crenulated shoreline dotted by many small bedrock islands.

East of Chapeau, the presence of an abandoned channel at an elevation of 380 feet, approximately 20 feet above the Low Terrace in the area, suggests that the river was diverted to the south of the Plains, leaving the Plains as an island in Chenal de la Culbute. That the use of this channel occurred during the 400-foot stage, even though there is no evidence of a terrace at a similar elevation in Chenal de la Culbute, is suggested by its position above the Low Terrace but below the Upper Terrace, both of which are well-developed east of Chapeau.

375/365-foot Stage (Fig.33, p.187)

The presence of a well-developed terrace parallel to and generally less than 100 yards from the present river records a drastic retraction of the shoreline from the preceeding 400-foot stage. The course of the river was similar to that of the present stream with the exception of a channel south of the Culbute/Islet Rapids, which separated Allumette Island from a small island in Chenal de la Culbute, and another channel which diverted waters from the main stream across southeastern Allumette Island northeast of Morrison Island.

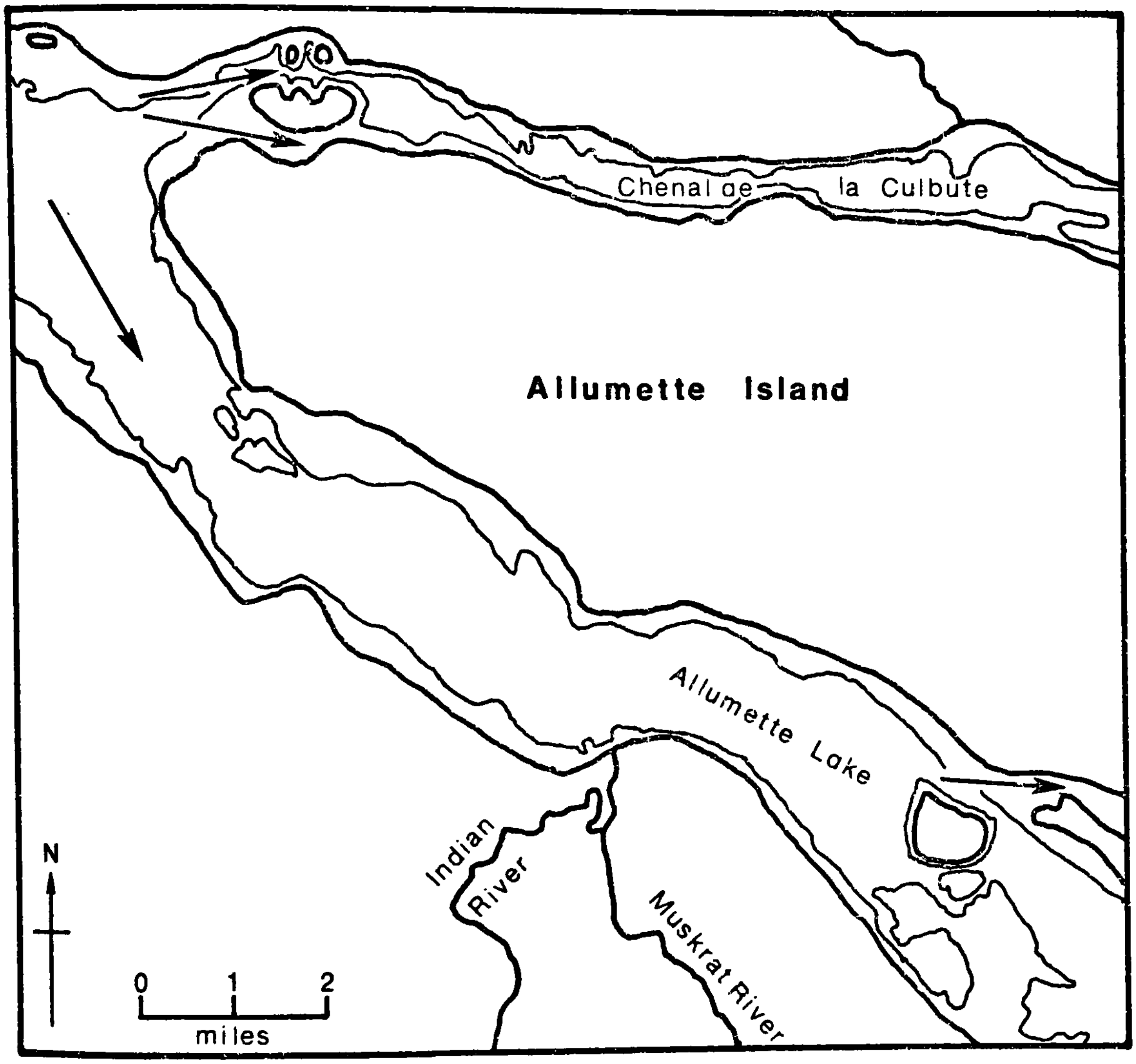


Fig. 33 375/365-Foot Stage (Low Terrace).

Between Morrison Island and Hales Creek, on both sides of Allumette Lake, the 375-foot terrace can be traced continuously with only a few breaks. West and east of this section, the terrace is only poorly-developed due to the presence of bedrock at or near the surface. Consequently, the shoreline in these areas has to be reconstructed by the extrapolation of the trends of fragmentary bluffs and by the use of generalised contours.

Because the streams in Allumette Lake and Chenal de la Culbute were probably related to separate base levels, it can be assumed that the formation of the Low Terrace in these channels, though at different elevations, was contemporaneous (see p.160).

The bluff of the 365-foot terrace on the south shore of Chenal de la Culbute, west of Chapeau, in contrast to the Low Terrace bluff elsewhere in the study area, is composite having been eroded during several different (falling) water levels (see p. 196). This is indicated by the top surface elevations of this bluff, which vary between 410 and 430 feet, and by the local absence of the 420 and 400-foot terraces.

5. Bedrock Control

The absence of thick and extensive spreads of alluvium suggests that with the withdrawal of the Champlain Sea from the study area, there was a change from a depositional to an erosional environment which has continued to the present-day.

Distinct terraces and bluffs are only developed in areas of thick, unconsolidated surficial deposits. Where the surficial overburden was initially thin, once the underlying bedrock had been exposed by fluvial erosion, a drop in water level caused a lateral displacement of the channel and the bluff (cut in the surficial materials) of the former water level was abandoned. The amount of lateral displacement would depend upon such factors as the bedrock topography and the amount of water level drop from one stage to the next. For example, the only terrace which can be traced for any distance on the north shore of Chenal de la Culbute is the High Level or 450-foot terrace because at this elevation bedrock is not generally exposed. The fragmentary development of the lower terraces gives an indication of the height of the bedrock topography and the (locally) thin surficial over-burden.

Another example of the influence of bedrock is indicated by the apparently anomalous height readings, which range from 402 to 442 feet, taken along the base of the highest bluff on the north shore of Allumette Lake. West of Morrison Island, the highest bluff was abandoned at the 420-foot stage when bedrock appeared at the surface. The terrace and bluff sequence in this area below 420 feet is replaced by a gently-shelving platform of Ordovician limestone with a discontinuous veneer of washed till and the terraces do not reappear again until downstream of the Allumette Rapids (Plate 38 p.190). Further west, however, the same contiguous bluff

Plate 38 Washed till over bedrock on the Upper Terrace (420-foot) on the north shore of Allumette Lake near Morrison Island (423768).

was not abandoned until the water level had fallen below an elevation of 400 feet. Here, downcutting was not curtailed because the bedrock was buried by a thick overburden of surficial sediments. On the north shore of Chenal de la Culbute, the irregular nature of the bedrock topography, in the form of protuberances at right angles to the river at the 450-foot stage, locally caused the deflection of the river channel producing a series of arcuate terrace bluffs in the overlying surficial sediments which resemble meander scars.

The present-day channel of the Ottawa River between Petawawa and its confluence with the St. Lawrence is characterised by a series of lake-like expansions separated by rapids where hard rock barriers cross the river. In the study area, there are three stretches of rapids which act as local base levels of erosion for the present stream: The Allumette Rapids at Morrison Island, and the L'Islet and Culbute (westernmost) Rapids at the western end of Chenal de la Culbute. In addition, there is a minor bedrock constriction of Chenal de la Culbute at Chapeau. Depending upon the time at which these rock barriers first exerted an influence on the drainage development, it can be envisaged that, like the present longitudinal profile of the river, part of the terrace profiles will show a local steepening in the vicinity of the rock barriers such that there are essentially two separate segments of the profile above and below the rock barriers.

Insofar as this affects the interpretation of the regression lines drawn from those control points taken astride the Allumette Rapids and the constriction at Chapeau, the regression lines may not, in fact, conform to reality. This is certainly true on the south shore of Chenal de la Culbute where the 365-foot terrace steepens more rapidly in the vicinity of Chapeau. The 400-foot terrace north of Morrison Island likewise shows a small increase in longitudinal slope.

It can be concluded, therefore, that bedrock topography is one of the most important controls of terrace morphology in the study area.

6. Composite Bluffs

A step-like arrangement of terraces gives an indication of a particular water level from which the various stages of the Proto-Ottawa River can be determined. Such a pattern is not common throughout the study area and consequently considerable extrapolation is involved in the reconstruction of the various drainage stages from fragmentary bluffs and terraces. This difficulty, although partly explained by the presence of bedrock, can be accounted for by the fact that, in the study area, the terrace sequence is characterised by composite bluffs which have been formed during several stages of downcutting by the river. Thus, although the top of the bluff in a given area may record the highest water level, the terrace at its base represents the maximum downcutting of the river at a later stage. This process probably accounts for the 75-foot high terrace bluffs found along the shores of Allumette Lake west of Pembroke (Plates 33 and 34, p.166). and locally north of Chichester on Chenal de la Culbute. Only if there was a significant lateral movement in the river channel upon a renewed phase of incision would portions of the higher terraces be preserved. It is important to note here that, from a study of the terrace elevations and the patterns of their associated bluffs, there was no significant retraction of the shoreline in many areas until the water level had fallen to below 400 feet. Except in areas of bedrock control, the terrace bluffs for long stretches are remarkably straight, a feature which supports the above observations and which precludes the possibility of meandering on a large scale.

7. Isostatic Uplift

Although the terrace elevation data is limited in its scope, the longitudinal profiles of the 420 and 450-foot terraces may indicate a slight degree of isostatic tilting such that the northern terrace in each case is somewhat higher. Assuming uplift was north to south, (i.e. the isobases trend east to west), then the amount of tilt for the 450-foot terrace is approximately 0.4 feet per mile (Fig.25, p.159). This compares with a maximum tilt of 1.5 feet per mile of the Rigaud Shoreline (200 feet) in the lower Ottawa Valley (Macpherson, 1967); this is the highest fluvial terrace and the only one which has been warped. If the isobases were to trend northeast-southwest, for example, the effects of any isostatic uplift would be to steepen the longitudinal profiles of the terraces rather than effect a north-south difference in elevation.

8. Radiocarbon Chronology

Several radiocarbon dates from the study area and adjacent areas provide an approximate chronology for the stages of the drainage development. Near Chalk River, an abandoned channel cut into the Petawawa sand plain at an elevation of 500 feet has been dated at 9,540 years B.P. (GSC-177) from gyttja at the base of a bog. This date establishes a minimum age for the withdrawal of the Champlain Sea and the commencement of fluvial dissection of the Petawawa sand plain of which Allumette Island is a part. The abandoned channel on Allumette Island (see p. 176) at an elevation of 460 feet, which provides the highest morphological evidence of fluvial erosion in the study area, may therefore be of a similar age.

Archaeological evidence with associated radiocarbon dates may help in the elucidation of the terrace sequence. Two archaeological sites, investigated by Kennedy (1970) on Morrison Island at an elevation of 426 feet and Allumette Island at 397 feet have been dated at 4,750 years B.P. (GSC-162; from charcoal) and 5,240 years B.P. (S-509; from human bone) respectively. Since these sites were obviously above the water level of the time and probably adjacent to the ancient river (the Indians used dugout canoes for fishing and transportation), the radiocarbon date for Allumette Island, at least establishes a minimum age for the formation and abandonment of the 400-foot (Main) terrace and a maximum age for the cutting of the 375-foot (Low) terrace. The latter assumption depends for its validity upon the premise that water still covered the area below the archaeological site. It can further be assumed that the formation of the 420 and 450-foot terraces were formed during the interval of time bracketed by the dates 9,540 years B.P. and 4,750 years B.P. respectively.

9. Fluctuations in Discharge

In any analyses of the terrace morphology, the effects of fluctuations in discharge of the Proto-Ottawa River have to be considered. The Upper Great Lakes drained through the Ottawa Valley via the Fossmill and North Bay-Mattawa channels and the waters of Glacial Lake Barlow-Ojibway for a time supplemented this discharge. The time ranges for these events are 11,200 to 6,000 years B.P. and 9,500 to 7,500 years B.P. respectively (Prest, 1970). In the study area, there was a considerable retraction in the shoreline when the water level had fallen to 400 feet. This probably reflects a drastic decrease in discharge at this time; the minimum date for the abandonment of the 400-foot terrace of 5,240 years B.P. is in broad agreement with the date for the termination of the North Bay-Mattawa discharge (6,000 years B.P.) such that a causal relationship may be suggested. In the lower Ottawa Valley, the Rigaud Shoreline (200 feet), which is the highest river terrace in the area, has been assigned an age of 8,500 years B.P. and is believed to have been formed when Glacial Lake Barlow-Ojibway drained through the Ottawa Valley (Brown, 1962; Macpherson, 1967). If an age of 6,000 years B.P. is a reasonable assumption for the 400-foot terrace, then either the 420-foot or 450-foot terraces, or both, may be related to the Lake Barlow-Ojibway discharge.

10. Conclusion

The terrace sequence of the study area is the result of a fine balance between several environmental conditions: Isostatic uplift, discharge fluctuations and bedrock topography. The effects of any fluctuations in river load during post-glacial time are more difficult to determine. There is no stratigraphical evidence to suggest successive periods of downcutting and aggradation as has been reported from the Ottawa area (Lemenestrel, 1969). Rather, the terraces of this part of the valley demonstrate several periods of erosion related to successively lower base levels. This is in accord with Mackay (1949a,49b) who suggested that following the regression of the Champlain Sea in the Ottawa Valley, the Proto-Ottawa River dissected the Petawawa sand plains and transported some of the sediments downstream, depositing them at successively lower elevations.

CONCLUSION

The late-Quaternary history of the study area is compressed into a relatively short period of geologic time. By 11,500 years B.P. the late-Wisconsin ice sheet had probably retreated to beyond the Pembroke area and marine waters had submerged most of the study area.

A study of the glacial landforms, south of Chenal de la Culbute, does not provide any definite information on the pattern of ice retreat in this part of the Ottawa Valley. This is to be expected because these landforms have been modified by wave action or buried beneath later marine sediments. Near the marine limit (approximately 540 feet), and locally, for example at Pembroke West and Government Road, fluvio-glacial deposits were an important source of sediment for the nearshore sands and gravels of the Champlain Sea.

In the northern portion of the study area, in Chichester Township, however, there is evidence that deglaciation and the Champlain Sea transgression were, in part, contemporaneous. The morphology and stratigraphy of the large body of outwash opposite Chapeau can best be explained by the hypothesis of deposition in the Champlain Sea in the form of an outwash delta. Although this outwash delta is localised in extent and cannot be easily linked to other glacial landforms in Chichester and Sheen Townships, it would appear that during the deposition of the outwash delta, the ice front was located between Chenal de la Culbute and the Shield escarpment. The presence of several large kettles in the outwash, and in the Nickabong sand plain, suggests that the ice stagnated in Chichester Township. To conclude that the outwash delta marks a major halt of the ice sheet in the Ottawa Valley (Antev's "Pembroke Halt") would be pure speculation, given the evidence of the present study and without investigation of other large glacial features to the east of the study area. Near the boundary of Sheen and Chichester Townships, the Indian Point moraine, which can be traced northeastwards from the Fort William boom to a point near Sheenboro, represents a subsequent halt in the ice sheet. A second outwash body, two miles west of Nickabong Village, may be part of the Indian Point moraine.

The Champlain Sea transgression probably followed the retreating ice sheet in the Upper Ottawa Valley and the sea could not reach its northwestern limit until the ice had retreated from the Indian Point position. Since marine clay rests unconformably upon either till, fluvio-glacial gravels or bedrock, it is apparent that there was an early deep water phase of the sea immediately following the retreat of the ice sheet. Near the marine limit, west and southwest of Pembroke, and on the flanks of the higher glacial features, beds of silty clay interdigitate with nearshore sands and gravels. This relationship has also been found in areas to the east of the study area in Renfrew and Lanark counties (Quinn, 1952) and in the Ottawa area (Gadd, 1961). An interesting feature of the Champlain Sea stratigraphy of the study area is the large extent of marine clay and the relatively limited extent of littoral sediments (nearshore sands and gravels) and, in addition, the notable absence of marine strandlines. These characteristics would appear to indicate that relatively still water conditions existed for a period of time during the early stages of the Champlain Sea such that wave action was relatively ineffective. Undoubtedly, this was the result of the narrow width of the marine embayment in this part of the Upper Ottawa Valley.

The influx of large volumes of fresh water from the Fossmill outlet into the marine embayment was heralded in the stratigraphic sequence by the transition from fossiliferous marine clay to unfossiliferous laminated silts. There was probably a changeover from brackish water conditions (suitable for a limited marine fauna east of Pembroke) to fresh water conditions, which was accompanied by an increase in the calibre of material reaching the marine embayment.

The deposition of the Petawawa deltaic sands terminated the true-marine phase of the Champlain Sea episode in the study area. A major characteristic of these sands is the remarkable uniformity in grain-size and bedding over both large areas and through great thicknesses. No thick bodies of gravels, such as those reported from the Petawawa River Valley (Gadd, 1963a),were found within the Petawawa sands.. That the sands are deltaic in origin is not readily indicated by their structural characteristics; thick foreset beds and horizontal topset beds are not revealed in any exposures in the study area. In some exposures, cross-bedding can be distinguished, but in many exposures the sands are found in thick, uniform, horizontal beds. The topographic expression of these sands, however, is indicative of deltaic sedimentation. Where the sands have not been dissected by subsequent fluvial erosion, they form a remarkably flat plain diversified by dunes in places, at elevations between 460 and 520 feet. The increase in elevation of the sand plain from 460 feet on eastern Allumette Island to 520 feet near the Petawawa River is probably a reflection of both the initial slope of the delta surface and subsequent isostatic uplift. The most eastern extent of the Petawawa sands is outside the study area, probably located in the Westneath peninsula. It is evident that not all the volume of deltaic sands was derived from the same source (i.e. the Fossmill system). The Indian River Valley, which probably served as a subsidiary route of the Fossmill system, conveyed large volumes of sand into the Champlain Sea. Some of the sands of the Nickabong sand plain and the Nickabong Valley were undoubtedly derived from streams issuing from the Shield escarpment.

In summary, there are three contrasting facies of the Champlain Sea in the study area: (1) deepwater (clay and laminated silts); (2) littoral (nearshore sands and gravels), and (3) deltaic (Petawawa sands). To the west of the study area, north of the Petawawa River, the Champlain Sea episode is only represented by the deltaic facies. This can probably be accounted for by the fact that ice still occupied the valley until a fairly late stage of the Champlain Sea and that when the area became ice-free the Fossmill system came into operation. In the Ottawa area, however, Gadd (1961) has identified four types of Champlain Sea sediments: beach gravels, shingle beach deposits, shallow water sands (sea floor sediments), and deep water marine clay. Thus, from a comparison of the three areas (Chalk River, Pembroke, and Ottawa), it can be seen that the stratigraphy of the study area is transitional in nature between Chalk River and Ottawa. In the study area an early deep water phase of the sea, in which wave action was generally ineffective, was terminated by the deposition of deltaic sands.

Since the Champlain Sea episode in the study area was never more than brackish, the transition from marine to fluvial conditions was essentially a change from a depositional to an erosional environment rather than a decrease in salinity. The two radiocarbon dates which bracket this event are 10,870 years B.P. (GSC-90) and 9,540 years B.P. (GSC-177) (see p.194). The marine/fluvial transition must have occurred when the water level stood at an elevation somewhat above 460 feet, the elevation of the highest identifiable terrace remnant. Below this elevation four major paired river terraces were eroded at successively lower elevations. A study of the longitudinal profiles of these terraces revealed that the 450-foot (High

Level) and 420-foot (Upper) terraces had experienced a small degree of isostatic tilting, indicating that isostatic uplift continued well into post-glacial time. When the water level had fallen to approximately 400 feet, there was a major retraction of the shoreline. This probably occurred between 6,000 and 5,000 years B.P. as a result of the termination of the Upper Great Lakes drainage via the North Bay-Mattawa outlet which caused a drastic decrease in discharge of the Proto-Ottawa River. Since the formation of the Low Terrace, there has been a further retraction of the shoreline. The modern Ottawa River, in contrast to the Proto-Ottawa River, is flowing over bedrock throughout most of its course.

The present-day modification of the landscape is restricted to small gully erosion and river bank erosion. Runoff was probably greater in the past as is evidenced by the presence of several dry valleys which dissect the terrace bluffs. Despite the presence of large areas of marine clay, no flow slides, which are characteristic of the marine clay plains of the Ottawa-St. Lawrence Lowlands, were observed in the study area.

A consideration of the problems revealed in this study has suggested several lines of investigation for future research which may further elucidate the glacial and post-glacial history of the Upper Ottawa Valley. The area between the north shore of the Ottawa River and the Shield escarpment, notably Waltham Township, contains several large outwash bodies which may have a similar origin to that described in Chichester Township. The study of these features would provide valuable information on the relationship between glacial and marine events. A study of the stratigraphy and morphology of the terraces of the Indian, Petawawa and Barron River Valleys could shed further light upon the history of the Fossmill outlet. A comprehensive investigation of marine strandlines west of Ottawa, with a view to the construction of uplift isobases, would fill a considerable gap in Champlain Sea history. Finally, river terrace studies, employing palynological and radiocarbon data would permit the correlation of river terraces in widely separated parts of the valley.

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LEGEND

QUATERNARY

WISCONSIN AND RECENT

Recent Sediments

7 Bog deposits: peat and muck; includes small areas of alluvium

6 Terrace alluvium: medium to fine, pale yellow to buff sand, silty sand and silt; non-calcareous and non-fossiliferous, includes small areas of gravel

Marine Sediments

5 Petawawa sands: medium to very fine, pale yellow to buff sand; non-calcareous and non-fossiliferous; deltaic facies of the Champlain Sea

4 Nearshore sand and gravel: marine gravel and sand with interfingering beds of clay locally, grading into fine sand over clay offshore; moderately calcareous; fossiliferous east of Pembroke; littoral and shallow-water facies of the Champlain Sea

3 Champlain Sea clay and silt: blue-grey silty clay, grey silt and laminated silt; fossiliferous silty clay commonly grades into unfossiliferous laminated silt above; deep-water facies of the Champlain Sea

Glacial Sediments

2 Fluvio-glacial sand and gravel: outwash and ice-contact gravels with some sand in indistinct, wave-washed landforms; includes outwash deltas (glacio-marine) in Chichester Township; variable carbonate content according to local bedrock

1 Glacial till: sandy, non-calcareous till in Precambrian areas; calcareous, reddish brown clayey till in Palaeozoic limestone areas

PALAEZOIC AND PRECAMBRIAN

R Bedrock: undifferentiated, includes thin veneer of younger unconsolidated sediments

Geological boundaries (approximate) 

Fossil locality Ⓕ

Quarry ⚒

Gravel or sand pit ✕

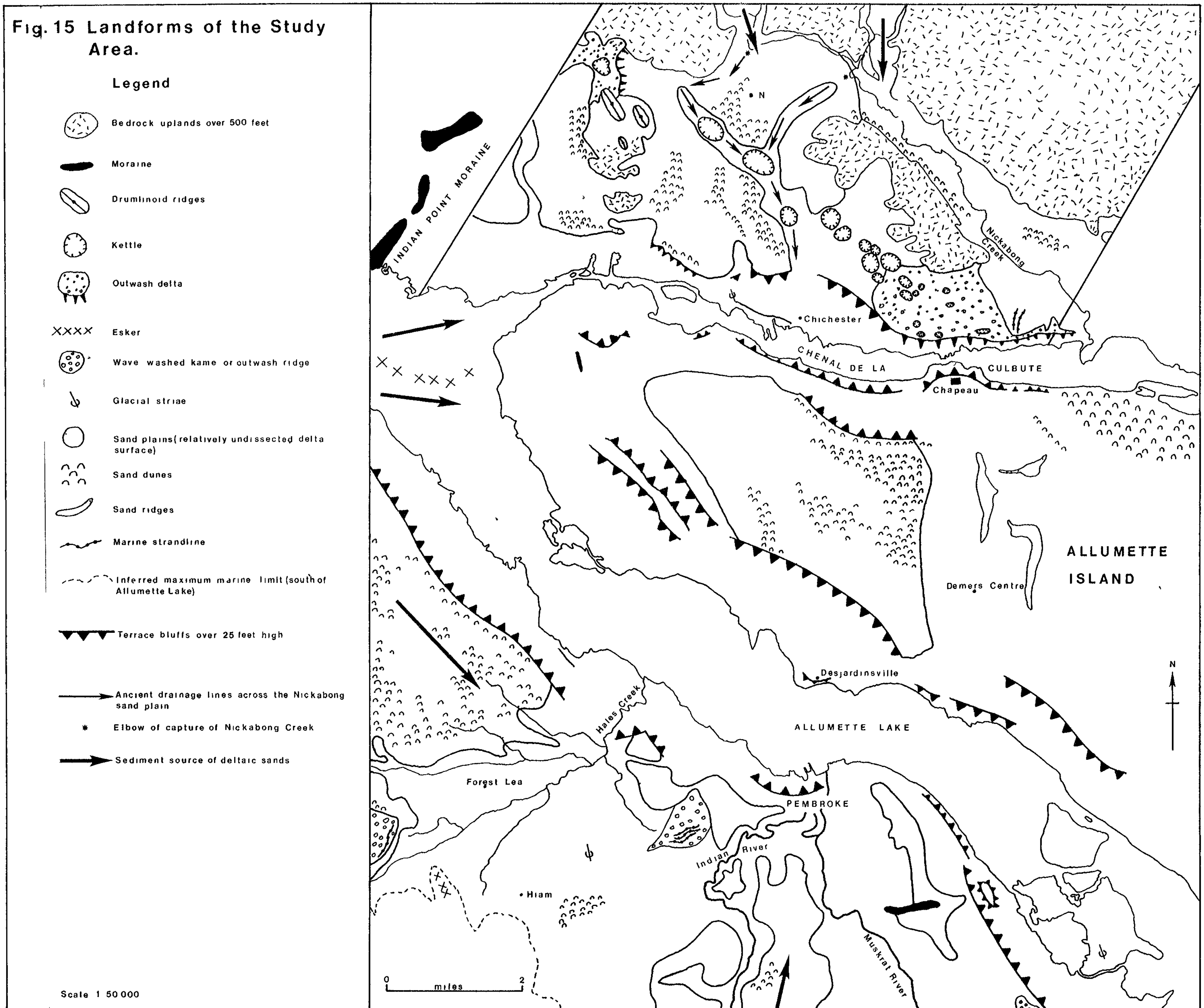
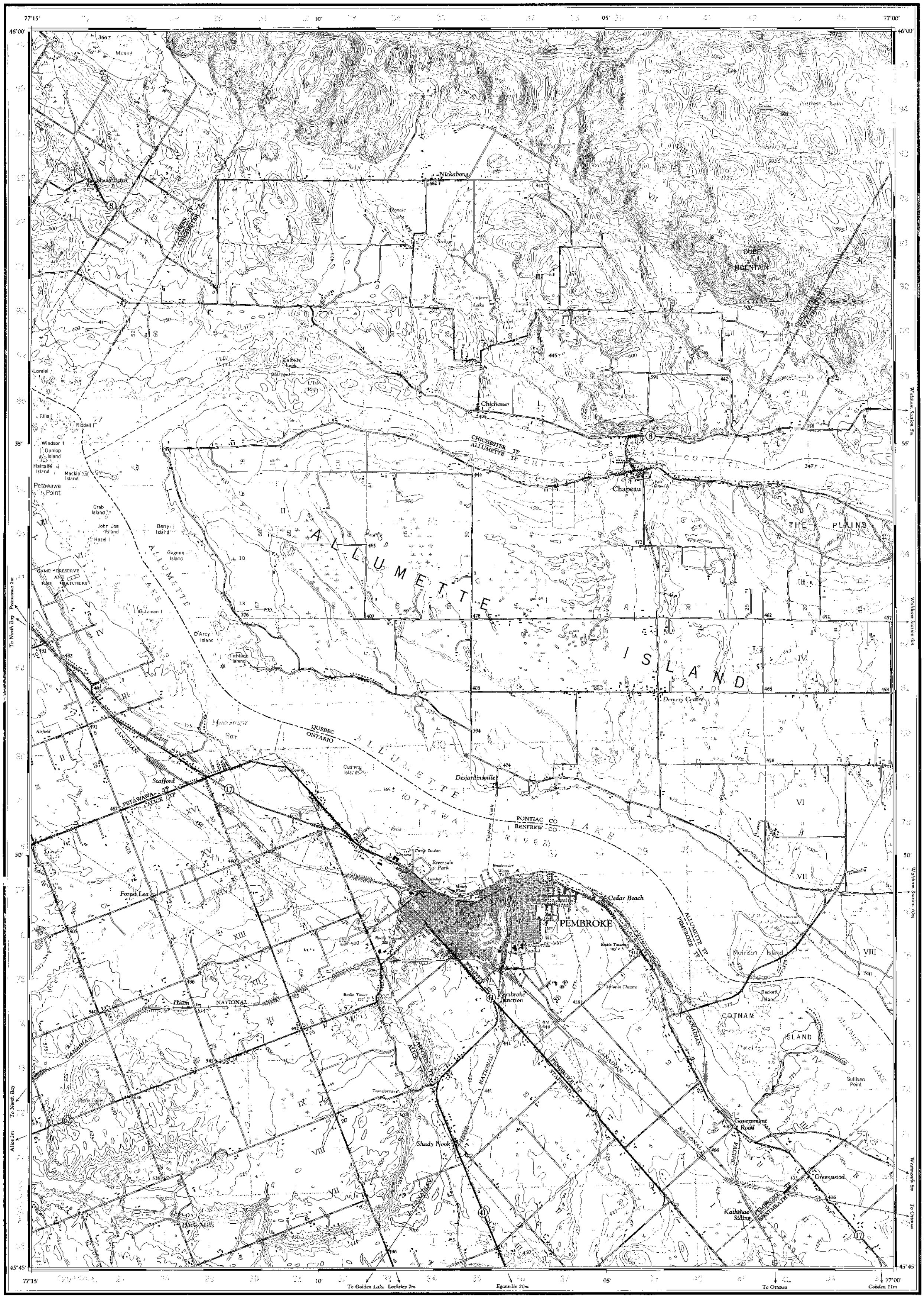


Fig. 15 Landforms of the Study Area.

NATIONAL TOPOGRAPHIC SYSTEM 1:50,000

CANADA

FOURTH EDITION SHEET 31 F/14 EAST



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Fourth edition published by the A.S.E. 1959.

PEMBROKE

ONTARIO - QUEBEC

SCALE 1:50,000

1.25 Inches to 1 Mile approximately

1 ½ 0 1 2 3 Miles

1000 500 0 1000 2000 3000 4000 Metres

1000 500 0 1000 2000 3000 4000 Yards

Copies may be obtained from the Map Distribution Office, Department of Energy, Mines and Resources, Ottawa.

CONTOUR INTERVAL 25 FEET
Elevations in Feet above Mean Sea Level

Transverse Mercator Projection
North American Datum 1927

REFERENCE

Roads:
hard surface, all weather
hard surface, all weather
loose surface, all weather
loose surface, all weather
dry weather
cart track; trail, or cut line
Railways:
normal gauge, multiple track
normal gauge, single track
abandoned or under construction
underpass, overpass
Tunnel; Drawbridge
Power line; Telephone line

Boundaries:
international, with monument
provincial
county or district
township or parish
township or parish, unsurveyed
city or town
park, reserve, etc.
Horizontal control point, with elevation
Bench mark, with elevation
Spot elevation; precise, approximate
Historical site; Cemetery
Mine or open cut; Quarry
Sand or gravel pit

REFERENCE

House; Building
School
Church; Church with spire
Post Office
Radio Station
Tower; Chimney
Well; Tank
Cutting
Embankment
Cliff
Contours:
elevation
depression
approximate

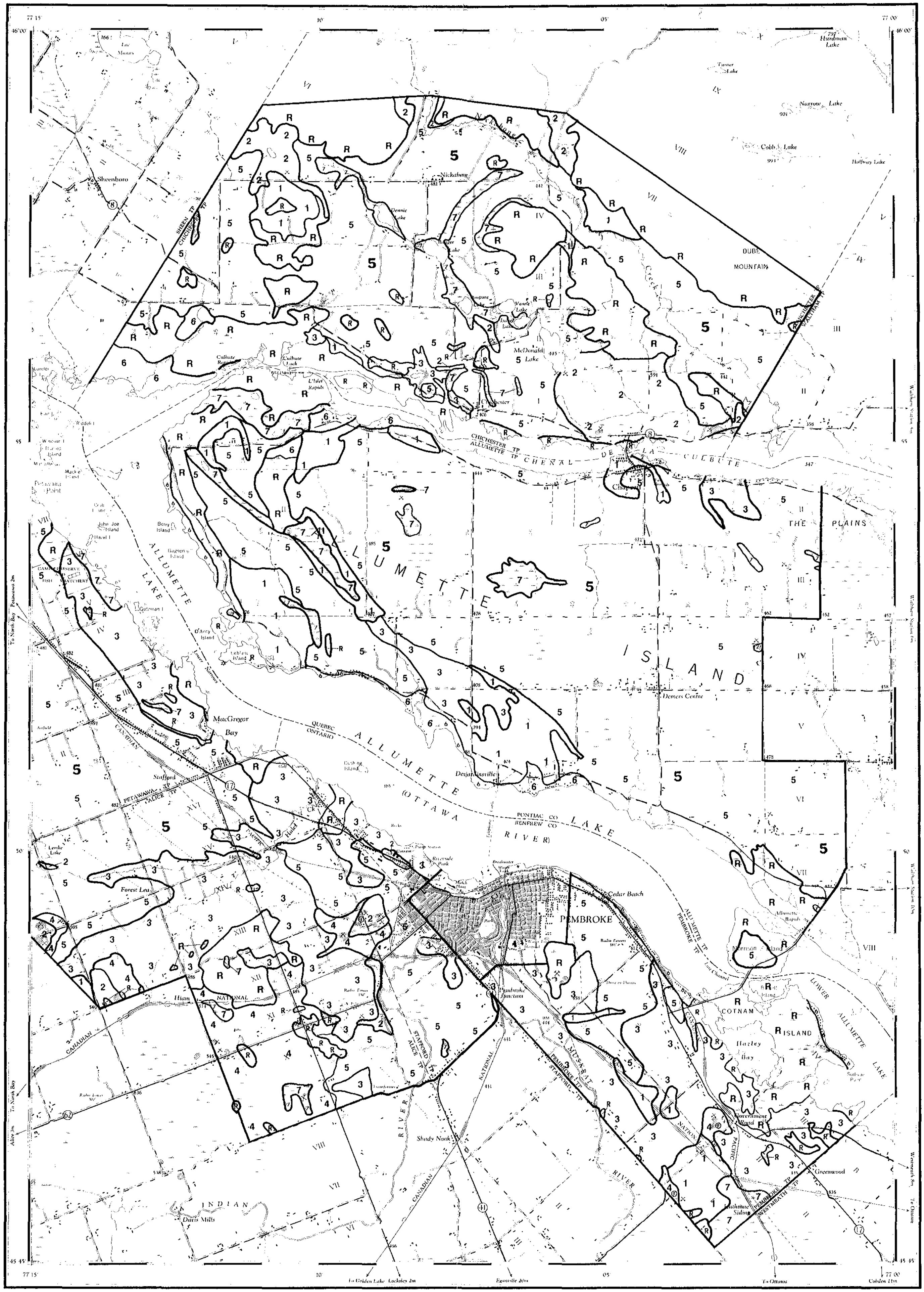
Foreshore flats
Lighthouse
Wharf or pier; Breakwater
Levee or dyke
Rocky reef
Swamp or marsh
Inundated land, seasonal
Intermittent lake, stream
Indefinite shoreline, stream
Rapids, large, small; Bridge
Ditch or flume
Snowfield; Glacier
Wooded area; unclassified, scrub
Vineyard; Orchard

INDEX TO ADJOINING SHEETS

31K/4 DES JOACHIMS	31K/3 CHALK RIVER	31K/2 USBORNE LAKE
31F/13 ACHRAY	31F/14 PEMBROKE	31F/15 FORT COULONGE
31F/12 ROUND LAKE	31F/11 GOLDEN LAKE	31F/10 COBDEN

PEMBROKE
31 F/14 EAST

NATIONAL TOPOGRAPHIC SYSTEM 1:50,000 CANADA FOURTH EDITION SHEET 31 F/14 EAST



PEMBROKE

ONTARIO - QUEBEC

SCALE 1:50,000

Fig.11