THE YORK FACTORY AREA, HUDSON BAY

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S. J. SIMPSON
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THE YORK FACTORY AREA, HUDSON BAY

AN ACCOUNT OF THE ENVIRONMENT AND THE EVOLUTION OF THE TRACT OF LAND BETWEEN THE MOUTHS OF THE NELSON AND HAYES RIVERS

DEDICATED TO

MANITOBANS
AND THE
SPIRIT OF KICHE-WUSKAKIGUN

ABSTRACT

The character and history of the growth of the land around Hudson Bay deserve much more study than they have yet received, and I feel quite convinced that the volume of new and valuable information which would be obtained from such a study would well repay the time and money spent on it.

J.B. Tyrrell

Presidential Address to
the Royal Society of Canada,
May 1916.

York Factory and the Hayes River estuary, located on the southwestern coastline of Hudson Bay, have an unique heritage of early trade and exploration. In 1957 this historic fur trading post closed after two hundred and seventy-five years of trading with the Indians. A series of early maps, dating from the 17th Century, when compared with contemporary surveys, indicate the distinct seaward progression and changes in the configuration of Beacon Point.

An inter-disciplinary studies group comprising representatives from the fields of Botany, Geomorphology, History and Soil Science visited the York Factory area during the 1969 and 1970 summer field seasons. The objective was the collection of botanical, geomorphological and pedological data concerning the existing environmental patterns, and the evolution of the point of land between the mouths of the Nelson and Hayes Rivers. This data has subsequently been synthesised within a geographical framework.

The most conspicuous relief elements of the area are the series of raised beach and inter-beach systems. There occurs a generally consistent zonation of soils and vegetation from the present coast inland, reflecting the emergence of new habitats and parent materials as the coastline of Hudson Bay recedes seaward. The occurrence and initiation of permafrost, following emergence, is closely related to the evolutionary sequence of soil, vegetation and topographic patterns. Radiocarbon dating of beach materials indicate the relatively recent emergence of the York Factory area in the last 2,500 years.

The progression seaward of Beacon Point is a function of glacial rebound on a regional scale along the southwestern coastline of Hudson Bay, and of localised channel and coastal aggradation processes operative nearshore in the estuarine environment. Present rates of post-glacial uplift are of the order of 4 feet per century. The combined effects of the endogenetic and exogenetic processes operative in the area have been the extension bayward of Beacon Point at a contemporary rate of 18 - 20 feet per year. Initially (i.e. circa 2,000 B.P.) this rate was of the order of 70 - 75 feet per year.

PREFACE

I went to the woods because I wished
to live deliberately, to front only
the essential facts of life, and see
if I could not learn what it had to
teach, and not, when I come to die,
discover that I had not lived.

Henry David Thoreau

In the summer of 1968 I visited York Factory in the company of Dr. R.W. Newbury, Department of Civil Engineering, The University of Manitoba. From this admittedly casual contact with Kiche-Wuskakigun and its immediate hinterland developed the York Factory project.

The distinguished Canadian geologists, Joseph Burr Tyrrell and Robert Bell, were perhaps the first to recognise the uniqueness of the York Factory area. This uniqueness is twofold; firstly, in terms of the existing landscape patterns and their evolution in the subarctic estuarine environment; secondly, in terms of Manitoba's heritage of early trade and exploration.

The York Factory project was primarily concerned with the collection in the field of data relating to various aspects of the environment - botanical, geomorphological, historical and pedological. This was achieved by the working together in the field of a group of staff and graduate students from The University of Manitoba. This manuscript represents the ultimate synthesis of their efforts and findings within a geographical framework of landscape description. A large number of people throughout Manitoba were also involved and participated in various ways. Consequently the logistics of the project defy brief summary and in view of this widespread participation acknowledgement is made at the outset to all who contributed to the success of the project.

The success of the project reflects in part the financial support provided by the National Research Council of Canada to Dr. R.W. Newbury for northern research and to myself in the form of a Graduate Scholarship. Financial assistance from the Geological Survey of Canada, the National Advisory Committee on Geographical Research and from the University of Manitoba through the Committee of Northern Studies, the Alumni Association and the Department of Engineering is respectfully acknowledged.

I wish to express thanks on behalf of the entire field crew to those who participated in the project by lending equipment essential for northern field operations, in particular Mr. W. Danyluk, Director, Parks Branch, Department of Tourism and Recreation, Winnipeg who kindly authorised the use of various equipment at the York Factory site. The co-operation displayed by the National and Historic Parks Branch, Department of Indian Affairs and National Development, both on the site and in regard to access to and from the area is respectfully acknowledged. The assistance of Miss S. Smith Librarian, Hudson Bay Company, Winnipeg who made available for consultation various early maps and plans of the York Factory site, is also acknowledged.

My thanks are also extended to Dr. R.J.E. Brown, Northern Research, Geotechnical Section, N.R.C.C., and to the examining committee, Dr. R.W. Newbury (Civil Engineering),

Dr. W.J. Brown (geography) and Dr. J.T. Teller (Earth Sciences), at The University of Manitoba, for their constructive evaluation of the manuscript.

The compilation of this dissertation was made possible by the work and comradeship of the field personnel involved. Special thanks are formally extended to those individuals who provided immeasurable assistance in the gathering of field data. I am particularly indebted to Dr. D. Punter, Department of Botany, to Mr. C. Tarnocai, Canada Department of Agriculture, Winnipeg, who compiled the data on the soils of the York Factory area as summarised in Appendix B, to Mr. R. Beare, formerly of the Department of Civil Engineering who conducted the baseline surveys, to Mr. G. Smith of Fertile, Saskatchewan who was camp cook during the 1969 field season and to Mr. R.V. Oleson, a graduate student from the Department of History who played the dual role of historian and cook during the 1970 field activities. Special thanks are extended to Mr. Oleson in regard to the compilation of background historical information throughout the duration of the project.

The interest and encouragement expressed by Dr. W.B. Ewart, Winnipeg Clinic, at all stages of the research program is gratefully appreciated.

I am deeply indebted to Mrs. Barbara Probert who not only typed the manuscript but contributed on innumerable occasions to the smooth running of the logistical aspects of the entire project.

It is with an enduring sense of personal gratitude that I acknowledge and respect the friendship of Robert Newbury, who introduced me to the river landscapes of Northern Manitoba and shared with me the "Spirit" of Kiche-Wuskakigun.

Finally I take this opportunity to formally acknowledge with humility, my parents who patiently listened and waited from afar and my wife Frances, who followed to share the agony and the ecstasy.

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INTRODUCTION

To him who in the love of nature holds
Communion with her visible forms, she speaks
A various language;

William Cullen Bryant 1794-1878

The York Factory area provides an unique location for geomorphological and related investigations. In an area of approximately eighty square miles a variety of subarctic processes are operative within the regional framework of crustal rebound.

On Beacon Point a series of beach ridges and interbeach zones are indicative of recent emergence and coastal aggradation. Soil, vegetation and permafrost patterns also indicate former and continued emergence of new habitats from Hudson Bay. The positive relationship between the above patterns and the topographic elements expedites investigations of the evolution of the York Factory area.

The area is of recent evolution; its emergence from Hudson Bay occurring in the last 2,500 years. The progression seaward of Beacon Point, the tract of land between the mouths of the Nelson and Hayes Rivers is a function of

(i) the interaction of local exogenetic processes operative in the estuaries and along the southwestern coastline of Hudson Bay, which are superimposed upon

(ii) regional endogenetic processes operative in the earth's crust in response to the glacial overloading of the Hudson Bay region during the Pleistocene epoch.

The relatively recent emergence of the area implies that contemporary processes have played a major role in the seaward progression of Beacon Point.

The geometry or boundary conditions of an environment largely predetermine the nature and the operation of local exogenetic processes. The lower reaches of the Nelson and Hayes Rivers and the southwestern coastline of Hudson Bay constitute the present boundary conditions of the York Factory area, providing a peninsular framework within which sedimentation occurs. Boundary conditions and the environmental geometry change with time. The energy, materials (deposits) and the biologic elements within the boundaries also change. Although the present analysis of landscape is confined to the last 2,500 years, the observed environmental patterns are not independent of the pre-emergence boundary conditions in the hinterland of the York Factory area. During and following the deglaciation of northern Manitoba, postglacial drainage patterns were developed which now constitute the framework for recent sedimentation along this particular section of the southwestern coastline of Hudson Bay.

A simple model within which to investigate the recent evolution of the York Factory area is presented in Figure I.1. The model is essentially similar to the Davisian concept of landscape evolution. Although certain components in the model (e.g. postglacial uplift, rates of erosion of river banks etc.,) may be assessed quantitatively, the model is regarded primarily as a framework of analysis, within which to systematise the collection and reporting of field observations. The boundary conditions and environmental patterns are presented in Chapter II and Appendix A. The processes operative within the boundary conditions are reviewed in Chapters III and IV. The operation of time in the model is expressed in terms of the evolutionary sequence of landscape patterns which have developed in the York Factory area during the last 2,500 years (Chapter V).

The York Factory area has a unique heritage of early trade and exploration. Since the 17th Century a series of fur posts was built in the vicinity. Charts and surveys of the Nelson and Hayes estuaries, together with the dispatches, journals and records compiled during the continual occupance of the area from 1682 - 1957, provide historical evidence of the seaward progression and changing configuration of Beacon Point in the last few hundred years. Since historical records of changes in the environment are of value to the geomorphologist in the study of contemporary landscape evolution, Chapter I has been devoted to a review of the history of the York Factory area during the period 1611-1957.

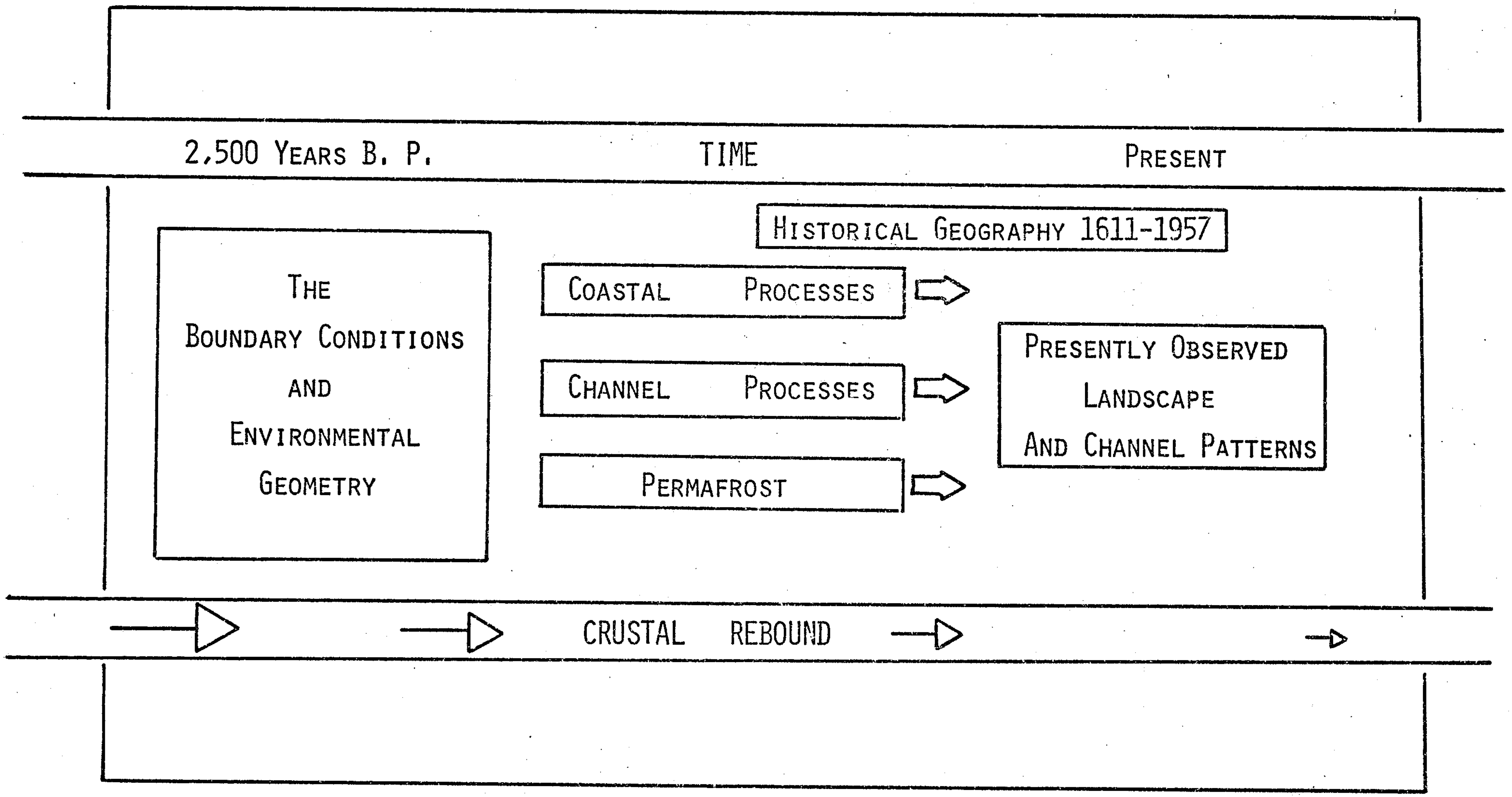

FIGURE I.1: FRAMEWORK OF ANALYSIS

CHAPTER I

AN HISTORICAL INTRODUCTION TO THE YORK FACTORY AREA

> Rivers must have been the guides which conducted the footsteps of the first travellers. They are the constant lure, when they flow by our doors, to distant enterprise and adventure, and, by a natural impulse, the dwellers on their banks will at length accompany their currents to the lowlands of the globe, or explore at their natural invitation the interior of continents.
>
> Henry David Thoreau 1849

By the 17th Century, the Canadian Shield was recognized by European entrepreneurs as one of the world's richest habitats of fur-bearing animals. The immediate problem facing the early fur traders was the inaccessible nature of the hinterland of Hudson Bay. In the 17th Century overland trading in furs by way of the Moose, Ottawa and St. Lawrence Rivers was developed by French Canadians. This route however, did not lend itself to the rapid transfer of bulk shipments of furs and trade goods. The need for a more direct contact with transatlantic shipping was soon realised.

The "Geography Behind History"

Hudson Bay like a giant horseshoe penetrates the Canadian Shield. Extending south from 63°N to 52°N this inland sea provides an initial means of access into the heartland of Canada. The nodality of the Bay is accentuated further by its radial river systems. Until the coming of the railroads in the 1860's, access to the Precambrian Shield and the Prairies was by water, either from the East by way of the St. Lawrence and the Great Lakes, or from the North inland along the rivers flowing into Hudson Bay. By virtue of its central position, its southerly penetration of the continent, and its network of radial drainage across and from the Shield, Hudson Bay has played a major role in the historical evolution of Western Canada. In many ways "the Prairie Provinces are the children of the Bay, as assuredly as Central Canada is the offspring of the St. Lawrence".[1]

Certain geographical factors gave York Factory an initial advantage as a collection and distribution centre for trade goods and furs. Not only is the Canadian Shield narrowest in the hinterland of York Factory, but also two navigable rivers, the Nelson and the Hayes, here enter Hudson Bay. The Nelson River Basin (Figure 1.1) extends west to the foothills of the Rocky Mountains, east to within a score of miles of Lake Superior, and south to the drainage divide between the Red River and the Mississippi-Missouri system. From York Factory it was possible to travel by canoe virtually the length and breadth of Canada. Thus it seems entirely logical that York Factory, with its estuarine location at the focal point of an extensive North American network of inland waterways, and accessible by the sea route through Hudson Strait, should become established as the chief trading post and warehousing depot of the Canadian fur trade.

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[1] Neatby, L.H., History of Hudson Bay, In Science, History and Hudson Bay, ed. C.S. Beals, Vol. 1, Chapter 2, p. 69, Queen's Printer, Ottawa, 1968.

This unique location accounts in large part for the emergence of the York Factory area as the fur trade headquarters of the Hudson Bay Company.

1.1 EARLY EXPLORATION 1612-1684

The first European to visit the Nelson estuary by way of the sea route through Hudson Strait was Thomas Button. In 1612 he sailed from England with two ships, the "Resolution" and the "Discovery" to search for Henry Hudson, whose voyage of 1610-11 had ended in tragedy, when his mutinous crew cast him adrift on the Bay. Button's expedition was trapped by the freeze-up of Hudson Bay. He was forced to winter at Heart Creek on the north bank of Nelson River (Figure 1.2). His sailing master, Francis Nelson did not survive the winter and in honour of him the river received its present name. The "Resolution" was damaged beyond repair by the winter ice, the "Discovery" returned safely to England in 1613.

Thomas Button
1612/13

In 1631 Captain Luke Foxe with his ship the "Charles" arrived at Nelson River. He located Button's wintering site and claimed the land which Button had named "New Wales" for the British Crown.

Luke Foxe
1631

The Coming of the Fur Traders

Two men, Medart Chouart, Sieur des Groseilliers and his brother-in-law, Pierre Esprit Radisson, provided the initial idea and most of the know-how, without which there might never have been an English Company trading into Hudson Bay. As MacKay (1966) remarks, it matters little why these two Frenchmen alternated allegiance between France and England, more important is the fact that from their services to both countries originated the "Adventurers of England Trading into Hudson's Bay".

Radisson and Groseilliers

Radisson and Groseilliers were also the first to demonstrate the practicability and the superiority of the sea route by way of Hudson's Strait to New France and to Europe. When they failed to gain support from the French, Radisson and Groseilliers established connections with the English. In 1665 they went to London to meet with interested investors. Three years later, in June 1668, the "Eaglet" with Captain Stannard and Radisson, and the "Nonsuch" with Captain Zachariah Gillam and Groseilliers sailed from England. This was the first truly commercial voyage to Hudson Bay. Previous expeditions were concerned primarily with the findings of the North West Passage, in order to trade into the Pacific

Ocean. The "Eaglet" was forced to turn back. By late September the "Nonsuch" reached James Bay where Groseilliers constructed Fort Charles on Rupert's River (Figure 1.3). In May 1669 Captain Stannard and Radisson in the "Wivenhoe" set out for Hudson Bay, they visited Nelson River. In Autumn both the "Wivenhoe" and the "Nonsuch" which had wintered at Fort Charles, returned to England with impressive cargoes of beaver pelts which they had acquired in trade for trinkets and various tools. Their commercial success led to the consolidation of the Hudson's Bay Company.

The Hudson's Bay Company 1670

On the 2nd May, 1670, Charles II signed the Charter which gave sweeping territorial and trading privileges to the "Company of Adventurers of England Trading into Hudson's Bay".

In 1670 the "Prince Rupert" and the "Wivenhoe" sailed for Hudson Bay, the latter ship with Bayly, the first resident Governor of the newly formed Company on the Bay, proceeded to Nelson River. Bayly planted the King's Arms and renamed Button's "New Wales", Rupert's Land. Both crews wintered at Fort Charles. Radisson took advantage of the winter stopover to explore the west coast of the Bay. In July 1671, both ships set out for England with their cargoes of furs. In the following year the Company dispatched three ships for trade on the Bay. On arrival at Fort Charles the English found that a French force had been there and claimed the Fort for the French Crown. The expedition in fact had been a reconnaissance of James Bay by Father Albanel and Sieur de Saint Simon, commissioned by the Governor of New France. The English constructed a new fort at Moose River (Figure 1.3) wintered at Fort Charles and returned in October 1673 to London.

Father Albanel

Father Albanel returned to James Bay in 1674. His objective was to encourage the expatriots, Radisson and Groseilliers to return to the services of France. Governor Bayly reacted by making prisoners of the three Frenchmen. In 1675 they were sent to England to be reprimanded. Father Albanel was eventually successful in his mission. Both Radisson and Groseilliers became increasingly disillusioned with English society. By nature of their birth and religion they were barred from holding positions of authority. In 1675, on promise that their debts would be paid by Colbert, the King's Minister, they returned to France. There being no immediate use for their

Radisson and Groseilliers Leave H.B.Co.

services as fur traders, Radisson went to the West Indies with the French Navy, and Groseilliers went into semi-retirement at his home, Trois Rivieres, Quebec.

In 1680 Governor Bayly was replaced by John Nixon. This entailed also a change of Company policy. Prior to 1680 trade was concentrated in the James Bay area, now it was planned to move to the west of the Bay, and particularly to the Nelson and Hayes estuaries.

Radisson and Groseilliers, now in the service of the French Crown, arrived at the mouths of the Nelson and Hayes Rivers in August of 1682. They had sailed from the St. Lawrence in two ships, the "St. Pierre" and the "Ste Anne", belonging to the newly formed "Compagnie de la Baie d'Hudson", organised by a wealthy New France merchant, Charles Aubert de la Chesnay. On arrival at Hayes River they established a fur post some fifteen miles upstream on the south bank, near Fishing Island (Figure 1.2). Unknown to the French Canadians an expedition from New England (Boston) in the "Bachelor's Delight", captained by Ben Gillam, the son of Zachariah Gillam, and commissioned by the Governor of Massachusetts, had

The New England Freetraders

already arrived at Nelson River. These were free-traders, intent on poaching the Company fur reserve. The New Englanders proceeded twenty-six miles up-stream and built a fort on Gillam Island[2] (Figure 1.2). On the 18th September, almost a month after the arrival of the French Canadians and the New Englanders, the Hudson's Bay Company ship, the "Prince Rupert" with Captain Zachariah Gillam and Governor Bridgar sailed into the Nelson estuary. Their objective was to establish a permanent fort. They proceeded to construct a post on the north bank of Nelson River, below Flamborough Head.

Arrival of Bridgar and Z. Gillam September 1682

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[2] Tyrrell located the site of Gillam's Fort, when he visited the area during the Hudson Bay Exploring Expedition of 1912. Tyrrell describes the site and remains as follows:

"It was situated on a terrace, now thickly wooded, twenty-four feet above the level of the water, and could be approached with a small ship through a channel west of Seal Island. Much of the site had been washed away in the two hundred and thirty years since Gillam had built the little fort, but parts of two sites of the stockade could be recognized by the butts of spruce stakes still standing in the ground, though much decayed. They were about twelve inches long, had been sharpened by an axe at their lower ends, and were charred at the tops where they had been burned off. In a thick layer of clay beside a heap of stones, probably representing an old chimney, the stem of a clay tobacco pipe, and an oil iron nail made by a blacksmith, were also found."

Bridgar's wintering place appears on Thornton's Map of Port Nelson, 1685 (Figure 1.4).The French Canadians, the New Englanders, and the English wintered at their respective posts. By February 1683 Radisson had seized Gillam's fort and in June Bridgar and his men were taken prisoner. Their forts were destroyed, and Radisson proceeded to Quebec with his prisoners on board the "Bachelor's Delight", since both the French vessels were severely damaged in the Spring break-up of Hayes River. His nephew, Jean Baptiste Chouart was left in command of the area. Not long after Radisson's departure, John Abraham arrived in the "George" with fresh supplies for the Company men at Nelson River. Finding Bridgar's fort destroyed, he constructed a new fort on the south side of Nelson River at Walker's Point (Figure 1.4). Frequent hostile contact between the French and the English during the winter of 1683/84 forced Chouart to go further upstream on the Hayes.

Chouart's Fort Rainbow Island

The exact position of the relocated French post is not known, but it is probable that it was on Rainbow Island (Figure 1.2) since the location is known to the Indians as Pakowemistikusha Menistik or Frenchman's Island.[3]

In 1684 Radisson returned to the employ of the Hudson Bay Company. In May he sailed from England in the "Happy Return" to recover the area from his nephew. Chouart and his men, having suffered from the rigours of winter, and having been harried by unfriendly Indians and the English, readily surrendered. Radisson returned to England with a cargo of some 20,000 beaver pelts, 12,000 having been given up by the French. John Abraham remained on the Bay and proceeded to build a substantial fort on the north west bank of the Hayes. This fort, later named York Fort, in honour of the Company's Governor, the Duke of York (later James II) is also depicted on Thornton's Map (1685). Located one half mile downstream from the present York Factory site, this fort is subsequently referred to as York Factory I.

Fort Hayes (York Factory I)

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[3] Tyrrell, J.B., 1916, Notes on the Geology of Nelson and Hayes Rivers; Roy. Soc. Can. Trans., ser. 3, vol. 10, Sec. 4, p. 3.

1.2 ANGLO-FRENCH RIVALRY ON THE BAY 1684-1713

Shortly after Radisson had sailed for England in 1684, Sieur de la Martiniere arrived at Hayes River. The French were surprised to find the English in command of the area, as news had not reached New France of the events that summer. Martiniere attacked York Fort, but finding the English well prepared and resolute, he negotiated a truce. Martiniere selected a wintering site on the east side of a small creek, now known as French Creek[4] about a mile from its mouth (Figure 1.2).The French site "consisted of three houses and a fort laid out by M. l'Allemande, made of logs and defended by two bastions at a salient angle".[5] The English

Martiniere's Fort, French Creek 1684/85

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[4] French Creek is known by a variety of names. La Potherie referred to it as the Matsisipi River, and also as La Garousse [Cartridge] or Canadian River. (Letters of La Potherie, p. 259 in Documents Relating to the Early History of Hudson Bay (ed.) J.B. Tyrrell, Champlain Society Pub. No. 18, 1931. Tyrrell (1931 p.56) states that "The Cree name given me for it was Notawatowi Sipi, meaning Fetching River".

[5] Journal of Father Silvy, p. 57 in Documents Relating to the Early History of Hudson Bay, (ed.) J.B. Tyrrell, Champlain Society Pub. No. 18, 1931.

destroyed Jean Chouart's fort on Rainbow Island during the winter of 1684/85. Martiniere rebuilt and temporarily occupied the Rainbow Island fort in the spring. According to La Potherie, Rainbow Island "was a natural fortress, accessible only in one small spot, where one without trouble could prevent the landing of canoes, and it has an impossible marsh all around it".[6] The French later abandoned Rainbow Island and moved to a site near Radisson's 1682 post, opposite Fishing Island. After trading with the Indians, Martiniere left for Quebec at the end of the summer, destroying their forts before departing. On his way out of Hudson Bay, Martiniere captured the Hudson's Bay Company ship, the "Perpetuana Merchant", seizing the cargo of beaver pelts as a reprisal for the furs Radisson had confiscated from Jean Chouart in 1684.

Relations between France and England now deteriorated rapidly. The Governor of New France, the Marquis de Denonville, authorised an overland

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[6] Letters of La Potherie, p. 243 in Documents Relating to the Early History of Hudson Bay, (ed.) J.B. Tyrrell, Champlain Society Pub. No. 18, 1931.

The French Control James Bay Posts

attack on the Company posts in Hudson Bay. In March 1686, one hundred men and thirty-five canoes left Montreal. They were led by Chevalier de Troyes, and with startling ease and rapidity the French seized Moose, Albany and Rupert forts, leaving York and a small post at Severn the only English footholds on the Bay. Troyes returned to Quebec with his spoils leaving a young officer, Le Moyne d'Iberville in command of James Bay. The British were unaware of their losses while negotiating a treaty of neutrality with the French in 1686/87. They found that they had blindly surrendered Moose, Albany and Charles (Rupert) forts to the French, promising not to use force to reclaim them. Unsatisfied with diplomatic methods, Lord Churchill, the new Governor of the Hudson's Bay Company, dispatched in 1688, two armed vessels, the "Churchill" and the "Yonge" under the command of Captain Marsh, to rectify the situation on the Bay. Marsh failed to expel d'Iberville from James Bay. Meanwhile in England, William of Orange had ascended the throne, James II being exiled to France. The new monarch was unsympathetic to the French, and open war was declared. In 1689 the man-of-war "Hampshire" along with the Company ship, "North West Fox" were sent to recapture Fort Albany. D'Iberville seized both ships, burnt the "North West Fox" and sailed for Quebec in the "Hampshire" with a cargo of furs.

In 1690 d'Iberville returned to Hudson Bay. Realising now that the battle for the fur trade would be won by sea power, he brought a small fleet of three ships, the "Ste. Anne", the "St. Francois" and the "Armes de la Compagnie". The French attacked York Factory, but found it well guarded by a thirty-six gun ship. Failing to take York, d'Iberville proceeded to James Bay, wintered at Albany and returned to France in 1691 where he petitioned for a stronger naval force to drive the English from the Bay.

In 1692 James Knight was selected by the Hudson's Bay Company to head the strongest expedition yet sent to the Bay. Twenty thousand pounds were spent outfitting four ships with two hundred and thirteen men, eighty-two guns, and supplies for twenty months. In August 1692 Knight arrived at York Factory with the "Dering", the "Royal Hudson's Bay", the "Perry" and the "Prosperous". The "Dering" unloaded her trade

James Knight
Regains Control
of James Bay
Posts
1692/93

goods, took on the furs collected at York, and returned to England. Knight and the other three ships moved south to James Bay. In 1693 they routed the winter-weakened French from the Bottom of the Bay.

York Fort Captured by d'Iberville 1694

In 1694 d'Iberville, having secured naval support in France, arrived in September at Hayes River, with two ships, the "Poli" and the "Salamandre". Before the seige of York Factory began, the ships were put in winter quarters, since it was now too late in the season to return to Europe. The "Poli" was wintered in the Nelson and the "Salamandre" in the Hayes River, half a league upstream of York Fort, where a large point juts into the river forming a cove.[7] On October 14th, Ste. Therese's Day, the Garrison at York Factory surrendered after heavy bombardment from French cannon. D'Iberville wintered at the fort with his prisoners. York Fort was

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[7] Douglas, R. and Wallace, J.N. Twenty Years of York Factory, 1694-1714; Jeremie's Account of Hudson Strait and Bay. Thorburn & Abbott, 1926 Ottawa, p. 27. The cove referred to was in the lee of Mile Bluff, which is marked on Robson's Map of 1745. The cove was located one and a half miles upstream of York Fort on the north bank of the Hayes River, that is one mile above the present site of York Factory (Figure 1.2).

renamed Fort Bourbon, and Hayes River, Riviere Sainte Therese. In September d'Iberville returned to France, leaving a garrison of sixty-seven men at Fort Bourbon. Jeremie, who accompanied the d'Iberville expedition describes York Fort as it appeared in 1694.

> The fort had four bastions, forming a square of thirty feet, in which was a large warehouse of two stories. The trading store was in one of these bastions, another served as a supply store, and the other two were used as guard houses to hold the garrison. The whole was built of wood. In line with the first palisade were two other bastions, in one of which the officers were lodged, the other serving as a kitchen and forge for the garrison. Between these two bastions was a kind of half moon space in which were eight cannon, throwing an eight pound ball, which commanded the river side. Below this half moon space was a platform, at the level of the water, which held six pieces of heavy cannon. No cannon was mounted on the side of the wood; [Meaning the rear of the fort] all the cannon and swivel guns were on the bastions. There were altogether in the fort, which had only two palisades of upright logs, thirty two cannon and fourteen swivel guns. There were fifty three men in the fort.[8]

In reply to the French victory of 1694 the British Navy dispatched two men-of-war, the "Bonadventure" and the "Seaforth" along with

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[8] Douglas, R. and Wallace, J.N. Twenty Years of York Factory, 1694-1714; Jeremie's Account of Hudson Strait and Bay, Thorburn & Abbott, 1926, Ottawa. p. 26.

three Company ships to Hayes River. Arriving at York Factory in August 1696, the sixty-seven French surrendered in the face of this display of naval force. Captain Allen, the fleet commander took the French prisoner, seized their fur pelts and returned to England, leaving the British temporarily in command of Hudson Bay.

The English Retake Fort Bourbon 1696

In 1697 the French made their most determined effort to clear the British from the Bay. A French squadron of four ships left France in April. D'Iberville joined them in Newfoundland, taking command of the "Pelican". In Hudson's Strait d'Iberville's ship got separated from the rest of the squadron. He proceeded across the Bay to the mouth of Hayes River. While waiting for the arrival of the other French ships, three English men-of-war arrived. These were the "Hampshire" (52 guns), the "Dering" (30 guns) and the "Hudson's Bay" (32 guns). D'Iberville in the "Pelican" sailed out to engage them, the "Hudson's Bay" immediately surrendered. The "Hampshire" with two hundred and ninety men on board was sunk, either, as claimed by the French, by a broadside from the "Pelican", or more likely as a result of trying to turn about in the gale that was blowing.

The "Dering" managed to escape under cover of darkness when pursued by the "Pelican". Both the "Hudson's Bay" and the "Pelican" were wrecked and swept aground in the heavy gale that raged during and after the sea battle (Figure 1.2). When the remainder of the French squadron arrived at Hayes River, d'Iberville set about retaking York Factory, where the survivors of the "Hudson's Bay" and the crew of the "Dering" which had managed to evade the French and slip back into Hayes River, had congregated. On September 11th, aided by a thick fog, the French installed their cannon and artillery onshore. After two days of heavy bombardment with mortars, the British surrendered. Terms were agreed upon, Governor Bayly had to relinquish the furs and the armaments at the fort, the "Dering" was allowed to return to England with the refugees. D'Iberville departed on September 24th, leaving his brother in command of the fort, now renamed again Fort Bourbon.

- **D'Iberville Recaptures York Factory 1697**

In 1700 the French constructed a second fort, with a large store, to serve as a retreat in case of an English attack to retake Fort Bourbon.

Fort Phelipeaux 1700

Fort Phelipeaux was located two leagues (six miles) upstream from Fort Bourbon, on the southeast bank of the Hayes River (Figure 1.2). In 1712 a party of French while hunting caribou were massacred by Indians. One wounded survivor managed to escape and warned Jeremie, the Governor of Fort Bourbon, of the hostility of the Indians. Jeremie decided to abandon Fort Phelipeaux, since the total French population was now reduced to nine men. Shortly after the French retired to Fort Bourbon, the Indians plundered and burnt Phelipeaux.

From 1697 until 1713, the Hudson's Bay Company retained only one fur post on the Bay, this being at Albany. York Factory, now renamed Fort Bourbon remained in the control of the French until July 1714, when James Knight arrived to accept the French surrender and reclaim the post for the British, by the terms of the Treaty of Utrecht (1713).

1.3 YORK FACTORY II 1714-1792

Construction of York Factory II 1715/18

When Knight repossessed Fort Bourbon, he found the buildings in extremely bad repair. In 1715 the spring break-up of the Hayes River was accompanied by severe flooding. The buildings were innundated to a depth of twenty feet. Knight was forced to rebuild the fort. In 1718 stone bastions were added. Knight's fort is subsequently referred to as York Factory II.

York Factory II

Joseph Robson 1744/47

Joseph Robson came to York Factory in 1744. An engineer by profession, he had formerly been in charge of the building operations at Fort Prince of Wales, near present day Churchill. Robson surveyed the York Factory area (Figure 1.5). Until the work of the Geological Survey of Canada at the end of the 19th Century, his map remained virtually the only source of geographical information on the Nelson and Hayes estuaries.[9] On Robson's map, Beacon Point is represented as an island, (an error common in early cartographic works), separated from the "mainland" by the Penny-cut-away.

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[9] Robson's Map (Circa 1744) was used for example in C.N. Bell's report, "Our Northern Waters; A Report Presented to the Winnipeg Board of Trade Regarding The Hudson's Bay and Straits." Winnipeg (1884).

Early navigators supposed the Hayes to be a branch of Nelson River. Arthur Dobbs (1744, p.14) refers to "York Port, on the southern branch of the Nelson River".

Robson gives us a detailed description of York Factory II, together with plans of the fort and environs (Figure 1.6).

> York Fort stands above high-water-mark, about eighty yards from Hayes's-river, and four miles from the sea. It is built with logs of white fir eight or nine inches square, which are laid one upon another....the timber both of the foundation, and the superstructure rots so fast, that in twenty-five or thirty years the whole fort must be rebuilt with fresh timber...

York Factory II

> It has four bastions, but not fit for cannon: the distance between the salient angle of each bastion is ninety feet. On each curtain there are three pateraroes, or swivel-guns, and loop-holes for small arms: it is also surrounded by two rows of pallisades, some three inches thick, and the largest seven inches; but there is no ditch. The magazine is in the west bastion; its wall is of the same thickness as the fort-wall, its floor is raised two feet and a half or three feet above the level of the fort, and its sides are lined with slit-deal plaistered. Upon the banks of the river are planted two batteries from twelve to six pounders, one of four guns, the other of ten.[10]

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[10] An Account of Six Years Residence in Hudson's-Bay, From 1733 to 1736, and 1744 to 1747, By Joseph Robson, Late Surveyor and Supervisor of the Buildings to the Hudson's-bay Company. London 1752, p. 30.

J.B. Tyrrell, during the Hudson Bay Exploring Expedition of 1912, made use of Robson's survey of York Factory II, to estimate the rate of recession of the northern bank of Hayes River. He writes:

> Fortunately, we have a survey of this site made by Joseph Robson in 1745, which shows a little stream with four bends within or close to the stockades of the Fort. These bends of the stream provide an excellent measure for determining the former position of this Fort and of the shoreline in front of it. Two of the bends have already disappeared, having been washed away by the stream, the other two being quite recognizable by a comparison of the old plan and the one made at the present time. These two plans show distinctly that the bank has been cut back a distance of 168 feet since Robson's plan was made one hundred and sixty-seven years ago, or a recession of practically one foot a year in that time.[11]

In August 1746 the "Dobbs Galley" captained by William Moore and the "California" commanded by Captain Francis Smith arrived at York Factory. This expedition in search of the North West Passage, was commissioned by Arthur Dobbs, a wealthy Irish gentleman, keenly interested in acquiring trading privileges on Hudson Bay. The crews wintered in log tents at Ten

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[11] Tyrrell, J.B. 1913, "Hudson Bay Exploring Expedition 1912", <u>22nd Annual Report, Ontario Bureau of Mines</u>, Part I, p. 184.

Montague House 1746/47

Shilling Creek (Figure 1.2). Montague House was constructed for the captains and officers, since James Isham, the Chief Factor at York Factory was antagonistic towards Arthur Dobbs, on account of the latter's attacks on the Hudson Bay Company's monopoly on Hudson Bay. Dobbs did not accompany the expedition, Henry Ellis his agent however records the location and the building of the expedition's winter quarters near Ten Shilling Creek (Figure 1.7).

> ...being certain there was no Possibility of living aboard the Ship for Cold, Wherefore some of the People were employed in cutting Fire-wood, others in building Log Tents. This is a Contrivance borrowed I suppose, from the Natives; and ours were made of Trees hewn and cut, about Fifteen Feet long, raised close together, their Ends lying one against another at the Top, but extending at the Bottom, in the Form of the Roof of a Country House. Between these Logs the vacancies were stuffed with Moss, and that being plaistered over with Clay, made a warm Hutt; the Door was low and small, a Fire-place in the middle, and a Hole over it, to let out the smoke.
>
> But the grand Business, and what engrossed most of our Attention, was the building a House for the Captain and Officers to dwell in. The Situation we chose for it, was equally pleasant and convenient; it was on an Eminence surrounded with Trees; the main River Hayes was half a Mile distant to the North West; the Creek where our Ship lay, near the same Distance; on the South West we had a handsome bason of Water, called the

> Beaver Creek, about 150 Yards distant in Front, which looked like a grand Canal, in prospect; and thick and tall Woods protected us from the North and North-East Winds. The Situation chosen, I drew a Plan of our intended Mansion, which the Captains approved of. The House according to this Plan, was to be twenty-eight Feet long, and eighteen Feet broad; to have two Stories, the lower one to be six, and the upper seven Feet high; the Captain and some of the principal Officers were to live above, and the Remainder below.... The Door was to be in the middle of the Front, five Feet high, and three broad, with four windows above Stairs, one in each Captain's Room, and one at each end, to enlighten the Passage and the Officers Cabins. The Ridge of the Roof was to be but a Foot higher than the Side-Walls, in order to let the Wet drain off, and to keep the House the warmer by being close and low. The Stove was to be placed in the Center, that every Body might partake equally of it's Heat.
>
> These Matters being thus adjusted, all Hands were set to Work: Trees cut down and hewed, Planks sawed, the Walls begun, by placing one large Log upon another with Moss between, and nailing them down. In a Word the House was raised, covered and almost finished by the 1st of November....
>
> It was christened (in the Sea-way) MONTAGUE-HOUSE, in Honour of that worthy Nobleman, and generous Patron of all useful Undertakings, his Grace the DUKE of MONTAGUE; who, from his considering this Expedition in that Light, was one of our Subscribers.[12]

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[12] A Voyage to Hudson's Bay by the Dobbs Galley and California In the Years 1746 and 1747, By Henry Ellis, London 1748 (Johnson Reprint Corporation, 1967 pp 154-57).

In June 1747 the "Dobbs Galley" and the "California" left York Factory to search for the North West Passage. The expedition was unsuccessful and returned to England in October. The failure prompted Arthur Dobbs to petition the English Parliament for trading privileges in Hudson Bay. He also laid several charges against the Hudson Bay Company regarding their methods of operation, and treatment of personnel.

During the latter half of the 18th Century York Factory served as the starting point of numerous expeditions to the interior of the North American continent. Expansion westward as far as the Rocky Mountains by French-Canadian traders was by now common place, and was hurting the volume of trade in furs by way of Hudson Bay. Formerly the Indians came to the Bay with their furs. By the middle of the 18th Century traders were going inland to persuade them to come. The Company was eventually forced to establish a network of fur posts in the interior of Western Canada at key locations, to prevent the loss of trade with the Indians to the French-Canadians.

Role of York Factory Changes from Trading Post to Warehousing Depot

York Factory still retained its superiority in the network of Hudson Bay Company fur posts, but its role changed to one of a warehousing depot. This was particularly evident after the consolidation of the North West Company in 1779.

Between 1754 and 1774 the Hudson Bay Company ordered no less than sixty inland expeditions from the Bay into the interior. Many of these used York Factory as their starting point (Figure 1.8). In June 1754 Anthony Henday, with a party of Assiniboine Indians ascended Hayes River and proceeded westward from The Pas to the Blackfoot country of Southern Alberta. Henday returned to York Factory in June 1755, completing a round trip of two thousand miles.

Anthony Henday
1754/55

Joseph Waggoner and Joseph Stewart went inland in 1757 and 1758 to encourage Indians to come to York Factory, apparently with great success.

Waggoner and
Stewart
1757/58

In the early 1770's Andrew Graham, the Chief Factor at York, sent Matthew Cocking, Samuel Hearne and William Tomison inland. Cocking left York Factory in 1772 for the interior to report on the activities of the "Pedlars"[13] and to select

Matthew Cocking
1772/73

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[13] The name given by Hudson Bay Company men to the traders who had come west from Montreal. The "Pedlars" formed the North West Company in 1779.

a suitable site on the Saskatchewan River for an inland fur post. Like Henday, he found that the Plains Indians were not interested in journeying to Hudson Bay to trade. Cocking returned to York Factory in June 1773, with sufficient evidence of the loss of trade to the "Pedlars".

Samuel Hearne
1774
William Tomison
1777

In 1774 Cocking returned to the Saskatchewan as Samuel Hearne's assistant, to build Cumberland House at Pine Island Lake. Tomison was placed in command of the new post in 1777, and from here he successfully organized trade along the Saskatchewan River.

French Return
To The Bay
1782

French Capture
York Factory
1782

In 1782 La Perouse, with three French warships entered Hudson Bay. The French sailed to Churchill River, landed a force of between two and three hundred men, and attacked Fort Prince of Wales. Hearne, with only thirty-seven men in his command surrendered the fort. It was sacked by the French and never again occupied. La Perouse sailed south to Nelson River. His force crossed Beacon Point and approached York Factory from the rear. Governor Marten surrendered without engaging the French. The fort was pilfered and the English taken prisoner to France.

After the Treaty of Paris (1783), Governor Marten returned to the Bay to re-establish York Factory. A prefabricated house was built at the same site. In 1785 flooding severely damaged the settlement. No attempt was made to relocate the buildings until 1788, when another severe flood precipitated the decision to move to higher ground. Joseph Colen, the Chief Factor selected a new site half a mile upstream, where the present York Factory depot is located (Figure 1.2). In 1792 the building at the new site was completed. After the relocation of the fort, the old site was used as a cemetery.[14]

York Factory III

1.4 YORK FACTORY III 1793-1830's

The "golden age of York Factory" occurred during the first half of the 19th Century. The amalgamation in 1821 with the North West Company revitalized the Hudson Bay Company by eliminating competition and adding new men experienced in the

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[14] Tyrrell, J.B. 1916, Notes on the geology of Nelson and Hayes Rivers; Roy. Soc. Can. Trans., ser. 3, vol. 10, sec. 4, p. 7.

Introduction of the York Boats (Circa 1800)

fur trade. The introduction of the York boat[15] also increased the volume and the rate of flow of trade goods and furs through York Factory. According to Black (1968), the York boat:

> ...was of several designs but it was a flat-bottomed, shallow draft boat built of softwood and driven by oars; a square sail was raised in favourable winds. On lakes the York was steered with a rudder, and in the rivers, when being rowed, by sweeps.... Yorks varied in length according to the routes on which they were used....On main routes such as the Red or the Saskatchewan the boats were likely to be 38 to 40 feet long, with a beam of 7 to 8 feet and a depth of 3 1/2 to 4 feet....Yorks were classified according to their carrying capacities as "60 piece, 100 piece and 120 piece boats", the standard piece... weighing about 100 pounds.

---

[15] York Boats were introduced in the latter part of the 18th Century. Joseph Isbister, the factor at Albany House is credited with the introduction of a modified version of the Orkney Islanders' fishing boat, which later became known as the York Boat. In 1795 George Sutherland of Edmonton House introduced these boats to the Saskatchewan waterways. Shortly after this time they appeared on the Hayes-Nelson route from York Factory. The greatest expansion in the size of the York boat brigades occurred after the founding of the Red River Colony (1812) when immigrants as well as supplies for the settlers were transported by York boat from York Factory.

> ...The York had striking advantages over...freighter canoes: it was more dependable and durable and could navigate lakes in fairly rough weather, or rivers containing drifting ice that kept canoes shorebound, and it could sail better. The York was not noticeably slower than the freighter canoe, only at portages did the canoe have an advantage...16

By the 1850's at the height of the York boat period, about 200 boats, manned by some 1200 men, were operating on the network of inland waterways connected to the York Factory entrepot. The York boat brigades generally left York Factory in June for Norway House, which had become by the 1830's an auxiliary depot. From here they proceeded to Cumberland House, moving either west to Fort Edmonton on the North Saskatchewan, or north west via Ile-a-la-Crosse and Methye Portage to Clearwater River and the Athabasca drainage system. Other brigades moved south from Norway House to the Red and Assiniboine Rivers. The Hayes River route from York Factory to Norway House was used in preference to the Nelson channel. The latter river, although navigable was considerably more dangerous,

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[16] Black, W.A. 1968, "Navigable Inland Waterways" in Science, History and Hudson Bay, (ed.) C.S. Beals, vol. 2, chpt. 12, pt. V, pp 859-60, Queen's Printer, Ottawa.

and tracking of the York boats was hindered by the longer persistence of ice on the banks. At Painted Stone Portage the brigades crossed to the Echimamish River, which leads into Little Playgreen Lake, and thus to Norway House (Figure 1.9).At the end of the summer the York brigades reassembled at Norway House with their furs, and subsequently returned to York Factory. A round trip of some three thousand miles was completed annually by the brigades that travelled to the Rocky Mountain posts (Figure 1.3).

Red River Settlers

The first party of Red River settlers had arrived at York Factory in September 1811. The expedition was led by Captain Miles Macdonnell, who had been appointed by the Earl of Selkirk to govern the colony. The newly arrived immigrants could not be accommodated at York Factory, and so they wintered at a camp (Figure 1.2) on the north bank of Nelson River, opposite Seal Island, before proceeding to Red River. Miles Macdonnell in a letter to Lord Selkirk, dated July 4th, 1812, describes York Factory as it was in the early 19th Century (York Factory III). Of particular interest is the reference to the site of York Factory II, one-half mile downstream.

York Factory III

> The Factory is built at the distance of 100 yards from the North Bank of Hayes' River, in low miry ground....The chief building is two storeys high and covered with lead....The best rooms have grates such as are used in England for burning coals....All their chimneys are deep narrow holes with straight jams, the wood is burnt in them on end, and except immediately in front the heat goes principally up the chimney....There is a ground cellar under one part of the building....The site of the old Factory about half a mile below was in my opinion preferable, on a dry point, where Hayes' River and a Creek coming into it washed two sites....
>
> The whole pile of buildings except the Launch House and the canoe store, are surrounded by a single pile of pickets forming an oblong square of 400 feet front to the river, and 300 feet depth.[17]

York Factory, "Port of the Pioneers"

In August 1812 a second party of immigrants arrived from the British Isles, under the charge of Owen Keveny. Other groups followed in 1814 and 1815. A final contingent of Swiss settlers passed through York Factory, bound for the Red River Colony in 1821.

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[17] Letter written by Miles Macdonnell to Lord Selkirk on July 4th, 1812. Source: Manuscript History of Port Nelson and York Factory on Hudson Bay from the earliest to the most recent times. R.A. Lowe, p. 79, circa 1910.

1.5 YORK FACTORY IV 1830's-1957

York Factory IV

Extensive renovations were carried out at York Factory during the 1830's and 1840's. The most important was the erection of the "new store", the building which remains today (Figures 1.10, 1.11 & 1.12. This structure was in the form of a square with an open court in the centre (Fig. 1.11). A three storey section formed the centre block in front: this was flanked by two storey sections around the courtyard. The new depot was built on the same site as Colen's 1793 fort (York Factory III), but set back further from the river. York Factory as it appeared in its heyday has been described by the Reverend John Ryerson who visited there in 1854. He writes:

> The Fort at York, as all the factories or depots are called, is a large square, of about ten acres, inclosed within high stockades, and built on the banks of Hayes River, about five miles from its mouth, where it empties itself into Hudson Bay. The houses are of wood, and certainly can make no pretensions to architectural beauty, but still their regularity, and clean white appearance have a very pleasing effect on the eye. The principal building is the general store, where the goods to the amount of two years outfit for the whole northern department are stored. The general store is the centre building, and is built with an open space or court, in the centre of

> it, after the manner of French hotels. On each side of the centre building is a long low painted house, with window frames and edgings painted. In one of these, visitors and company residents are lodged in the summer season; the other is the mess room or dining hall. Four large stores stand at right angles, to these houses, and forming thus three sides of the front square. Behind the front buildings stands a row of small and low buildings, painted yellow, for the labourers and tradesmen; and on the right hand is the dwelling house of the chief factor, and adjoining it is the clerk's house, called "Bachelors' hall"; and in front of the chief factor's house, Mr. Mctavish is now building a parsonage for the chaplain. On the left hand is the provision store and the Indian trading shop. A few other buildings, the oil store, the lumber house; among which is seen a tall singularly-looking building, the observatory, called the look-out place, from which the inhabitants have an extensive view of their wild domains; and just near it stands the ice house.[18]

In the latter half of the 19th Century, York Factory declined in importance. By 1875 Fort Garry had gained superiority as the new headquarters of the Hudson's Bay Company operations. The coming of the railroads and the introduction of steamboats on the Red River increased the importance of Fort Garry as a collection and distribution centre.

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[18] Letter written by Reverend John Ryerson, 1854. Source: Manuscript History of Port Nelson and York Factory on Hudson Bay from the earliest to the most revent times. R.A. Lowe, p. 122, circa 1910.

Economic considerations also precipitated the abandonment of the Hudson Bay entrepot. Freightage was considerably less from London to St. Paul than from London to York Factory. The St. Paul route was more reliable and involved less time. In the face of strong competition from the American Fur Company, a major shortcoming of the York Factory entrepot became apparent. The volume of trade could not be easily increased, since the distribution and collection of trade goods and furs was dependent on the York boat brigades. The latter had often proved unreliable, crews mutinied, several were stricken by epidemic, several simply got lost or arrived too late at Norway House to complete the return journey to York before the winter arrived. Transporting goods by way of St. Paul to Red River was cheaper and less hazardous. By 1885, when the Canadian Pacific Railroad was completed, York Factory was of secondary importance.

The Fading Glory

During the 20th Century, the fur trade became less and less important and by 1933 York Factory ceased to be a customs outport. In 1957 the Indian population moved to Shamattawa, following the abandonment of the post by the Hudson's Bay

Company. So ended two hundred and seventy-five years of trading at York Factory; so began a heritage of early trade and exploration, which still awaits to be realised.

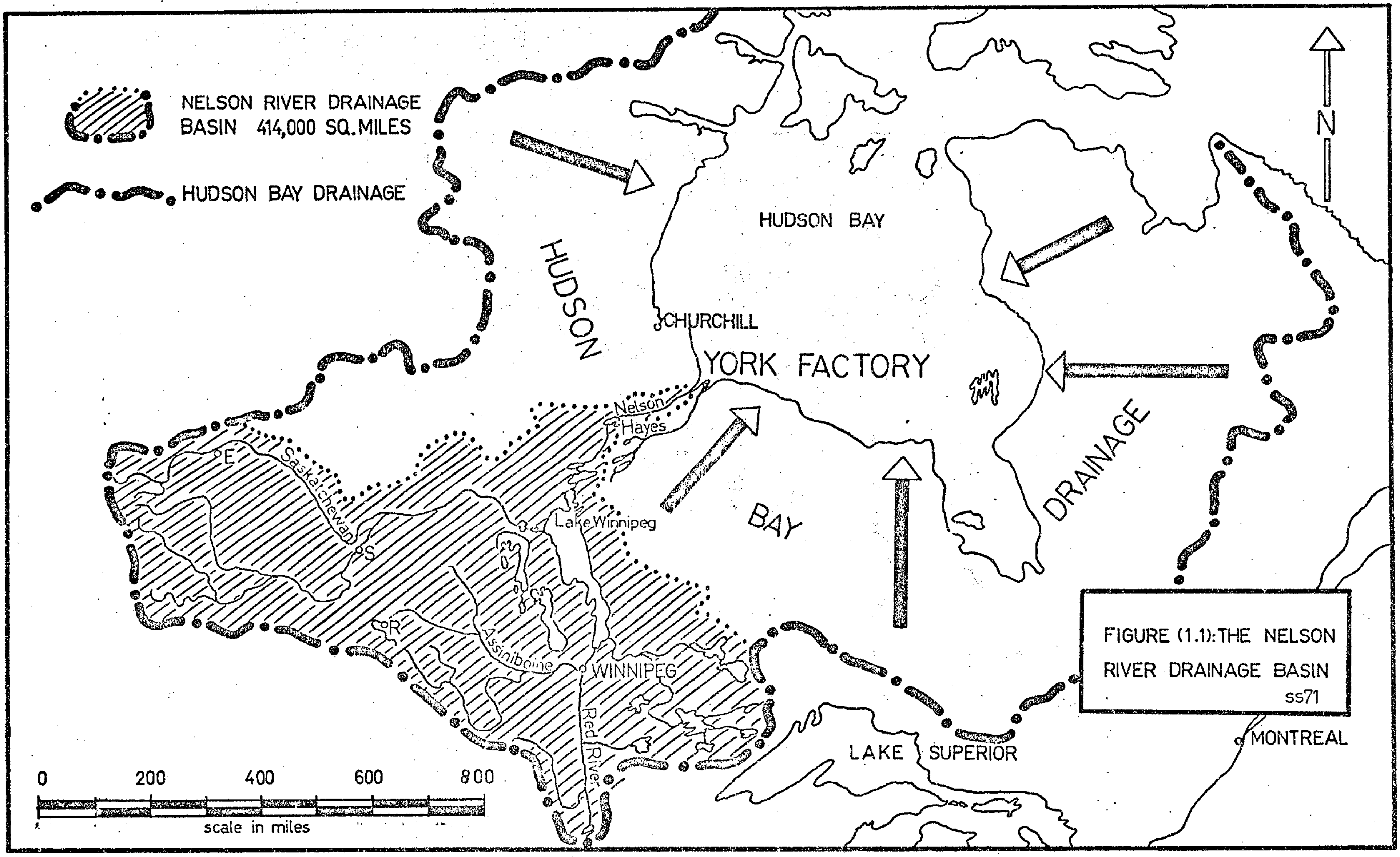
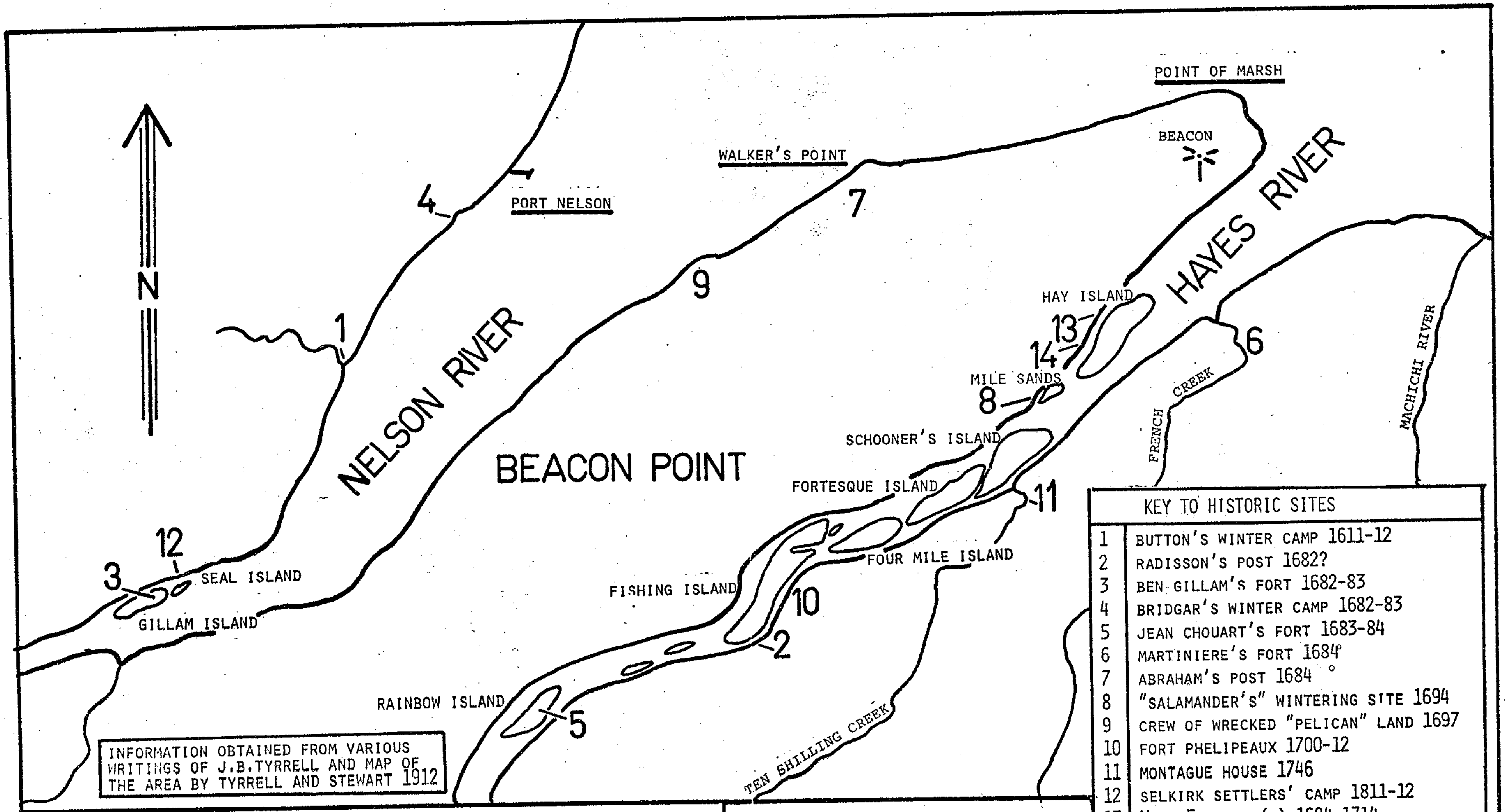


FIGURE (1.1): THE NELSON RIVER DRAINAGE BASIN
ss71



INFORMATION OBTAINED FROM VARIOUS WRITINGS OF J.B.TYRRELL AND MAP OF THE AREA BY TYRRELL AND STEWART 1912

KEY TO HISTORIC SITES

1	BUTTON'S WINTER CAMP 1611-12
2	RADISSON'S POST 1682?
3	BEN GILLAM'S FORT 1682-83
4	BRIDGAR'S WINTER CAMP 1682-83
5	JEAN CHOUART'S FORT 1683-84
6	MARTINIERE'S FORT 1684
7	ABRAHAM'S POST 1684
8	"SALAMANDER'S" WINTERING SITE 1694
9	CREW OF WRECKED "PELICAN" LAND 1697
10	FORT PHELIPEAUX 1700-12
11	MONTAGUE HOUSE 1746
12	SELKIRK SETTLERS' CAMP 1811-12
13	YORK FACTORY (I) 1684-1714 YORK FACTORY (II) 1714-1793
14	YORK FACTORY (III),(IV) 1793-1957

FIGURE 1.2 : HISTORICAL SITES OF THE YORK FACTORY AREA, HUDSON BAY

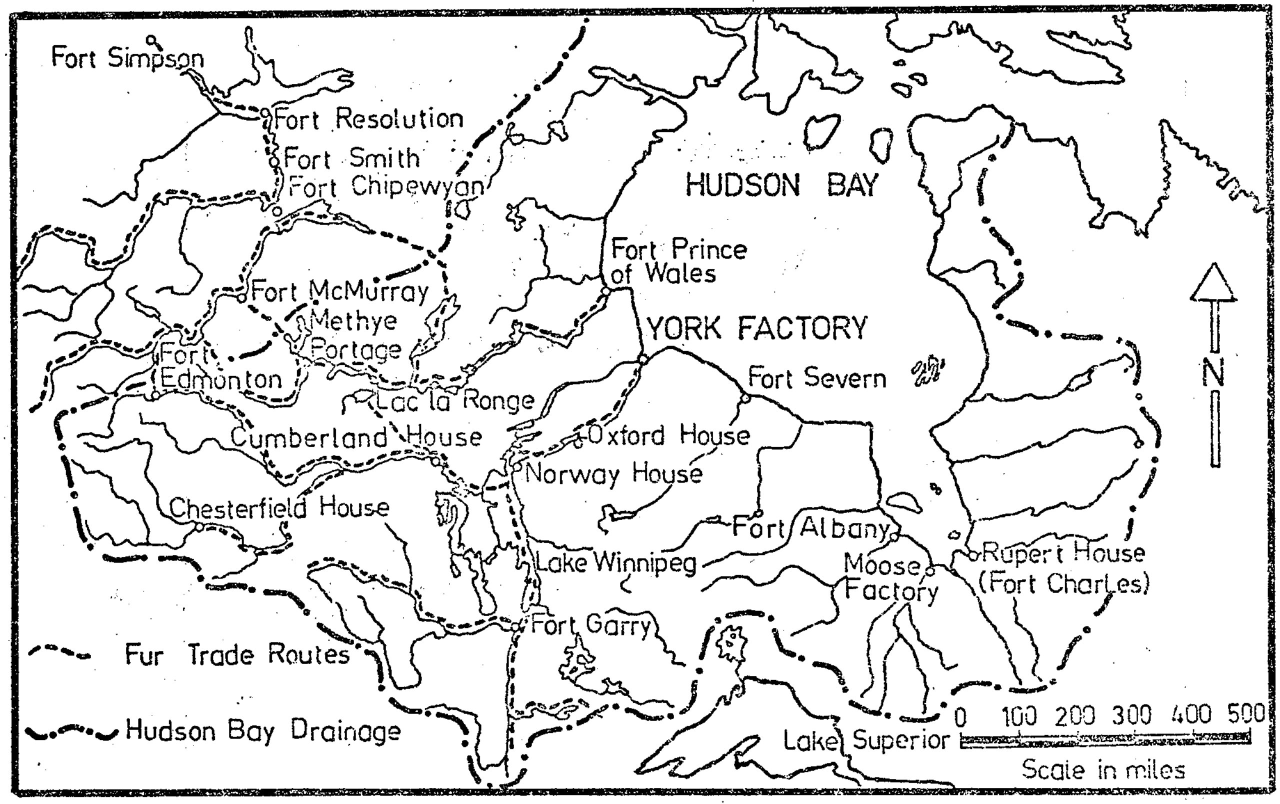
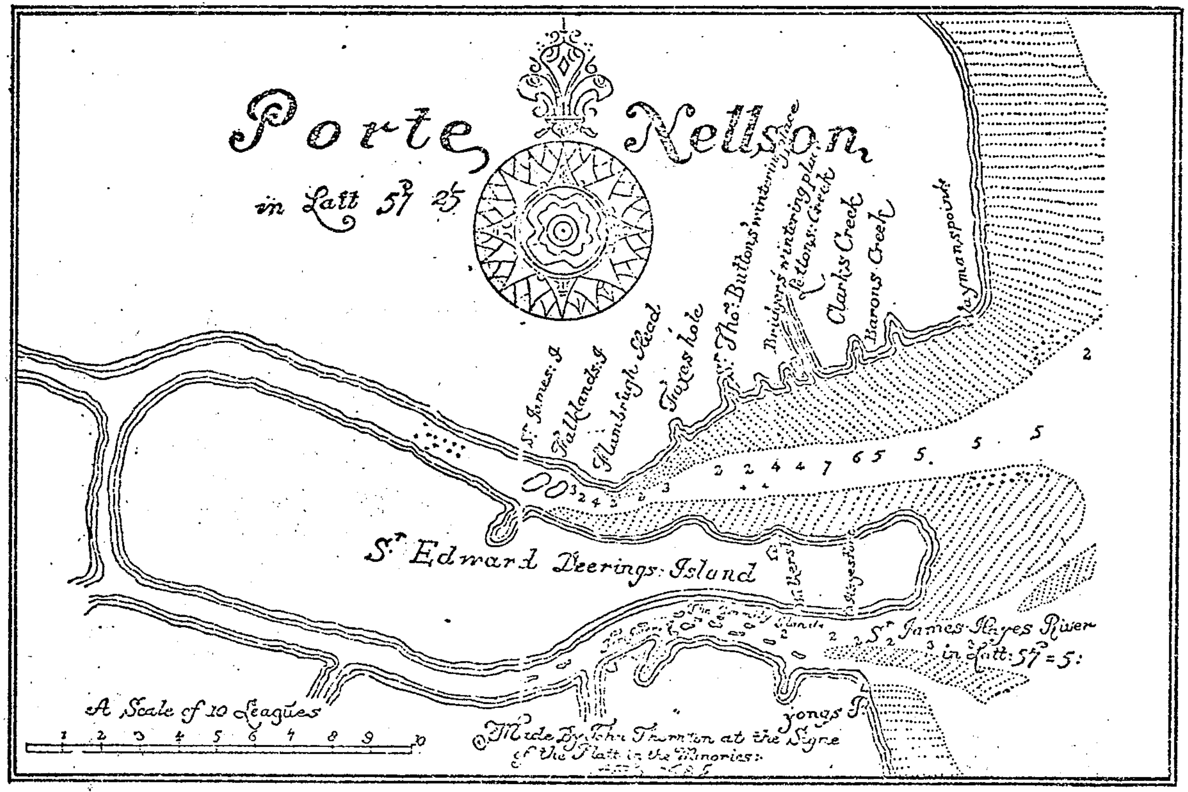


FIGURE 1.3

FUR TRADE ROUTES

(SOURCE; PHILIPS HISTORICAL ATLAS OF CANADA)



From a copy in Canadian Archives

FIGURE 1.4

THORNTON'S MAP OF PORT NELSON 1685

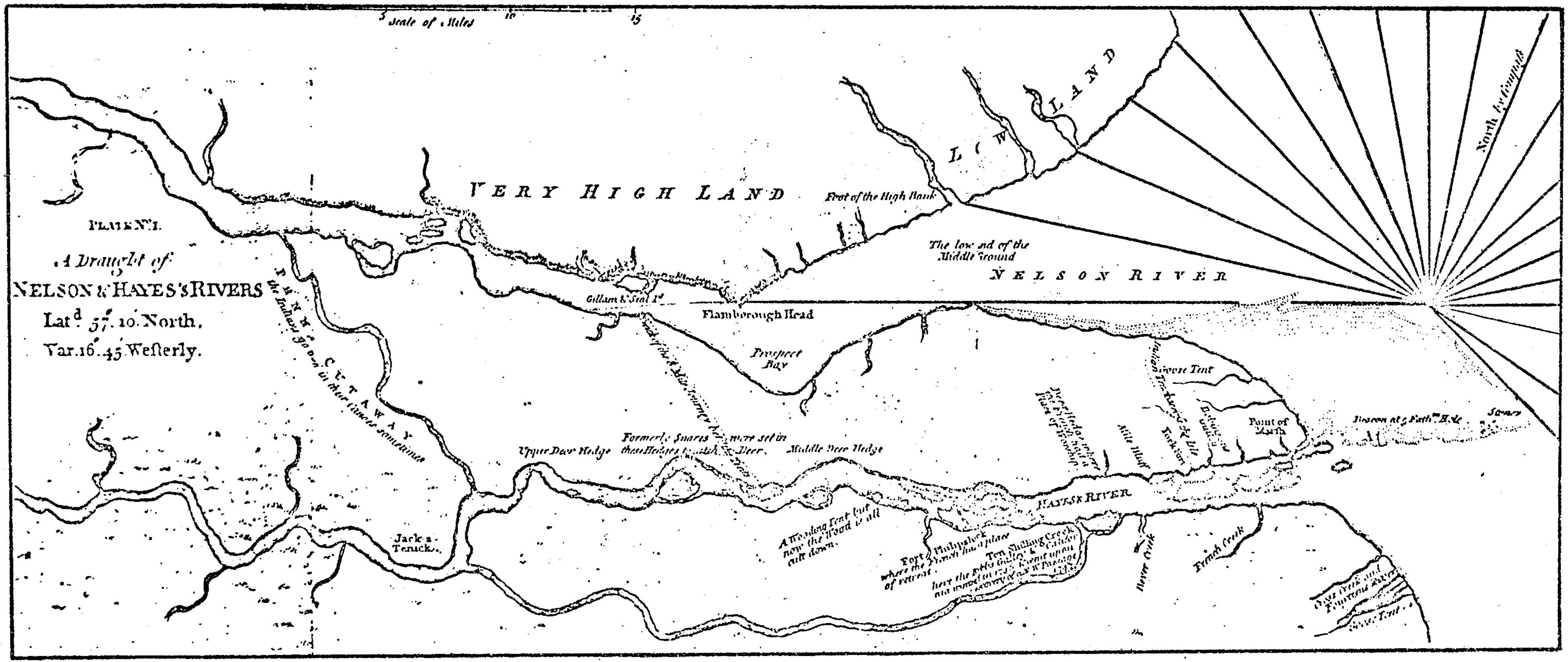


FIGURE 1.5

ROBSON'S SURVEY OF THE YORK FACTORY AREA 1745

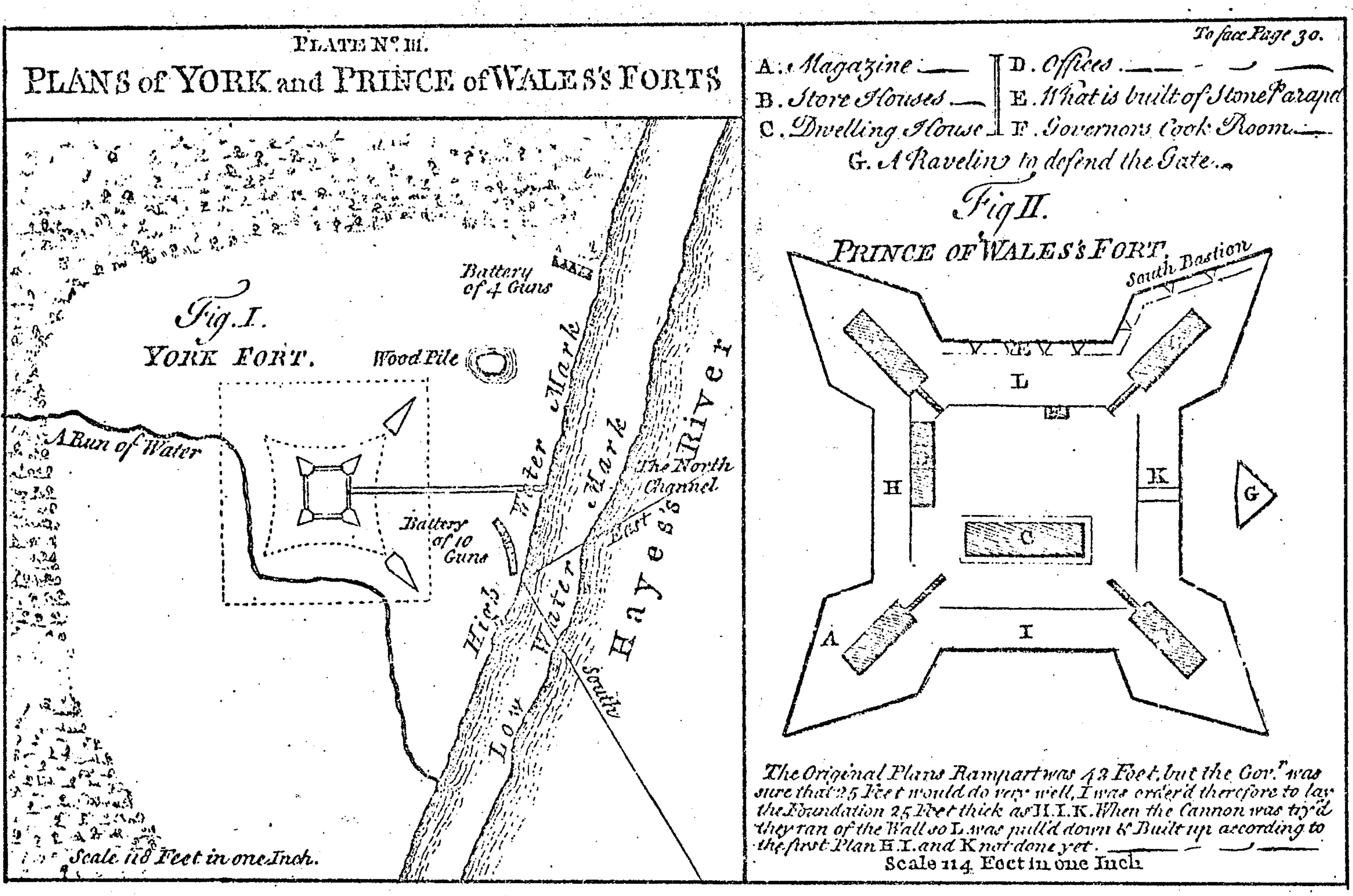


FIGURE 1.6

ROBSON'S PLAN OF YORK FACTORY 1745

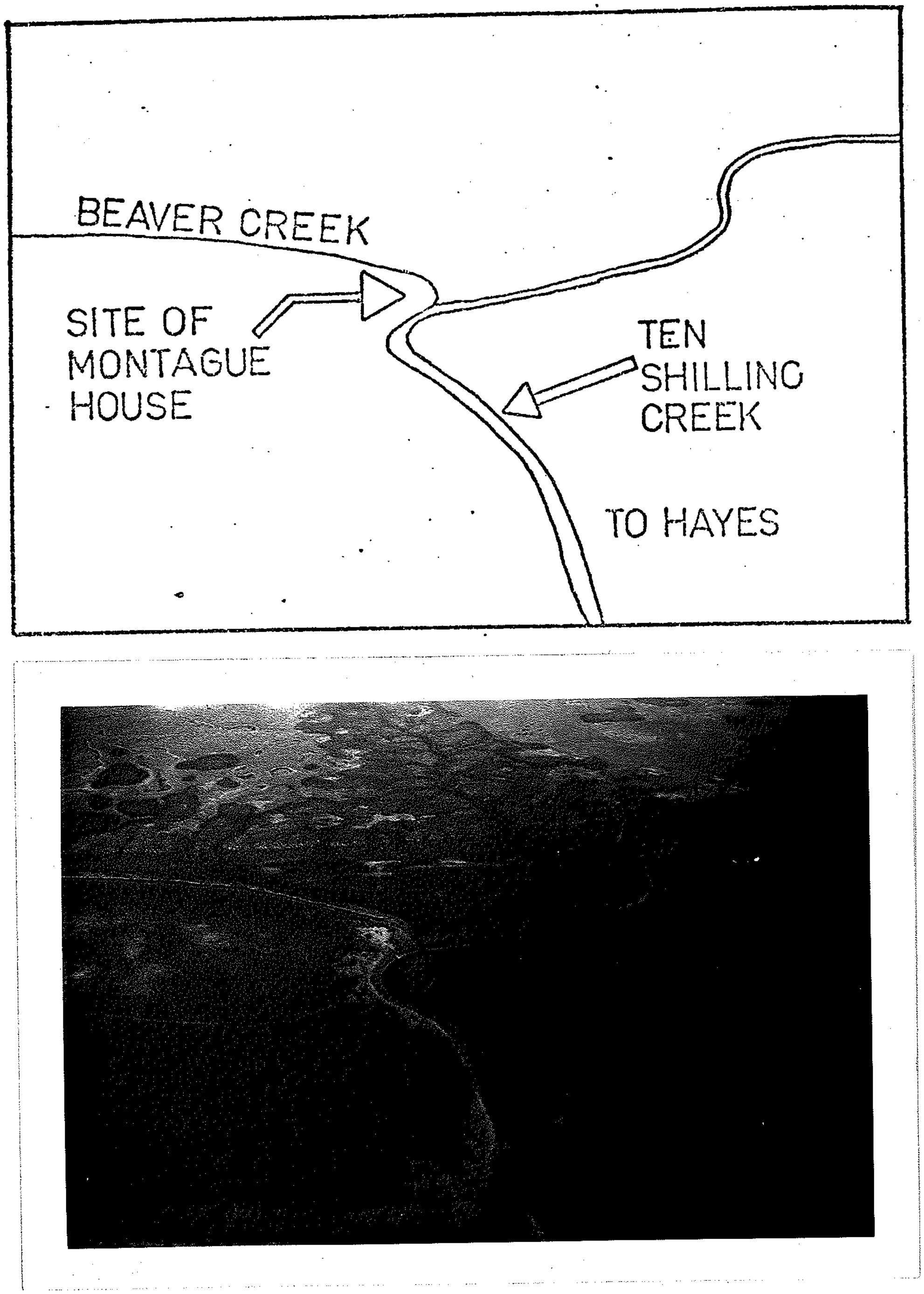


FIGURE 1.7
TEN SHILLING CREEK

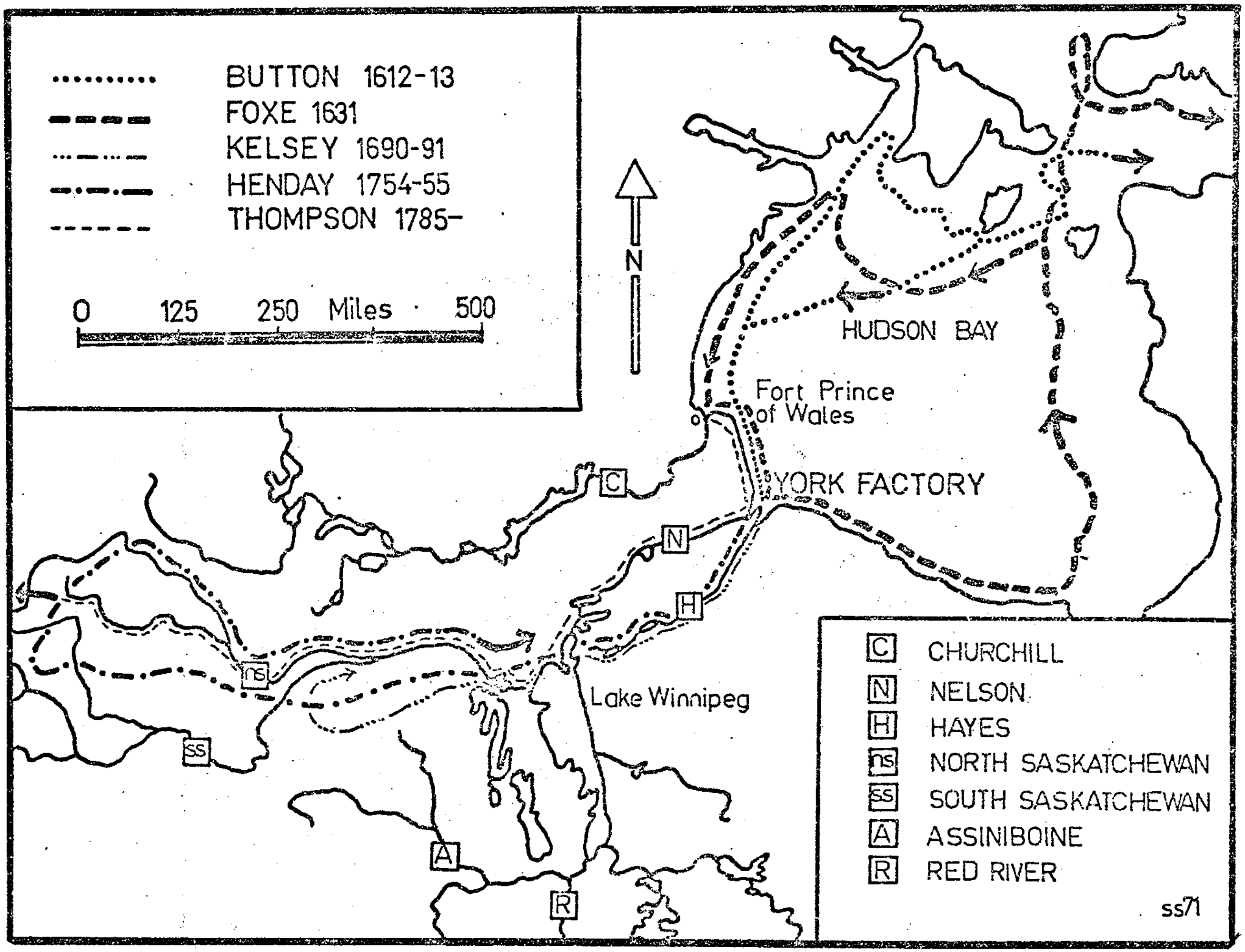


FIGURE 1.8

EXPLORATIONS ASSOCIATED WITH YORK FACTORY

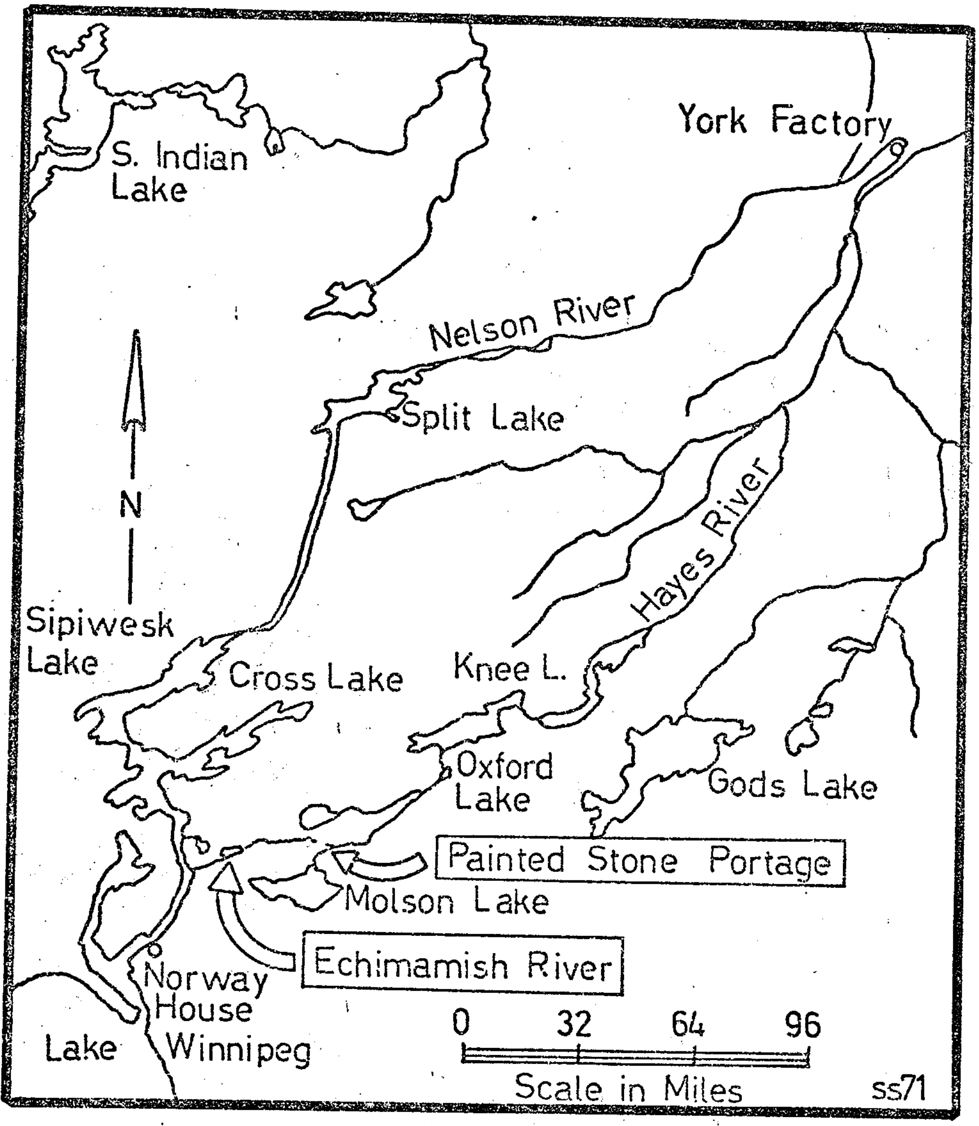


FIGURE 1.9

YORK FACTORY TO LAKE WINNIPEG

ROUTE VIA THE ECHIMAMISH RIVER

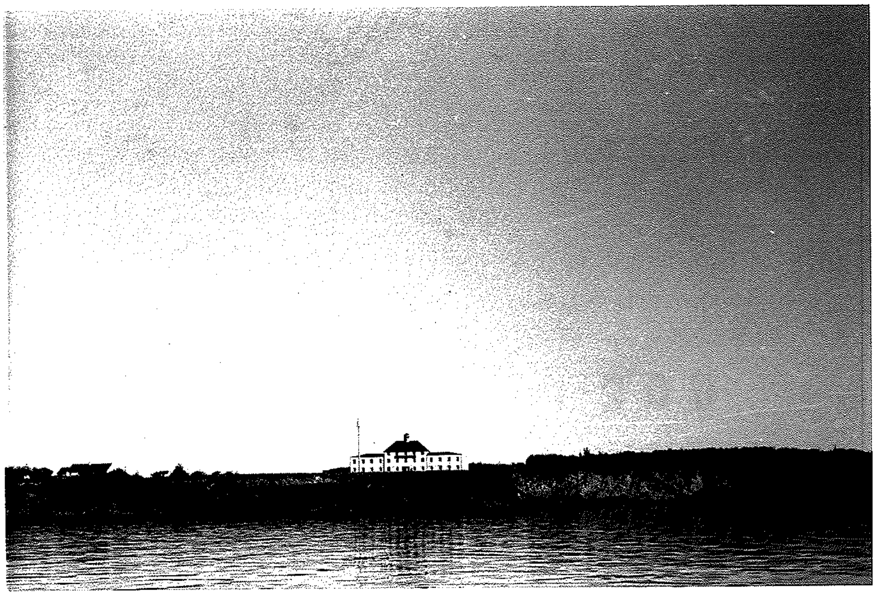


FIGURE 1.10

YORK FACTORY - JULY 1970
VIEWED FROM HAYES RIVER

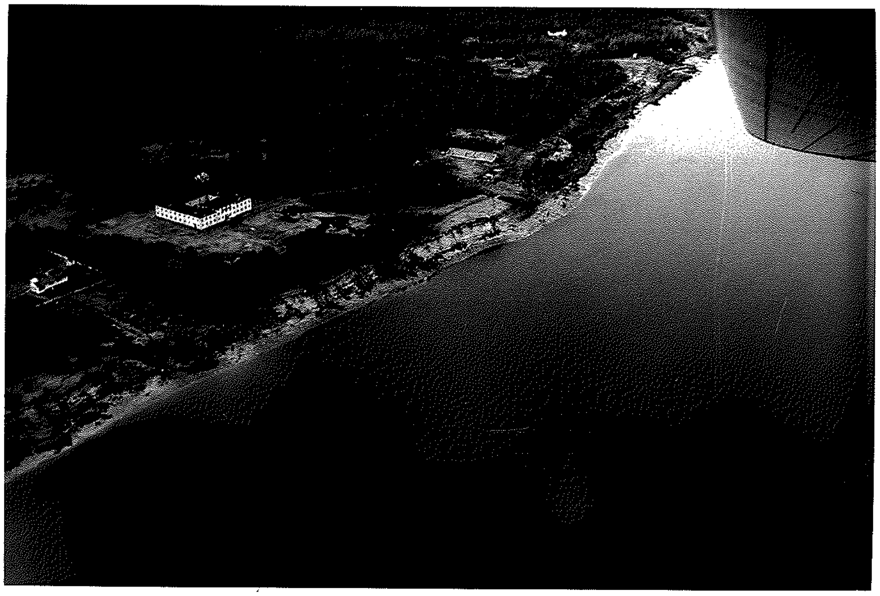


FIGURE 1.11

YORK FACTORY SITE

(Photo - R.W. Newbury, 1968)

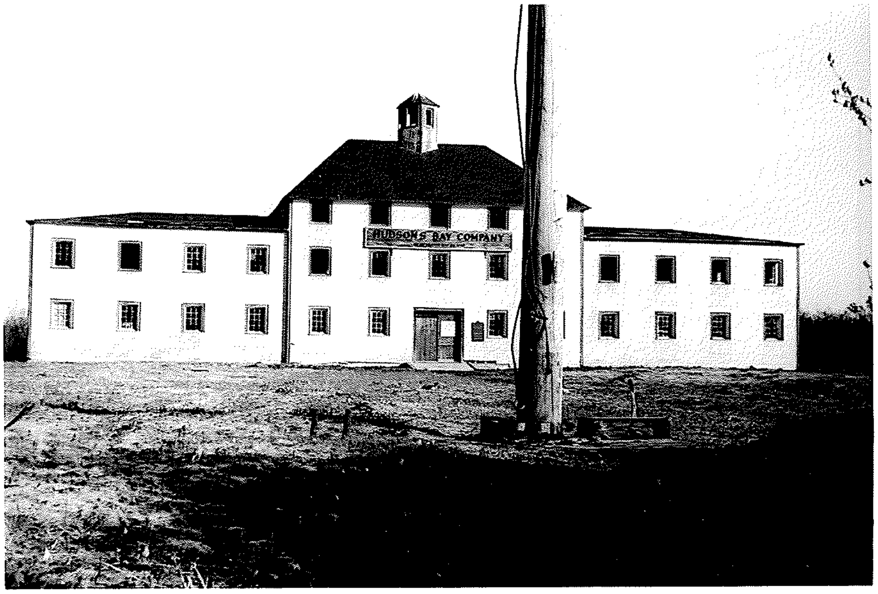


FIGURE 1.12

YORK FACTORY

(Photo - R.W. Newbury, 1968)

CHAPTER II

THE ENVIRONMENT

...the land seems from its quality
to have been thrown up by the sea...

Thomas Simpson 1830.

The pre-emergence stages in the evolution of the York Factory area were characterised by continual modification of boundary conditions and environmental patterns, during and following the deglaciation of northern Manitoba. To provide the regional setting of the area, prior to the description of the York Factory environment, a review of the Physiography (A-I.1), Climatic Patterns (A-I.3) and the Surficial Geology (A-I.4) of northern Manitoba and adjoining areas of the Hudson Bay lowlands is presented in Appendix A.

2.1 PHYSIOGRAPHIC, SOIL & VEGETATION PATTERNS

Beacon Point, the peninsular tract of land between the estuaries of the Nelson and Hayes Rivers is traversed by a series of beach ridges and inter-beach areas (Figure 2.1). The majority of the beaches possess limited relief, but their presence in the landscape is strongly emphasized by the soil and vegetation response (Figure 2.2). The abandoned beaches are colonised by stands of white spruce (Figure 2.3), the inter-beach areas are dominated by willow-fen (Figure 2.4) and temarack-fen associations (Figure 2.5).

The Hayes Estuary

The Hayes estuary (Figure 2.6) is two miles across at Marsh Point, narrowing to half a mile in width at the head of tidewater, near the southwestern end of Fishing Island. Several islands and numerous shoals are located along the estuary (Figure 2.1). The main channel follows the left bank (Figure 2.7), which is steeply cliffed and undergoing active seasonal erosion, on account of its southern aspect and permafrost condition (2.3; 4.3). At York Factory cliffs up to thirty feet high occur. The cliffs continue to increase in height upstream. At the head of tidewater, near the upstream end of Fishing Island almost vertical river cliffs of sixty feet in height occur. The northwestern bank of Hayes River possesses numerous slump scars, as a result of seasonal mass movement processes (4.3). The southeastern bank on the other hand is aggrading. A distinct bluff (Figure 2.8), south of the present channel is indicative of the migratory trend of the Hayes towards the northwest. The complex of channels between the islands and the right bank have partly silted up, but are maintained by peak flow intervals and spring flooding due to ice accumulation in the estuary. Several right bank tributaries in the lower estuary have been important historically as anchorages for French and British ships. These streams which occupy relatively broad valleys with stable vegetated banks (Figure 2.8), contrast with the gullies of the northwestern bank; e.g. Four Mile Gully (Figure 2.9), Robinson's Gully (Figure 2.10).

Nelson Estuary

The Nelson estuary is fifteen miles across at its maximum width and narrows to one mile and a quarter at the head of tidewater, near Gillam and Seal Islands. At Flamborough Head, almost vertical cliffs reach 100 feet in height. River cliffs in the Nelson estuary are composed mainly of unstratified till materials, whereas the Hayes estuary is characterised by high banks of stratified marine and fluvial sediments. Cliffs are absent on the lower Nelson estuary along the northwest coast of Beacon Point, where the shoreline consists of a gently sloping, actively aggrading beach similar to the southeastern shore of the Hayes estuary.

The York Factory area can be subdivided into several environmental zones (Figure 2.11) based on topographic, soil and vegetation patterns which reflect the progression seaward of Beacon Point in the last few thousand years.

Detailed surveys of the soils and surficial deposits of the York Factory area are presented in Appendix B and Appendix C.

2.1.1 Mudflats

At Marsh Point, mudflats extend offshore for several miles (Figure 2.12). The landward limit of this zone is present high water mark. The mudflats possess a tacky blue-grey clay surface, studded with debris of cobble and boulder sizes. Mare's tails (*Hippuris*), and spike rushes (*Eleocharis*), which are tolerant of brackish conditions and tidal inundation are found immediately seaward of high water mark. The clump-like distribution of these species on the foreshore traps and stabilises sediment of dominantly sand size.

2.1.2 Backshore Zone

Extending inland of the normal high water mark is a zone subject to periodic inundation by exceptional high tide and storm waves. On the north and northwestern side of Beacon Point the landward limit of this zone is marked by a continuous driftwood line, 2-3 feet high and 15-30 feet wide (Figure 2.13). Sands and gravels are found in association with the driftwood debris (Figure 2.14). Towards the Hayes River side of Beacon Point the driftwood line becomes discontinuous and less well marked. The driftwood line is subject to breaching by ice pans driven onshore during the break-up period (Figure 2.15). The mode of formation of driftwood lines and the accumulation of beach materials is discussed in Chapter IV.

Sedges (*Carex spp*.), cotton grass (*Eriophorum*) and arrow grass (*Triglochin*) are the dominant colonisers of the Backshore Zone. Incipient soil development on the most recently emerged portions of Beacon Point, reflects the very poor drainage and the mildly alkaline, calcareous parent materials. The Marsh Point Series (Appendix B) consists of poorly drained Rego Gleysols, which are presently developing a layer of surface fen peat. These soils which were formerly submerged by brackish water are now subject to periodic inundation.

2.1.3 Beach Ridge/Willow-Fen Zone

This zone is characterised by a sequence of fossil beach and inter-beach lagoonal areas. Along the Nelson River side of Beacon Point the beaches parallel the coastline of the lower estuary and are closely spaced. The ridges extend across the peninsula in broad arcs, as illustrated in Figure 2.1 and are truncated along the northwest bank of Hayes River. The truncation is due to continued erosion along the southeastern side of Beacon Point, associated with the migration of the Hayes channel towards the northwest (4.2). Tyrrell (1913, p. 183) estimated that the Hayes River was cutting away its northwestern bank at the rate of about three feet in a year.

Due to the subsequent colonisation of the beaches by stands of white spruce, it is difficult to assess the lateral extent of the initial beach forms. Several miles inland from Marsh Point where the ridges are colonised by white spruce (*Picea glauca*), willows (*Salix spp*.) and tamarack (*Larix laricina*), they are 300-500 feet in width. The height of the beach crests above the level of the inter-beach lagoonal areas varies from 2-3 feet.[1] On the more recently formed beaches gravels are still visible on the surface (Figure 2.16). Farther inland on the forested ridges a dense mat of mosses and undecomposed fibrous peat mantles their surface. Under the surface peat cover, stratified alternate layers of peat and alluvium attest to the periodic inundation of the ridges by floodwater.

The beach ridges of Zone 3 are associated with the Machichi Soil Series (Figure 2.17, Appendix B), imperfectly drained Cryic Cumulic Regosols. Soils of the inter-beach areas in Zone 3 are classified as the Hayes River Series, which have developed on shallow to deep mesic fen peat and alluvium.

The most recently formed beaches are colonised by sea lyme grass (Elymus), sandworts (Arenaria), soap berry (Shepherdia), willows and rushes (Juncus balticus). The mat-like

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[1] The subsequent up-doming of abandoned beach ridges as a result of the development of permafrost in the better drained sites provided by the ridges, makes it impossible to accurately determine the height of the crest of the original beach form.

vegetation on the ridges tends to trap and stabilise sandy and silty materials, during flood periods. On the Nelson River side of Beacon Point, balsam poplar (*Populus balsamifera*) are common on recently emerged ridges.

The "younger" willow-fen environments, with extensive tracts of open water (Figure 2.18) support colonies of horse tails (*Equisetum*), cotton grass (*Eriophorum*), dock (*Rumex spp*.) and marsh fleabane. Further inland willows increase in importance and eventually dominate the fen vegetation.

By the third beach ridge inland from Marsh Point, balsam poplar and isolated white spruce have become established. Farther inland mature stands of white spruce, tamarack and willow form the tree layer on the beaches, under which occurs a shrub layer of alder (*Alnus*) and dwarf birch (*Betula grandulosa*). Spruce occupy the crest of the ridges, there being a gradation outward from the centre to the willow-fen. Below the shrub layer, a herb stratum of willow, wintergreen, ground orchids, dwarf raspberry and various lichens is present.

2.1.4 Beach Ridge/Tamarack - Fen Zone

Approximately four miles inland from Marsh Point along the York Factory baseline tree cover becomes continuous (Figure 2.18). The beach ridges are recognizable because of the mature spruce stands, but the relatively open willow-fen is replaced by tamarack-fen (Figure 2.19). Beach ridge vegetation is essentially similar to that of Zone 2.1.3. The inter-beach areas however are dominated by open stands of tamarack, with a shrub layer of birch and willow. The ground stratum of sedges and herbs is similar to that of the willow-fen.

2.1.5 Levee Zone

Along the northwestern bank of Hayes River there occurs a calcareous, medium to fine textured alluvial deposit, which has resulted from former and continued inundation by floodwater. Part of this zone is no longer subject to flooding from the Hayes channel, but in the lower estuary where bank elevation is less than 12-15 feet,periodic inundation occurs, probably due to the break-up when the ice accumulation in the estuary causes the Hayes

River to overflow its banks. The Levee Zone is delimited primarily on the basis of its soil characteristics. Gleyed Cumulic Regosols (Ten Shilling Series: Appendix B) have developed, which possess a thin peaty surface layer, underlain with alternate layers of peat and alluvium (Figure 2.20). The overbank flooding has inhibited continuous organic accumulation. The vegetation consists of white spruce, willows and feather mosses.

2.2 STRATIGRAPHY AND SURFICIAL DEPOSITS

The York Factory Baseline

During the 1969 and 1970 field seasons a baseline was cleared and surveyed from York Factory to Marsh Point. The baseline was used primarily to determine the existing topographical patterns on Beacon Point, and to provide a representative traverse of the succession of beach and inter-beach areas which extend across the peninsula. The baseline (Figure 2.18) also served as a means of access for botanical and pedological reconnaissances. Selected sites along the baseline were investigated in detail, particularly those inter-beach areas with organic micro-relief features. A closed circuit of levels (Figure 2.21) was run along the estuarine beach on the northwestern bank of the Hayes River during the 1970 field season, to establish the altitude of the stratigraphic units which overlie the fossiliferous marine clays. The slope of the Hayes channel downstream of Fishing Island was recorded.

Stratigraphic Investigations

Stratigraphic relationships at thirteen selected sites[2] along the northwest bank of Hayes River were examined (Figures 2.1 and 2.21).

General Stratigraphic Succession

The general stratigraphic succession encountered along the northwestern bank of Hayes River is illustrated in Figure 2.22. Recent peat and alluvial materials overlie a general coarse over fine sequence of marine sediments. The latter sequence consists of (i) marine fossiliferous clays overlain by (ii) a sandy clay/clayey sand unit, (iii) a fine to medium sand unit, and (iv) a coarse sand and gravel unit with cobbles and boulders. Shells collected from the marine sequence were identified as <u>Macoma balthica</u>, a subarctic marine species. The shells examined indicated a healthy condition of the living

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[2] Sites were chosen where recently observed slumping of the river bank had produced fresh exposures.

specimen, suggesting that the environment was truly marine, with no brackish or fresh water present.[3] Several lines of evidence indicate that the marine sand and gravel unit is part of a regressive shore facies (3.3.3).

Detailed stratigraphic data for sites 1-13 are summarised in Appendix C. The topographic profile of Beacon Point, northeast of York Factory, with the generalised soil, vegetation and stratigraphic patterns superimposed is presented in Figure 2.18.

Radiocarbon Dating

Samples of wood, extracted from the continuous sand and gravel unit were radiocarbon dated. The sampled sites (Figures 2.1 and 2.21) were chosen in order to provide a representative sequence of dates along the northwest bank of Hayes River, from a point eleven miles inland seaward to Marsh Point.

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[3] Personal communication, Mrs. Irene Lubinsky, Department of Zoology, University of Manitoba.

2.3 PERMAFROST AND PEAT LANDFORMS

In the York Factory area there occurs a variety of peat landforms, in various stages of development, whose presence is closely related to a permafrost[4] condition. In Manitoba the southern limit of permafrost coincides approximately with the 30°F mean annual isotherm. North of the 25°F isotherm permafrost is widespread; north of the 20°F isotherm permafrost is continuous (Brown 1964). The transitional boundary between the continuous Permafrost Zone and the Discontinuous Zone in northern Manitoba occurs in the vicinity of York Factory. Zoltai and Tarnocai (1969) have delineated several permafrost zones in Manitoba, based on the occurrence of permafrost features, and related to broad ecological patterns (Figure 2.23).

Permafrost Occurrence

In terms of broad regional climatic patterns the York Factory area lies within the Continuous Permafrost Zone. Field investigations indicate however that local terrain conditions, particularly

---

[4] Permafrost, or perennially frozen ground has been defined exclusively on the basis of temperature, referring to the thermal condition under which earth materials exist at a temperature below 32°F (0°C) continuously for a number of years. Permafrost includes ground which freezes in one winter, remains frozen through the following summer and into the next winter. This is the minimum limit for the duration of permafrost. (Brown 1969, pp. 13-14).

drainage, have produced a discontinuous permafrost pattern. In addition emerging habitats from Hudson Bay, hitherto unexposed to the influence of a subarctic climate on their ground thermal regime, are not frozen. Inter-beach fen areas also exhibit a patchy occurrence of permafrost, perennially frozen ground being confined to organic micro-relief features (Figure 2.24). In general permafrost distribution mirrors the local pattern of better drained sites (beach ridges, palsas and peat plateaux) which are found on Beacon Point. The development of permafrost following emergence, and its role as a geomorphic agent operative during the evolution of the present environmental patterns of the York Factory area is discussed in Section 4.3.

Distribution of Permafrost in the York Factory Area

Palsas

In the inter-beach zones northeast of York Factory low mounds of peat rise above the general levels of the willow-fen (Figures 2.25 and 2.26). These perennially frozen peat mounds are known as palsas, in this instance minerotrophic palsas, since intermittent inundation by floodwater from the Hayes channel maintains a base-rich environment for peat accumulation (Figure B-3, Table B-12). The palsas rise approximately three feet above the general level of the willow-fen (Figure 2.27) and may be up to 200 feet in diameter.

Cryic Cumulo Mesisols (York Fort Series: Appendix B) which are neutral to mildly alkaline (pH 7.0-7.5) have developed on the palsas. Plant cover is sparse (Figure 2.28). Species recorded are more akin to those found in Tundra environments, reflecting the palsa micro-climate conditioned by local topographic, drainage and thermal ground patterns within the willow-fen. Herbaceous plants, dominantly sedges, together with Lapland buttercup, dwarf raspberry, false asphodel, spike moss and dwarf scouring rush were recorded. Low woody shrubs such as soap berry, dwarf willow and dwarf birch, along with alpine blueberry and red bearberry are also common. Where trees are present, these are white spruce and/or tamarack.

"Black Spruce Islands"

West and southwest of York Factory within the tamarack-fen zone, there occur isolated and linear belts of "black spruce islands" (Figure 2.29). The distribution of these wooded peat plateaux with perennially frozen cores coincides with the pattern of abandoned beach lines, the latter providing better drained sites conducive to the development of permafrost. The wooded peat plateaux contrast with the minerotrophic peat accumulations of the willow-fen zone. Peat plateaux are ombrotrophic, precipitation being the primary source of moisture and mineral salts.

The peat plateaux of the York Factory area represent the accumulation of Sphagnum and forest peat (Seal Creek Series and Woodcock Series respectively: Appendix B). Although the peat plateaux do exhibit a sequence of organic and alluvial layers, they are not presently subject to flooding by base-rich water (Figure B-3, Table B-12). Consequently the soils are extremely acid. The vegetation consists of black spruce (*Picea mariana*), *Ledum* and *Cladonia* species with a shrub layer of willow and birch, and low woody colonies of black crowberry, small cranberry, blueberry and lichens.

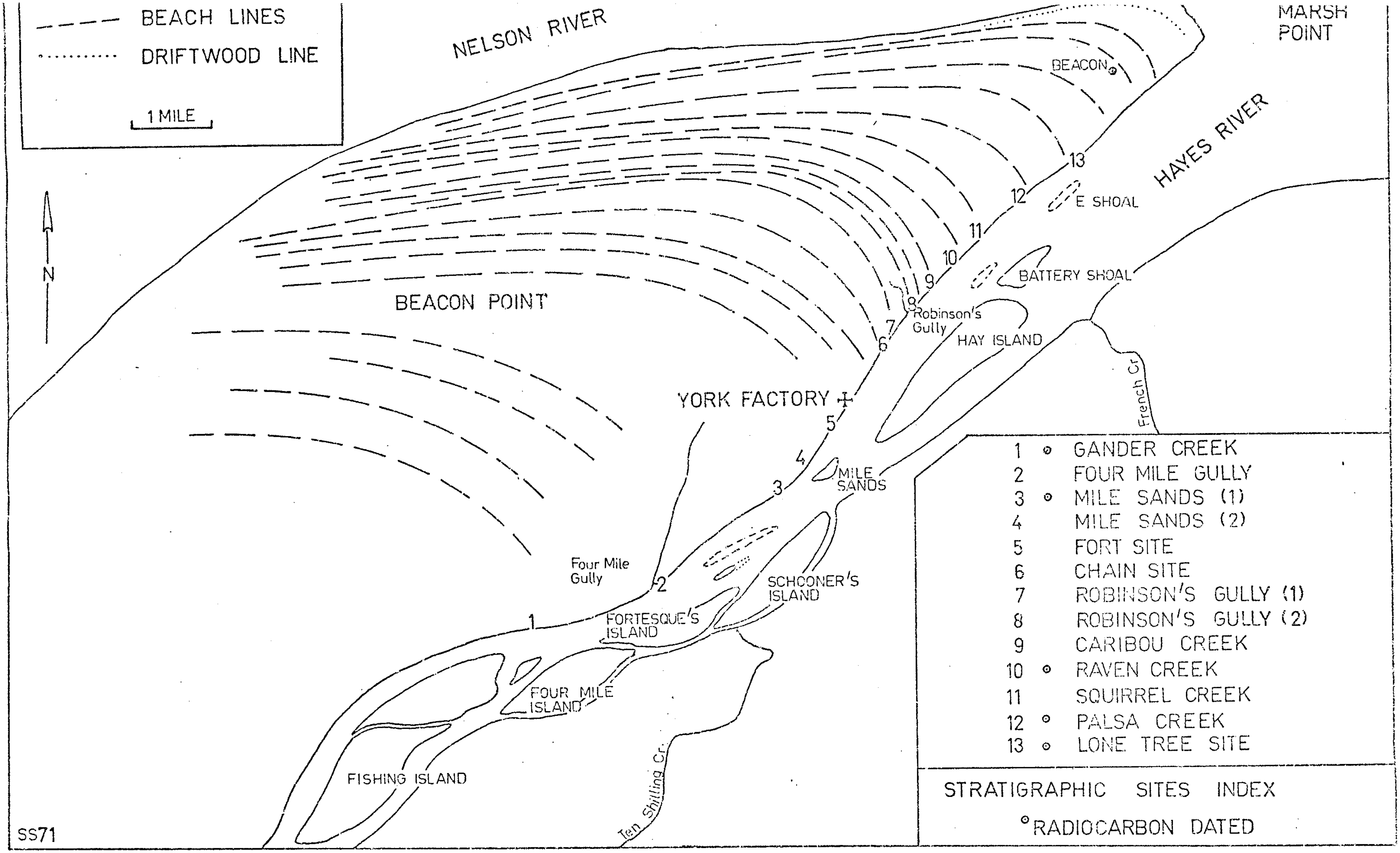


FIGURE 2.1

THE YORK FACTORY AREA, HUDSON BAY

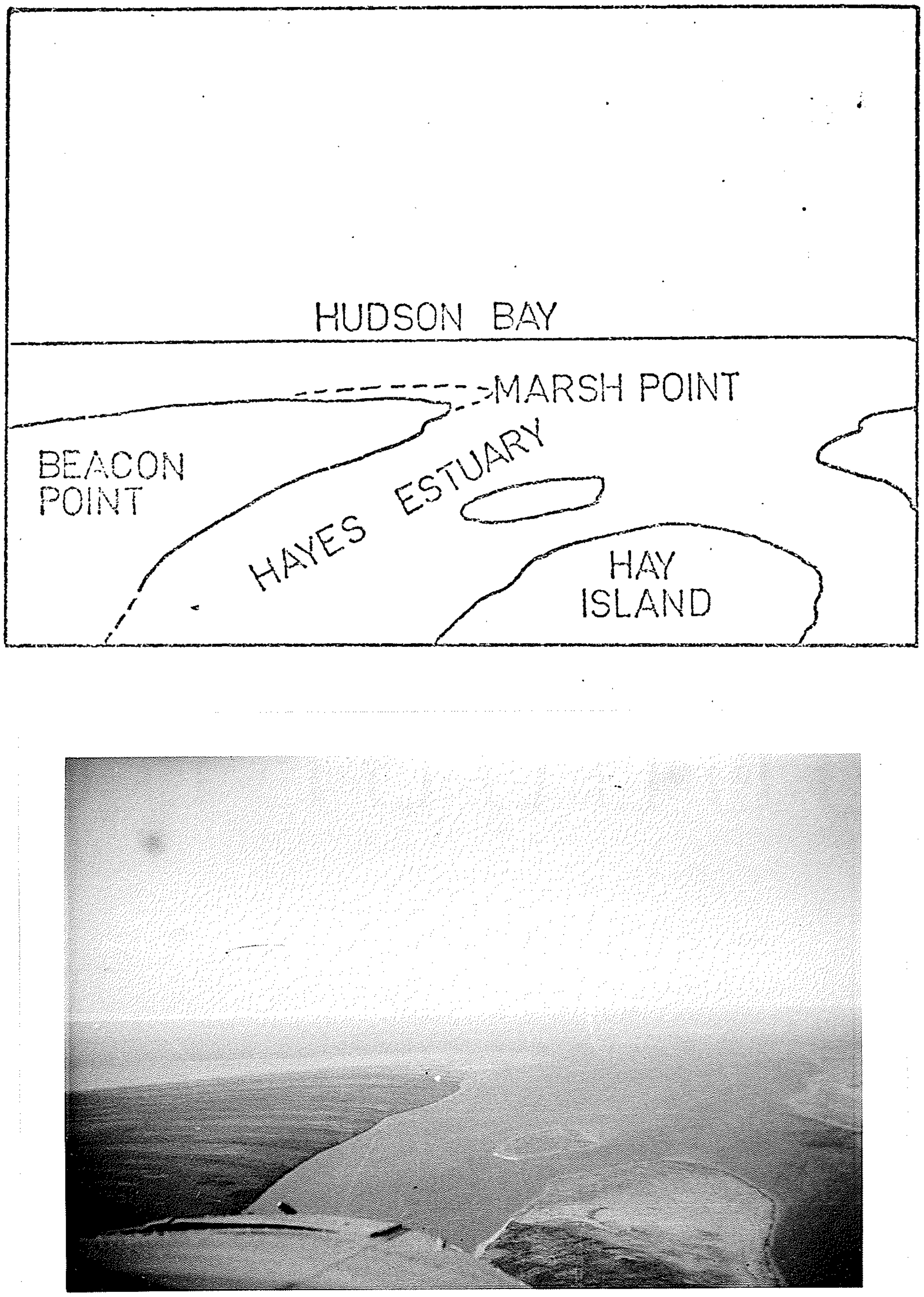


FIGURE 2.2

BEACON POINT AND LOWER HAYES ESTUARY

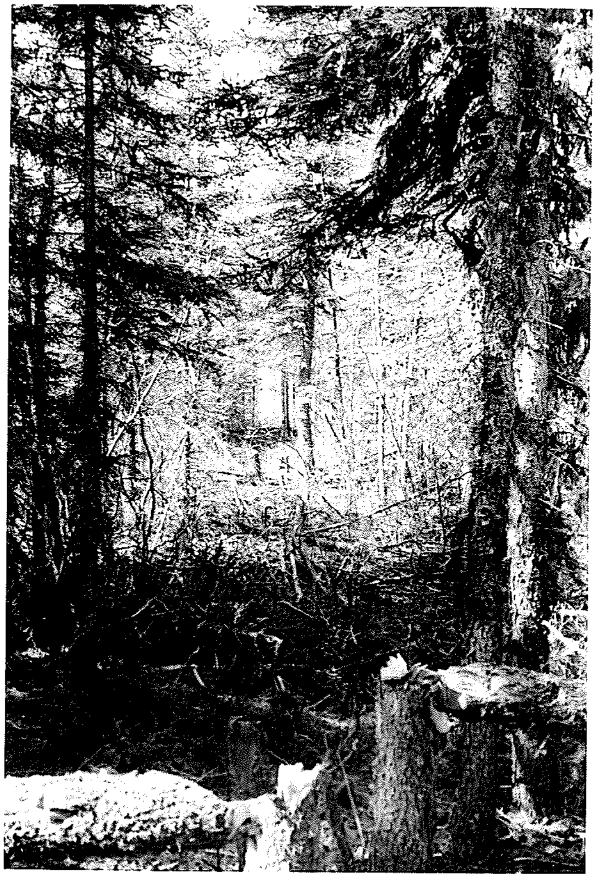


FIGURE 2.3

WHITE SPRUCE STANDS ON
ABANDONED BEACH LINE, BEACON POINT

FIGURE 2.4

WILLOW FEN (FOREGROUND) WITH
WHITE SPRUCE STANDS ON ABANDONED BEACH LINE

FIGURE 2.5

TAMARACK FEN

(In background white spruce on abandoned beachline)

FIGURE 2.6

AERIAL PHOTOGRAPH MOSAIC OF THE YORK FACTORY AREA

(Scale 1 inch = 5 miles)

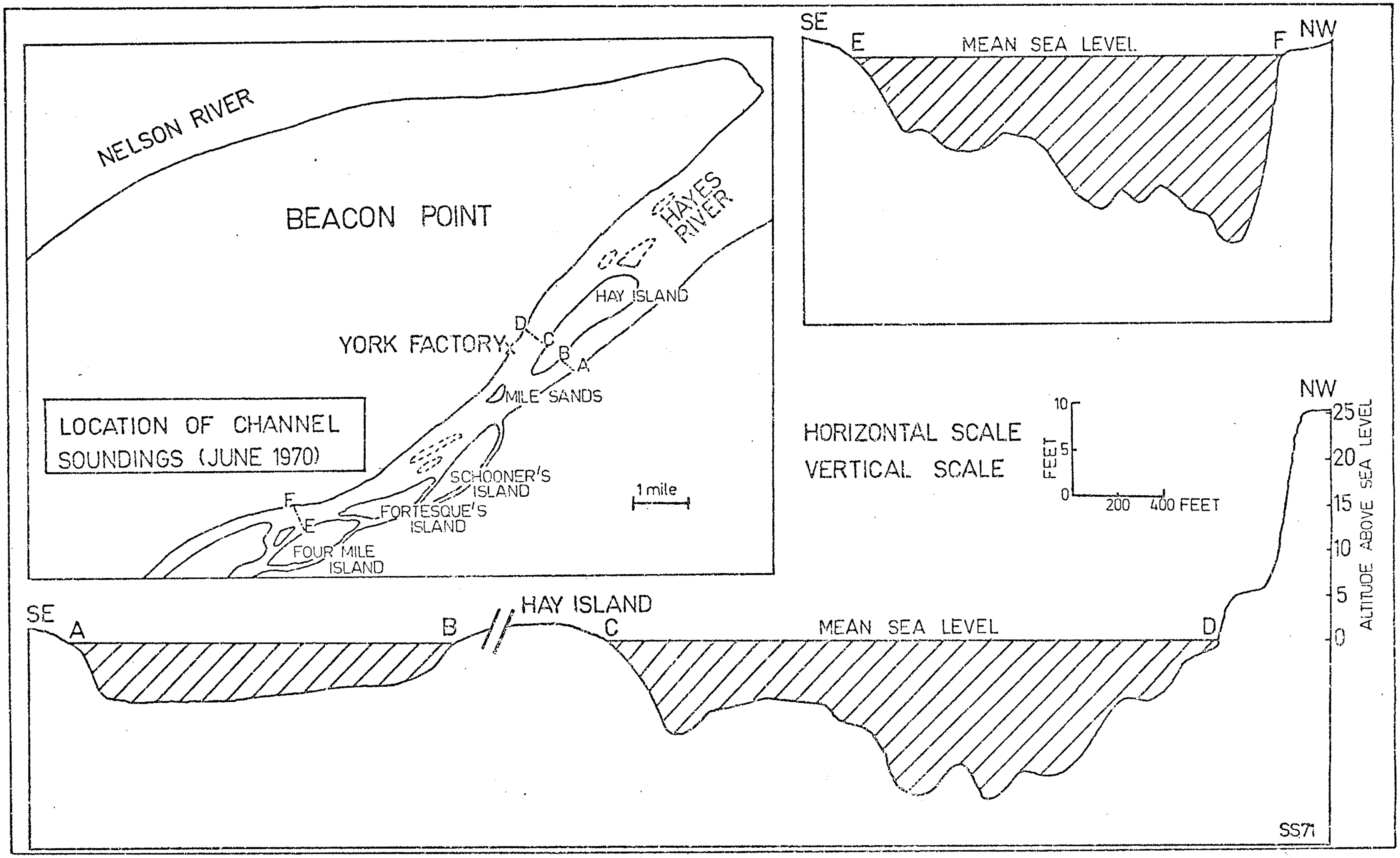


FIGURE 2.7

CHANNEL CROSS SECTIONS, HAYES ESTUARY

FIGURE 2.8

TEN SHILLING CREEK

The river bluff southeast of the creek (top of photograph) is accentuated by the change in vegetation and marks the approximate boundary of stratified sediments.

FIGURE 2.9

FOUR MILE GULLY

FIGURE 2.10

ROBINSON'S GULLY

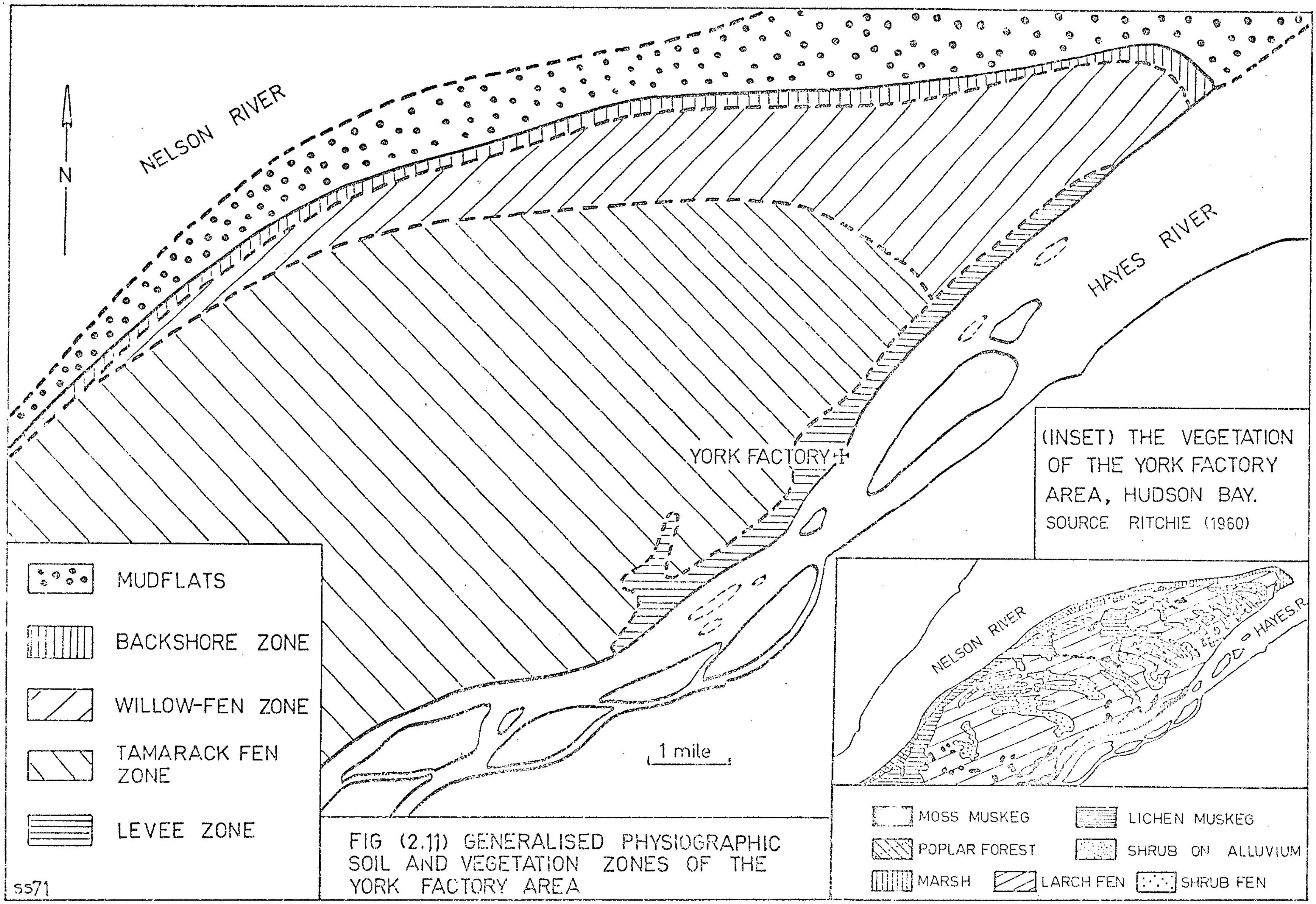


FIG (2.11) GENERALISED PHYSIOGRAPHIC SOIL AND VEGETATION ZONES OF THE YORK FACTORY AREA

(INSET) THE VEGETATION OF THE YORK FACTORY AREA, HUDSON BAY.
SOURCE RITCHIE (1960)

FIGURE 2.12

MUDFLATS AT MARSH POINT

FIGURE 2.13a

BACKSHORE ZONE AT MARSH POINT

The willows to the extreme left of the photograph mark the position of the driftwood line.

FIGURE 2.13b

DRIFTWOOD LINE AT MARSH POINT,
INTER-BEACH ZONE AND SECOND BEACHLINE INLAND,
THE LATTER COLONISED BY WILLOW AND POPLAR STANDS.

FIGURE 2.14

COARSE GRAVEL MATERIAL ON DRIFTWOOD LINE.

IN THE BACKGROUND THE BACKSHORE ZONE & HUDSON BAY.

FIGURE 2.15

DRIFTWOOD LINE BREACHED BY
ICE PANS DRIVEN ONSHORE

FIGURE 2.16

GRAVEL AND COBBLE SIZED DEBRIS
ON THE THIRD BEACH INLAND FROM MARSH POINT

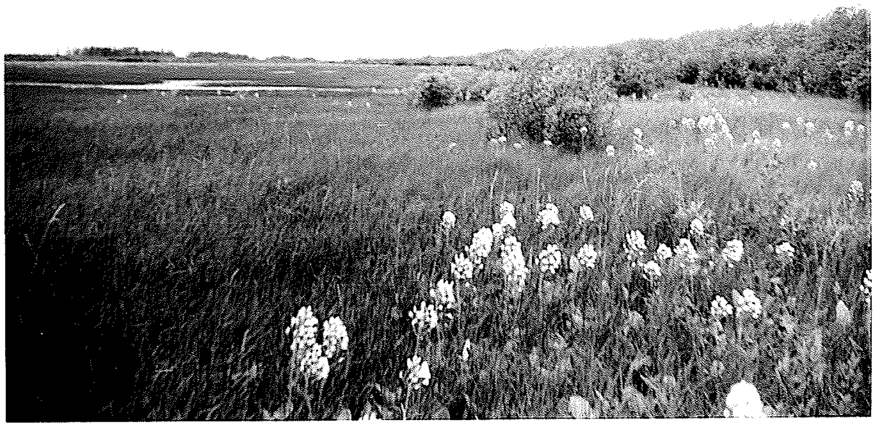


FIGURE 2.17

INTER-BEACH WILLOW FEN ZONE

BETWEEN SECOND AND THIRD BEACHES

INLAND FROM MARSH POINT

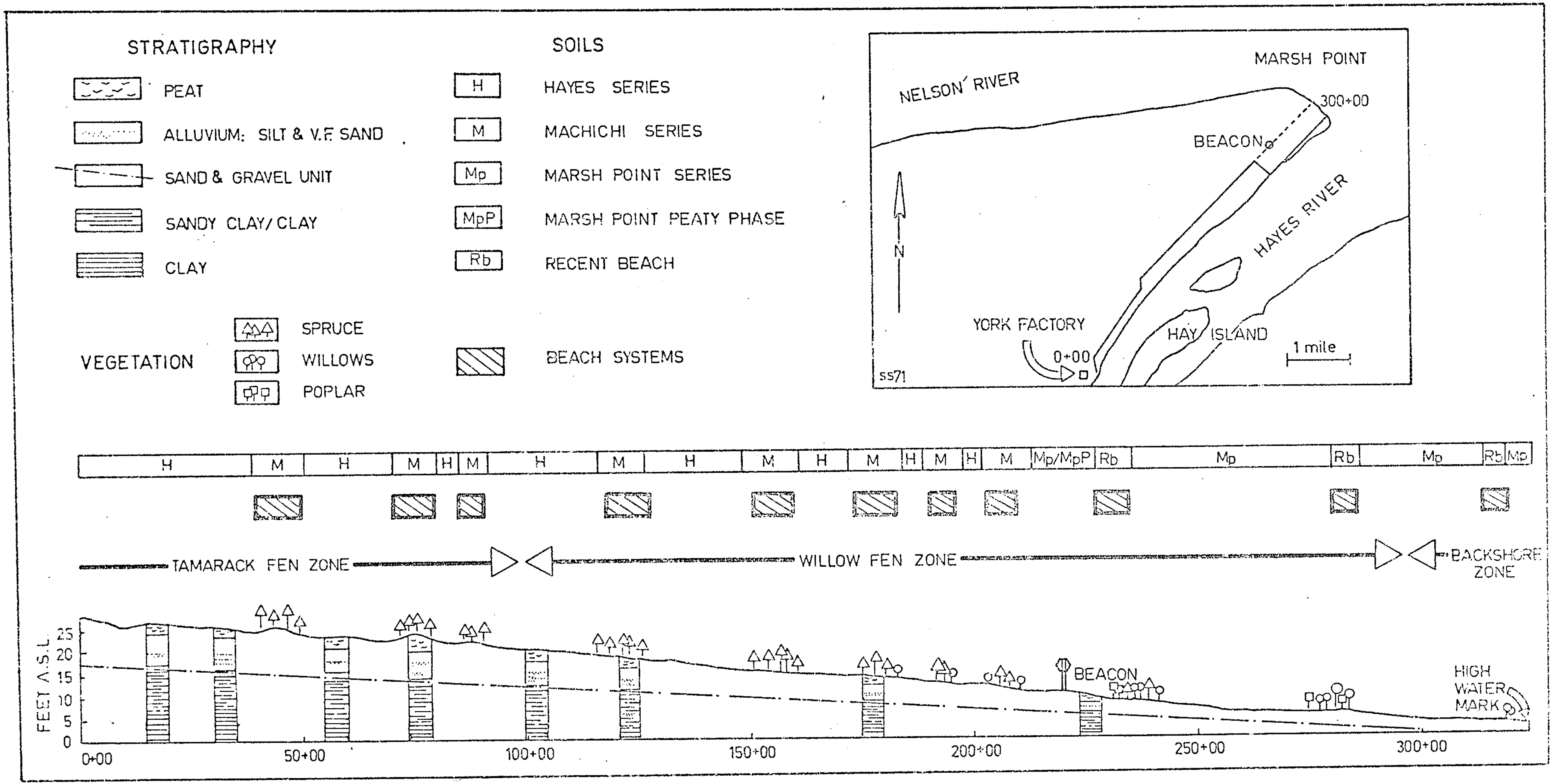


FIGURE 2.18

THE YORK FACTORY BASELINE

FIGURE 2.19

TAMARACK FEN

FIGURE 2.20

OVERBANK DEPOSITS, PREDOMINANTLY SILT,
WITH ORGANIC AND CLAY LAYERS
NORTHWEST BANK OF HAYES RIVER (LEVEE ZONE).

The profile is classified as the
Ten Shilling Soil Series (Appendix B).

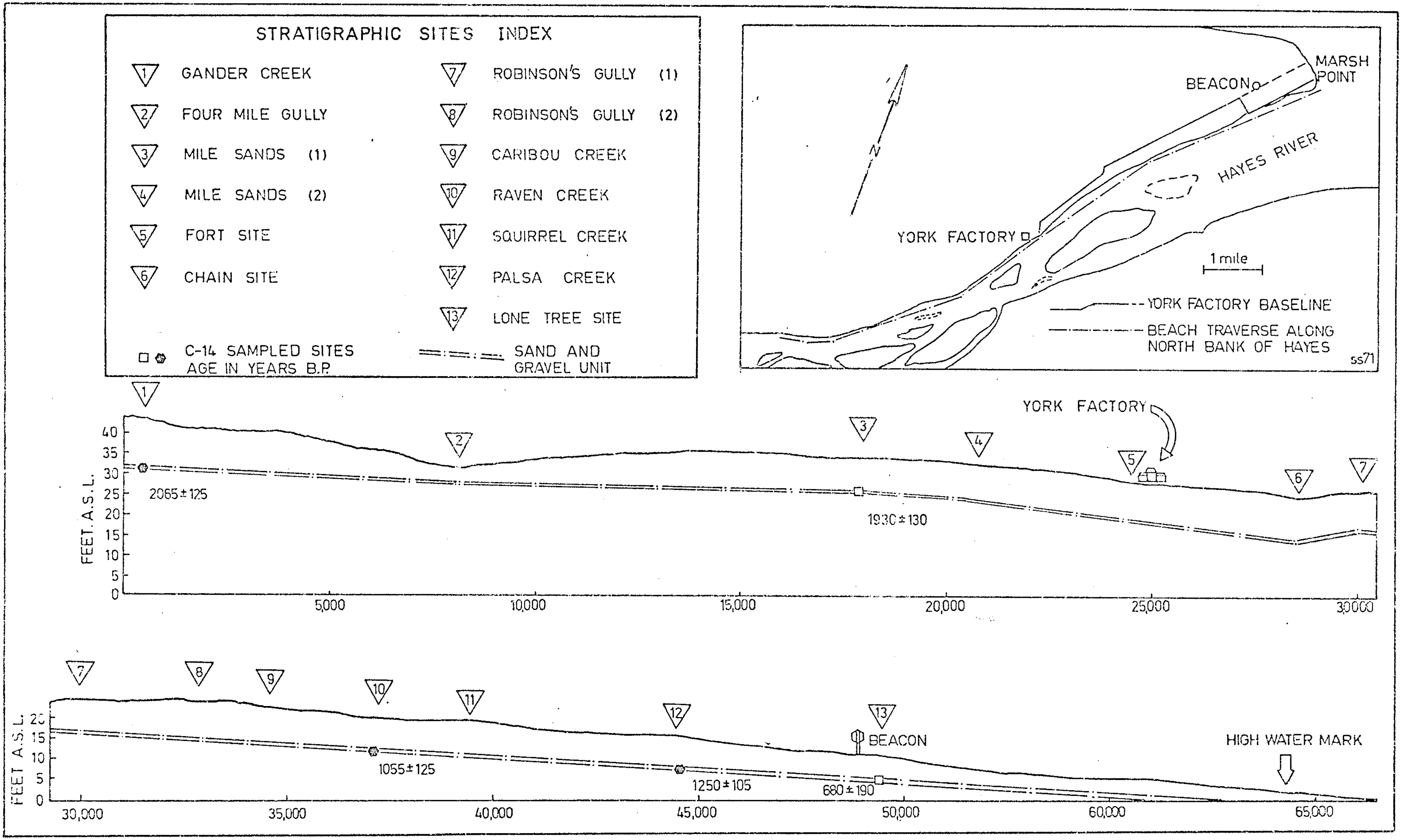
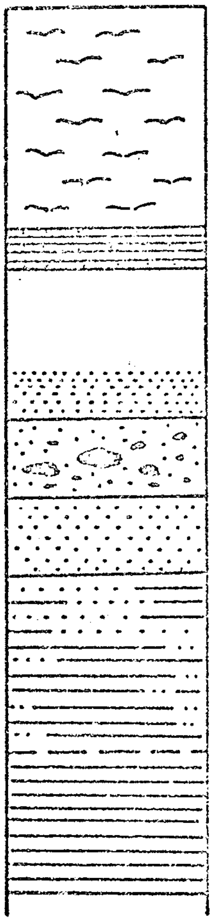


FIGURE 2.21

STRATIGRAPHIC SITES:



UNIT	DESCRIPTION
6	PEAT: LARGELY UNDECOMPOSED
5	ALLUVIAL MATERIALS: DOMINANTLY SILT AND FINE SAND; ALTERNATE SILT AND ORGANIC LAYERS AT TOP OF UNIT; FINE CROSS BEDDED SAND AT BASE OF UNIT
4	COARSE SAND AND GRAVEL, COBBLES AND BOULDERS: MARINE SHELLS
3	FINE TO MEDIUM SAND, WITH SOME INCLUSIONS OF CLAY
2	CLAYEY SAND/SANDY CLAY
1	MARINE FOSSILIFEROUS CLAYS

FIGURE 2.22

GENERALISED STRATIGRAPHIC SUCCESSION,
NORTHWESTERN BANK OF HAYES RIVER,
YORK FACTORY AREA, MANITOBA

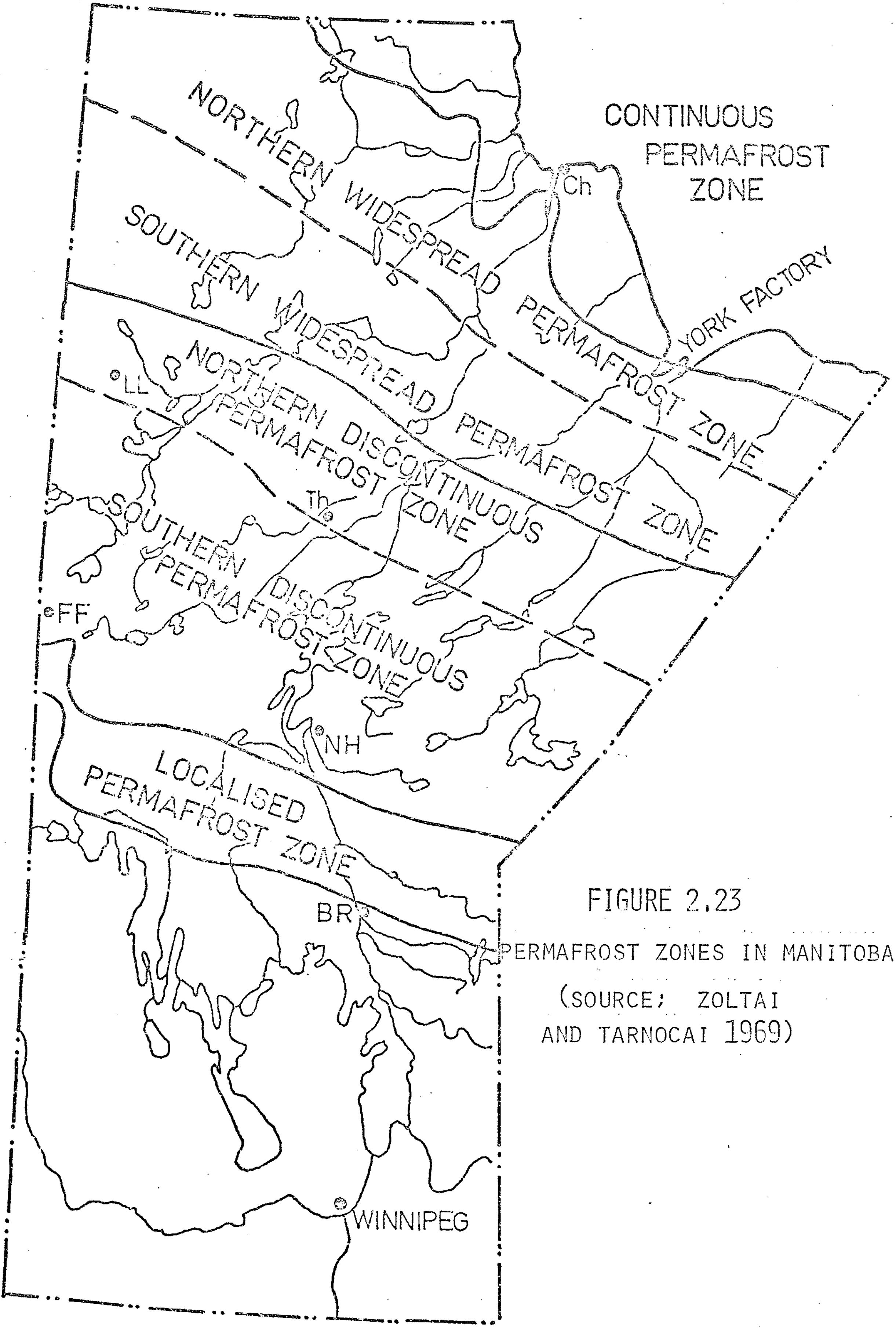


FIGURE 2.23

PERMAFROST ZONES IN MANITOBA

(SOURCE; ZOLTAI AND TARNOCAI 1969)

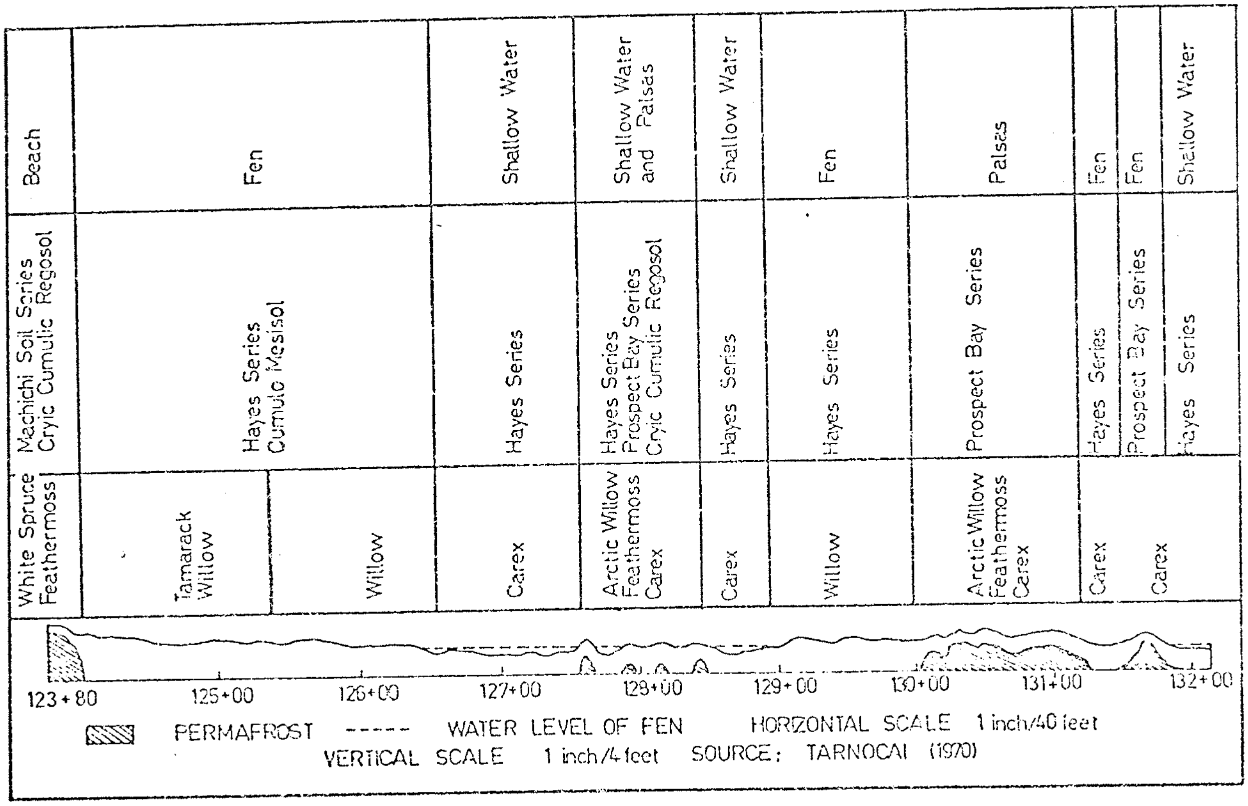


FIGURE 2.24

INTER-BEACH FEN ZONE

YORK FACTORY BASELINE

FIGURE 2.25

MINEROTROPHIC PALSA,
INTER-BEACH FEN ZONE

FIGURE 2.26

MINEROTROPHIC PALSA, INTER-BEACH FEN ZONE.
BEACH LINE IN BACKGROUND COLONISED BY WHITE SPRUCE.

FIGURE 2.27

PALSA (IMMEDIATE LEFT FOREGROUND)
RISING ABOVE GENERAL LEVEL OF THE WILLOW-FEN

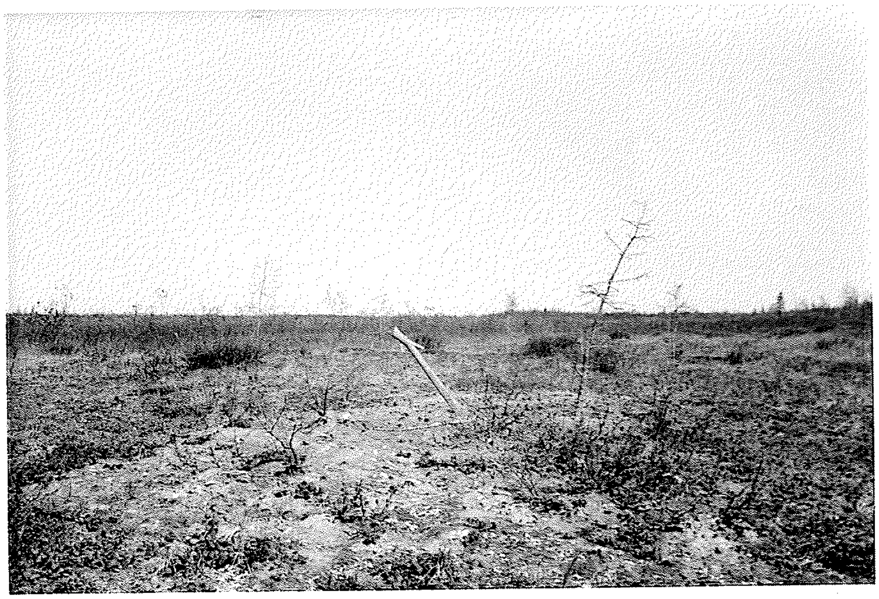


FIGURE 2.28

SPARSELY VEGETATED SURFACE
OF MINEROTROPHIC PALSA

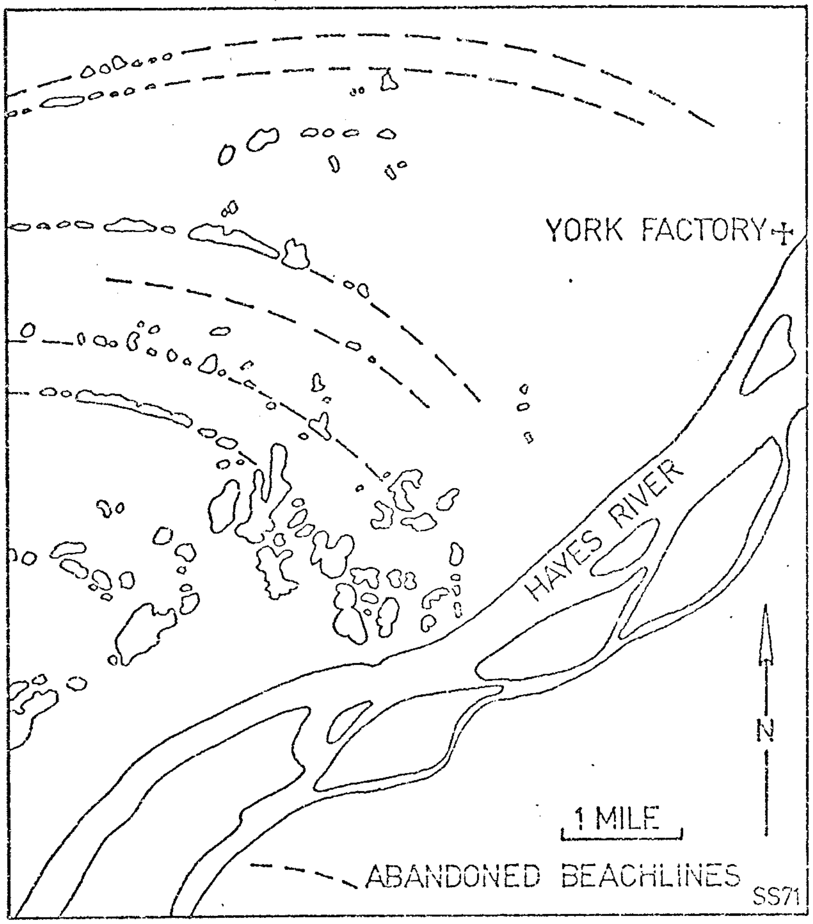


FIGURE 2.29

DISTRIBUTION OF PEAT PLATEAUX
WEST AND SOUTHWEST OF YORK FACTORY

CHAPTER III

CRUSTAL REBOUND

You have only to take in what you please and leave out what you please; to select your own conditions of time and place; to multiply and divide at discretion; and you can pay the National Debt in half an hour. Calculation is nothing but cookery.

Lord Brougham 1849

Endogenetic processes within the earth's crust affect the gross evolution of landscapes. Crustal movements are basically of two kinds; those that originate at depth in the earth's crust or subcrustal layers, and those which occur in response to the loading and unloading of the earth's surface.

Isostasy

The surface of the earth responds to the changes of load placed upon it. The transfer of materials from one part of the earth's surface to another sets up stresses within the crust, which trigger a process of isostatic[1] adjustment, whereby lateral transport of materials at the earth's surface by erosion and deposition is compensated by lateral movement of materials in a subcrustal layer. Glacio-isostasy represents a specific occurrence of isostatic adjustment for a particular segment of the earth's crust, following the growth and decay of large masses of ice

Glacio-isostasy

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[1] The term "Isostasy" derived from the Greek word "isostasios" inferring equal standing, refers to an ideal condition of flotational balance among segments of the earth's crust.

on the earth's surface. The accumulation of an ice sheet depresses the earth's crust.[2] Unloading, during and following the melting of ice sheets results in the uplift of the depressed crustal segment, which subsequently rises towards the preglacial state of isostatic equilibrium. The latter process involves the horizontal transfer of a mass of mantle material at depth equivalent to that of the ice.

In the York Factory area contemporary crustal rebound during the last 2,500 years has resulted in continued marine regression and the emergence of Beacon Point. Previous investigations of glacial rebound in the vicinity of the York Factory area are reviewed in Sections 3.1 and 3.2. Evidence of crustal rebound during the evolution of Beacon Point is presented in Section 3.3. The nature and rate of emergence and uplift during the last 2,500 years is discussed in Section 3.4.

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[2] In the simplest analysis, an ice sheet 2,500 metres thick having a density of 0.9 would displace mantle material with an average density of 3.3 so as to produce 682 metres lowering of the crust (Farrand 1968, p. 886).

3.1 EARLY INVESTIGATION

Tyrrell 1896

Tyrrell (1896) examined several names cut in rocks at Sloops Cove, two miles from Fort Prince of Wales, near Churchill. The names were carved by sailors at various times between 1741 and 1753. Tyrrell concluded from the position of the names relative to present sea level that "...there has been no great change in the relative heights of land and water..." since the middle of the 18th Century.

Bell 1896

The same evidence at Sloops Cove was used to indicate not stability, but a fall in sea level. Bell (1896) estimated that "the relative level of the sea and land in this vicinity is changing at the rate of about seven feet in a century".

O'Sullivan 1906

O'Sullivan (1906) mapped the shoreline to the east of York Factory, and found a succession of old beaches which he concluded were indicative of land rise along the southern coast of Hudson Bay.

> From Ship river, old wave made beaches or sand ridges lie parallel to the water line most of the way eastward to Fort Severn.... Occasionally they are mixed with shells, driftwood and other debris and are from one to four chains in width and from half a mile to five miles in length. Near the tree line some of these ridges obtain an elevation of about 30 feet above the present water mark.... These facts show that the land is rising somewhat rapidly along the coast.[3]

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[3] O'Sullivan, O. 1906, A Survey of the Coast of Hudson Bay from York Factory to Severn River, Geol. Surv. Can. Summ. Rept. 1905, pp. 73-76.

McInnes 1913

McInnes (1913) based his estimates of the relative movements of land and sea on the occurrence of marine fossiliferous sediments in the Hudson Bay Lowlands:

> On Churchill river marine fossils have been found up to an elevation of about 350 feet above the sea, and similar clays extend farther up the river, though so far as observed, without fossils. On Nelson river shells were found in the clays at an elevation of about 200 feet, and the clays were observed at points considerably higher...
>
> In the region bordering the bay, farther to the east, the presence of these clays has been recognized on all the rivers explored; on Winisk river they have been found at an elevation of about 350 feet above the sea, and in a branch of Albany river at an elevation of 380 feet. The depression of the land, in reference to sea-level during the period immediately following the deposition of the boulder clays was, therefore, at least as much as 380 feet, and probably a little more.[4]

3.2 RECENT INVESTIGATIONS

Johnston 1939

Johnston (1939) supported Tyrrell's conclusion that uplift had ceased along the western coastline of Hudson Bay.

> Re-determination of the elevation of the names cut on the rocky walls of Sloops Cove near Churchill on Hudson Bay in the 18th Century, confirms Tyrrell's conclusion that little or no uplift of the coast at Churchill has occurred since the names were cut....the

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[4] McInnes, W. 1913, The Basins of the Nelson and Churchill rivers, Can. Dept. Mines. Geol. Surv. Mem. No. 30, p. 69.

> prime cause of post-glacial uplift was the removal of the ice sheet; this cause has apparently long ceased to act at Hudson Bay.[5]

Gutenberg 1941,1954

Gutenberg (1941) concluded from an investigation of tide gauge records at Churchill for the period 1928-39 that

> ...the present rate of uplift of the coast near Churchill exceeds one meter per century and is probably nearer two meters per century; even a value of three meters per century must be considered as possible...[6]

Gutenberg (1954) revised his earlier estimates of the rate of uplift, since they were considered inaccurate due to the poor location of the tide gauge at Churchill. Revised data based on longer term summer averages indicated an emergence of 1.05 ± 0.18 meters per century.

Barnett 1966, 1970

Barnett (1966) re-investigated the rate of uplift at Churchill, as indicated by tide gauge observations. Data for the period 1928-39 were rejected as unsatisfactory for reasons of tide gauge location and observational procedures. Statistical analysis of data for the period 1940-65, indicated a

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[5] Johnston, W.A. 1939, Recent changes of the land relative to sea level, Amer. Jour. Sci. (237) p.98.

[6] Gutenberg, B. 1941, Changes in sea level, post-glacial uplift and the mobility of the earth's interior, Bull. Geol. Soc. Amer. (52) p. 747.

rate of relative emergence of 0.02 feet per year or 2.00 feet (61 cms) per century. At Churchill the rate of emergence as recorded by the tide gauge includes the eustatic[7] rise of sea level, which is of the order of 12.0 cms per century.[8] After correcting for this eustatic change in sea level Barnett concluded that the Churchill area is undergoing isostatic uplift at the rate of 2.4 feet (73 cms) per century.

Barnett (1970) further investigated the rate of uplift at Churchill. Applying more rigorous statistical treatments to the extended data (1940-69) it is now concluded that emergence is occurring at only 1.3 feet per century. Addition of the eustatic rise in sea level results in an uplift value for the Churchill area of 1.75 feet (53 cms) per century.

Craig 1969

Radiocarbon dating of marine shells in the vicinity of Churchill (Craig 1969 pp. 73-74)

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[7] Changes in climate which alter the amount of ice on the land will affect world sea levels correspondingly. These changes in sea level are termed eustatic. A glacio-eustatic rise of sea level results from the melting of the ice sheets, the water subsequently being returned to the oceans.

[8] Barnett's eustatic factor is obtained from current sea level rise measured by tide gauges, summarised in Fairbridge (1961) and Russell (1957, p. 428).

indicate that the land was rising during the period 3,000-1,000 years B.P. at a rate of approximately 5.0 feet (1.52 metres) per century (Figure 3.1, Table 3.I).

3.3 EVIDENCE OF CRUSTAL REBOUND

(a) Contemporary Evidence

Tide gauge observations at Churchill, Manitoba, during the period 1940-68 provide evidence that the land is continuing to rise along the western coast of Hudson Bay. Present calculations of uplift after correction for the eustatic rise of sea level indicate that the land is rising at the rate of 1.75 feet (53 cms) per century (Barnett 1970, p. 626).

The contemporary emergence of the York Factory area since the end of the last century is evidenced by the progression seaward of the broad vegetation zones on Beacon Point. The beacon at Marsh Point (Figures 2.1 and 3.4) provides a careful landmark, by which to demonstrate the relative change in the distribution of vegetation zones since 1878. Bell's map illustrates the seaward limit of timber relative to the beacon (Figure 2.1). Today poplars and willows are found approximately one mile seaward (NE) of the beacon. A corresponding seaward progression of the zone of grasses and sedges between high water mark and the timber line has likewise occurred since the end of the last century.

A world wide rise of sea level is presently occurring[9] and in the order of 1.2 mm per year (Fairbridge 1961). Contemporary evidence from tide gauge data (1940-1968) and from the observed extension of vegetation zones seaward in the last one hundred years imply on the other hand that a fall in sea level is occurring along the south western coast line of Hudson Bay. Emergence of the York Factory area, while subject to a world wide rise in sea level is therefore indicative of contemporary uplift of the land at a rate exceeding the eustatic rise of sea level.

(b) Historical Evidence

A series of charts and surveys (Figures 3.2 to 3.7 inclusive) of the mouths of the Nelson and Hayes rivers provide historical evidence of the seaward progression of Beacon Point since the 17th Century.

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[9] The evidence for a rising sea level during the last 10,000 years, and the controversy regarding the nature of Holocene Sea Level changes is discussed by Jelgersma (1971).

Bell (1878b, p.32C) summarises the evidence indicative of a falling sea level along the East main coast of Hudson Bay and concludes that:

> The same phenomenon is manifest in the neighbourhood of the mouths of the Nelson and Haye's River. It is said that within the recollection of the generation preceding the present one the island called Mile Lands, [Mile Sands] just above the present site of York Factory was submerged at high tide. Now it is a dry island, several feet above high tide-mark....Four-mile Island has become overgrown with small poplars, while it is evident that at no very distant period Six-mile Island [Fishing Island] formed two islands, which are now covered with full-sized trees, while the old channel between them now supports a growth of tall bushes. Further up the river, similar dry channels, more or less ancient, separate former islands from the main shores, and the appearances indicate that the conditions which once existed here, have been removed further down the river. It is said that about the beginning of our present century [18th] some vessels wintered in Ten-Shilling Creek, which could not now approach its mouth, and an old sketch-map shews a channel connecting Haye's and Nelson Rivers [Penny Cutaway, Robson's Survey 1745: See Figure 1.5] which does not now exist. There is no evidence of the sea anywhere encroaching upon the land. On the contrary, the wide open border between the woods and the water indicates that the latter is retiring. On Beacon Point and the opposite side of Haye's River, in traversing this border from the sea inland, one meets first with sedge and grasses; next comes bushes, then small trees and finally, the full sized timber of the country. There is much old drift-wood near the tree-line, which is now apparently never touched by the water. The Indians say that their old goose hunting

> grounds along the coast to the northward of the mouth of the Nelson River are now deserted by the geese, the water having "dried up".10

(c) <u>Stratigraphic Evidence</u>

Stratigraphic relationships in an area may indicate former marine regression or transgression (Krumbein & Sloss 1963, Table 9.1 p. 315).

The stratigraphic succession in the York Factory area (Figure 2.22), provides evidence of former marine regression. Several lines of evidence confirm that the sequence of marine sediments represents a regression shore facies:

Marine Shore Facies

(i) The marine origin of the units underlying recent peat and alluvial materials is known from the presence of shells identified as a truly sub-arctic marine species.[11]

(ii) Radiocarbon dating of driftwood (Figure 2.21) extracted from the course sand and gravel layer (Unit 4, Figure 2.22) demonstrates that the unit becomes progressively younger towards Hudson Bay (i.e. towards the marine point of reference).

(iii) The coarse over fine sequence of marine deposits (Units 1-4, Figure 2.22) represents a classical offlap relationship (Krumbein & Sloss 1963 pp. 314-315), originating from marine regression.

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10. Bell, R. 1878b, Report on the Country between Lake Winnipeg and Hudson Bay, <u>Geol. Surv. Can. Report of Progress</u>, 1877-78 (VI) p. 25CC.
11. Personal communication: Mrs. Irene Lubinsky, Department of Zoology, University of Manitoba.

(iv) Contemporary sedimentation at Marsh Point involves (a) beach formation (Section 4.1) during periods when exceptional high water occurs in association with onshore NW winds, and (b) more or less continuous addition of sand and gravel and driftwood debris on top of the marine clays exposed on the mudflats. Tide gauge observations and the progression seaward of vegetation zones during the last hundred years confirm that sedimentation is occurring during a fall of sea level. In the light of the principle of Uniformitarianism[12] the operation of the observed sedimentation processes during a falling sea level, over a period of several thousand years would give rise to the stratigraphic sequence and the distribution of beach ridges presently found on Beacon Point.

It is concluded therefore that stratigraphic succession of the surficial deposits along the northwestern bank of Hayes River has resulted from sedimentation during a fall of sea level.

(d) Geomorphological Evidence

Tyrrell Sea Phase

In northern Manitoba the limit of the marine transgression (Tyrrell sea phase) which reached its maximum extent 7-8,000 years ago (Lee 1960, 1968) occurs between 400-500 feet above sea level. The extent of the marine inundation is known from the distribution of fossiliferous marine clays and wave

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[12] Processes which operate at present have continued to do so throughout the past, though not necessarily at the same rate.

modified landforms (Figure A-15). Extending seaward of the marine limit there occurs a succession of abandoned beach ridges which generally parallel the present coastline of Hudson Bay. The beaches are manifestation of deposition during the regression of the Tyrrell Sea.

At present available data indicate that world wide sea level has continued to rise throughout the last 10,000 years. Contemporary, historical, geomorphic and stratigraphic evidence from the Hudson Bay region demonstrate on the other hand, a regression of sea level throughout post-glacial time. The relative rise in the land during a period of known rising sea level, in an area close to the centres of ice accumulation in the Hudson Bay region, is therefore attributed to glacial rebound of the earth's crust. Uplift of the land has taken place, and continues to occur at a rate significantly greater than the post-glacial rise of sea level.

(e) Geophysical Evidence

The terrestrial gravity[13] for any point on the earth's surface may be calculated by use of the

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[13] The resultant force on any body of matter at or near the earth's surface, due to the attraction by the earth and to its rotation about its axis (Howell et. al., 1962, p. 218).

International Gravity Formula[14] adopted by the International Union of Geodesy and Geophysics in 1930 (Parasnis 1962, p. 31). Direct measurements of terrestrial gravity can be obtained by various instruments (gravimeters). The difference between theoretical calculated and observed terrestrial gravity is called a gravity anomaly. Excess observed gravity is referred to as a positive anomaly; a deficiency of observed gravity is known as a negative anomaly. The magnitude of the gravity anomaly is expressed in milligals[15]. Since the force of gravity outside the earth varies in inverse proportion to the square of the distance from the earth's centre, a free-air correction is usually made relative to a selected datum or to sea level. Corrected readings are known as free-air anomalies.

Gravity Anomalies

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[14] $g = 978.049 \ (1 + 0.0052884 \ \mathrm{Sin}^2\phi - 0.000005 \ \mathrm{Sin}^2 2\phi) \ \mathrm{cm/sec.}^2$

where ϕ = latitude.

[15] One milligal is 1/1000 of a gal., which is the c.g.s. unit of acceleration (1 cm/sec2) named after Gallileo.

Negative gravity anomalies in an area indicate a deficiency of mass in the crust and the subcrustal layers. Isostasy refers to the equilibrium condition in which elevated masses such as continents and mountains are compensated by a mass deficiency in the crust beneath them (Howell et. al., 1962, p. 266). The existance of a large continental ice mass produces a similar effect, the ice load being compensated by the development of a deficiency of mass in the crust beneath as a result of the horizontal transfer of viscous mantle materials from below the area of ice cover. When the ice melts a return to isostatic equilibrium[16] is initiated. If the recovery is incomplete, negative gravity anomalies are observed, reflecting the tendency of the crust to rise to eliminate the displacement caused by the Pleistocene ice loads.

The distribution of mean free-air anomalies in the Hudson Bay region (Figure 3.8) is characterised by an anomaly low in the order of -50 milligals centred over Eskimo Point, and a second low of about -40 milligals centred over the Foxe Basin. Walcott (1971, p. 719) concludes that the distribution of

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[16] It is assumed that a preglacial state of isostatic equilibrium existed before the growth of the ice sheets.

negative anomalies, crustal rebound and continental glaciation are closely related. The two gravity lows over Hudson Bay in the vicinity of Keewatin and the Foxe Basin correspond to the position of the last remnants of the Wisconsinan ice sheet. Isobases[17] generally parallel the gravity contours, both the latter and the isobases exhibiting a concentric elliptical distribution over the Hudson Bay region (Figures 3.8 and 3.9).

Negative anomaly contours for the Hudson Bay region demonstrate presently occurring compensation within the crust, following deglaciation. If the greatest part of the presently observed negative anomalies are due entirely to the isostatic effects of the ice load, no tectonic movements having contributed to the observed over compensation taking place in the Hudson Bay region, then it is possible to estimate the amount of glacial rebound still to occur. By multiplying the observed anomaly in milligals by 7, the remaining uplift in metres at any point may be estimated (Walcott 1970, p. 719). The York Factory area corresponds to the -27 milligal contour (Figure 3.8). Thus the estimated amount of uplift yet to occur is in the order of 190 metres (623 feet).

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[17] Isobases are lines, plotted on a map, joining points of equal uplift.

3.4 POSTGLACIAL UPLIFT AND EMERGENCE

The emergence of the York Factory area refers specifically to the change of sea level relative to the land during the evolution of Beacon Point. The amount of postglacial uplift on the other hand, includes an eustatic rise of sea level correction, since world wide sea level has fluctuated throughout the last 10,000 years. The postglacial uplift of the land at any particular time is obtained from the present elevation of a shoreline feature indicative of the former sea level, plus the subsequent rise in sea level since that time. As a result postglacial uplift can only be estimated from stratigraphic-geomorphological evidence, because there is no absolute curve of sea level fluctuations available for the Hudson Bay region. Estimates of sea level rise are based on the curves (Figures 3.10, and 3.11) derived by Shepard (1964) and Scholl and Stuiver (1965).[18]

Postglacial Uplift

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[18] The smoothed curve of Shepard (1964) was used to estimate the eustatic rise of sea level prior to 4,000 years B.P. The curve of Scholl and Stuiver (1965) was used to estimate sea level rise during the last 4,000 years.

Investigations of the emergence and postglacial uplift of the York Factory area, and the Hayes River area, are based on the altitude and radiocarbon age of marine shells and driftwood materials. The latter were extracted from the continuous sand and gravel unit (Figure 2.21) observed along the northwestern bank of Hayes River in the vicinity of York Factory. This stratigraphic unit was selected in preference to the sequence of abandoned beaches which traverse Beacon Point, as the indicator of former sea level for several reasons.

Sand and Gravel Unit

(i) Beaches on Beacon Point possess permafrost cores, a condition that develops subsequent to their formation (4.1). The up-doming of beaches by permafrost renders it impossible to determine accurately the height of the original beach form above sea level.

(ii) Beach ridges on Beacon Point are subject to intermittent inundation by floodwater, during periods of high water in the lower estuaries. Deposition of alluvial materials and the accumulation of peat has considerably modified the lateral extent and the height of the original beach forms.

(iii) Beaches presently forming at Marsh Point do so during periods of exceptionally high water accompanied with strong onshore winds (4.1). This introduces the problem of relating the beach form to the mean sea level at the time of its formation. The sand and gravel unit on the other hand represents more or less continuous sedimentation along the foreshore during open water conditions. This unit is regarded as a more reliable indicator of mean sea level.

Stratigraphic Sites & Radiocarbon Dating

Data from stratigraphic sites (1), (3), (10) and (13) were used to determine the rate of emergence and uplift (Tables 3.II, 3.III and 3.IV). Data from an additional site approximately eighty miles upstream on Hayes River was incorporated in the sample. Marine shells from this site at an elevation of 375 feet above sea level were dated at 7570± 140 radiocarbon years B.P. (Craig 1969, p.69). The addition of the latter site extends the limited temporal range (2100 - 490 radiocarbon years B.P.) of the Beacon Point sites, minimising in part errors in the estimation of uplift and emergence based on a small sample of dates from a single locality.

At site (12), driftwood material at 7.1 feet above sea level in the continuous sand and gravel unit, yielded a date of 1250± 105 radiocarbon years B.P. Dates from sites (1), (3), (10) and (13) indicate that the unit becomes progressively younger towards Marsh Point (Figure 2.21). Site (12) is not included in the sample due to this inconsistency in the stratigraphic sequence. The redeposition of driftwood from an older site may account for this discrepancy.[19]

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[19] Andrews (1968a, p. 42) has summarised other sources of error associated with the construction of uplift curves.

In the present analysis of the time/emergence and the time/uplift data, obtained from field observations (Tables 3.II, 3.III and 3.IV) certain assumptions have been made regarding the duration of the rebound process. It is assumed that:

(i) The time of deglaciation corresponds to the initiation of uplift. Thus uplift is defined as postglacial uplift.[20] The deglaciation of the Nelson-Hayes River area is dated at 7570±140 radiocarbon years B.P. (Craig 1969).

Assumptions Made for Postglacial Uplift Models

(ii) The marine inundation of the Hayes River area occurred immediately after deglaciation, so that the marine limit at 375 feet above sea level is synchronous with the event of deglaciation.

(iii) The age of the marine shells and driftwood materials approximates the time of formation of the respective marine limits.

Time/emergence and time/postglacial uplift relationships may be plotted and expressed in several different ways. In the present analysis the independent variable, time, is expressed as radiocarbon

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[20] The recovery of the earth's crust may have begun during the thinning of the ice sheets, and before the inundation of the Hudson Bay Lowlands by the Tyrrell Sea. If the recovery of the crust was initiated before the marine transgression, this initial phase of uplift cannot be estimated by stratigraphic-geomorphological investigations based on the observation of the age and altitude of former marine limits. An unknown amount of recovery of the crust may have occurred, which is not detectable by geomorphological field work, before the formation of the marine limit at 375 feet above sea level.

years[21] since deglaciation. Thus (t) = 7570 represents 0.0 years B.P. Postglacial uplift and emergence are plotted as the amount of uplift or emergence accomplished at (t) radiocarbon years since deglaciation. By plotting field data in this manner it is possible to extend the computed curves beyond the present, and the mathematical model has predictive value.

Mathematical Models of Postglacial Uplift

Time/emergence and time/uplift curves for the Hayes River area are presented in Figures 3.12 and 3.13. Using the method of least squares the computed curves were found to be

$$E_a = 218.66 \log(t) - 471.98 \quad (1)$$

$$U_a = 236.24 \log(t) - 500.14 \quad (2)$$

where E_a and U_a are the respective amounts of emergence and postglacial uplift accomplished at (t) years since deglaciation. The present rate of postglacial uplift is obtained from the slope of the curve at (t) = 7570 (i.e. 0.0 years B.P.).

$$U_a = f(t)$$

$$f'(7570) = 3.12 \text{ feet } (94 \text{ cms}) \text{ per century.}$$

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[21] Time recorded as radiocarbon years B.P. may differ from absolute time (Stuiver and Suess 1966).

The general form of equation (2) may be written as

$$U_a = a + b\ (\log t) \tag{3}$$

where U_a is the uplift accomplished at time (t), and (a) and (b) are derived constants. Inspection of function (3) reveals that the rate of change between U_a and (t), given by $f'(t)$ varies with the inverse of (t). Figure 3.13 indicates that the rate of uplift is initially rapid and decelerates with time. The rate of deceleration is not constant, since by equation (3), $f''(t) = -b/t^2$, indicating that the deceleration of the uplift process varies with time. Equation (3) has the shortcoming that at (t) = 0, that is at the time of deglaciation, $U_a \to -\infty$. Thus the graph does not go through the origin. By using a function of the form

$$U_a = c(t)^d \tag{4}$$

the curve does go through the origin (0.0 time, 0.0 uplift). The above function does fit closely the observed field data (Figure 3.14). The best fit curve computed by the method of least squares is

$$U_a = 1.003(t)^{0.682} \tag{5}$$

The present rate of uplift (t = 0.0 years B.P.) is given by the derivative of equation (5):

$$f'(7570) = 3.89 \text{ feet } (119 \text{ cms})/\text{century}$$

which is slightly higher than the estimate derived from equation (2). Inspection of Figure 3.14 indicates that the uplift accomplished decelerates with time. From equation (4), $f'(t) = (d)(U_a)/(t)$, thus the rate at which uplift is occurring varies with both (U_a) and (t). The rate of deceleration is also non-uniform, since $f''(t) = d(d - 1)(U_a)/t^2$, indicating that the rate of deceleration varies with time.

Knowledge of the total amount of crustal depression, the present rate of uplift and the amount of uplift accomplished since deglaciation, enables prediction of the duration of the rebound process. The distribution of free-air anomalies (Figure 3.8) indicates that there are 460-620 feet of uplift remaining in the Hayes River area. Assuming a mean value of 540 feet remaining uplift, the total crustal depression was of the order of 955 feet, since field evidence (Table 3.IV) indicates that at present 415 feet of postglacial uplift has been accomplished. Inspection of Figure 3.14 reveals that the time required to reduce uplift to zero, that is to accomplish the total recovery of 955 feet is approximately 24×10^3 years. Using equation (5) as a model of the uplift process implies that as $(t) \rightarrow \infty$ then $(U_a) \rightarrow \infty$. This means that the uplift process continues after the compensation for the total crustal depression of 955 feet. A function in which $(t) \rightarrow x$ years as $U_a \rightarrow 955$ feet is required to approximate both the rate and the duration of uplift. By using a function of the general form

$$U_a = k - m(n)^t \tag{6}$$

where U_a is the uplift accomplished at (t) years since deglaciation, (k) is the total crustal depression, and (m) and (n) are derived constants, then the line $U_a = 955$ is an asymptote to the curve, and the amount of uplift accomplished may be expressed in terms of the initial crustal depression. Plotting the modified field data (Table 3.IV) as in Figure 3.15 the best fit computed curve was found to be

$$U_a = 955.0 - 501.1\ (0.9479)^t \tag{7}$$

which is equivalent to

$$U_a = 955.0 - 501.1e^{-0.0857(t)} \tag{8}$$

Inspection of Figure 3.15 indicates that the time taken to accomplish a total uplift of 955 feet is approximately 50×10^3 years. The present rate of uplift, given by the derivative of equation (8) at (t) = 0.0 years is 4.29 feet (130 cms) per century.

Using functions (7) and (8) as models of the uplift process implies that the latter may be approximated by a modified exponential function. This suggests a uniform behaviour of the crust, since from equation (6), $dU_a/U_a = \ln(n)dt$. Thus the rate of change of U_a is proportional to U_a.

Discussion of Uplift Models

Three mathematical functions have been considered as models of the postglacial uplift process:

(1) $U_a = a + b \log(t)$

(2) $U_a = c(t)^d$

(3) $U_a = k - m(n)^t$

Each model provides an adequate approximation of the observed field data, on the basis of statistical tests of correlation and "goodness of fit". Each model implies however a different operation of the uplift process with respect to time. Although the effect of the recovery of the crust may be simulated by any of the above models, this does not necessarily mean that the models simulate the actual operation of the uplift process. By the principle of Equifinality, the same end condition in the landscape may result from different processes. Thus the rationale for curve fitting assumes paramount importance, as each of the models provides an adequate approximation of the field data, but imply on the other hand a different operation of postglacial recovery of the crust. Stratigraphic-geomorphological investigations are concerned with the "effects" of uplift, and by their nature do not provide a direct means of investigation of the crustal processes associated with glacio-isostasy. Defining a model which simulates both the effects of glacio-isostatic recovery and the actual recovery process is therefore a geophysical problem.

Model (1), although providing the best fit ($r = 0.99$) to the observed field data for the period 7570-0.0 years B.P., indicates that the time required to compensate for the total crustal depression is of the order of 10×10^6 years. The latter period seems unrealistic in terms of the length of the former glacial and interglacial periods. Model (2) implies that the uplift process will continue indefinitely, thus the model does not satisfactorily simulate the compensation process, which theoretically should proceed until an equilibrium condition prevails similar to that preceding the overloading by the ice sheets. In regard to model (3), Walcott (1970 pp. 719-20) has questioned the validity of a simple exponential decay function. A more complicated mathematical model may be required. Niskanen (1949) contends that the stresses produced in the crust during the downwarping by an ice load have decayed completely by the time of deglaciation. Consequently inward flowing mantle material has to work against the elastic stresses produced in the crust by uplift, and uplift is retarded.[22]

It is not possible at this level of analysis to accept without reservation, any of the three models applied to the field data due to the small sample size, and due to the unreliability of prediction that may result from a small sample of altitudes and dates from a single locality. The non-linear relationship between U_a and (t) also precludes any statement regarding the average rate of uplift in the Hayes River area.

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[22] As quoted in Walcott (1970, p. 720).

Rates of Postglacial Uplift

Present rates of postglacial uplift, based on models (1), (2) and (3) are 3.12 feet (0.94 metres), 3.89 feet (1.19 metres) and 4.29 feet (1.31 metres) per century. In view of the relative paucity of data concerning the age and elevation of former marine shorelines in the lower Hayes River area, Model (3), Figure 3.15, which presently provides the simplest and most logical approximation of field observations, is favoured.

TABLE 3.1

RADIOCARBON DATES ON MARINE SHELLS, CHURCHILL AREA, MANITOBA

LOCALITY	APPROX. ALT. OF SAMPLE (ft. a.s.l.)	AGE (RADIOCARBON YEARS B.P.)
1	124	3,180 ± 140
2	90	2,370 ± 130
3	72	2,120 ± 130
4	35	1,240 ± 130
5	21	1,020 ± 140
6	15	3,430 ± 140
7	125	2,800 ± 110
8	100	3,190 ± 80
9	12	385 ± 80

SOURCE: CRAIG (1969, p.74)

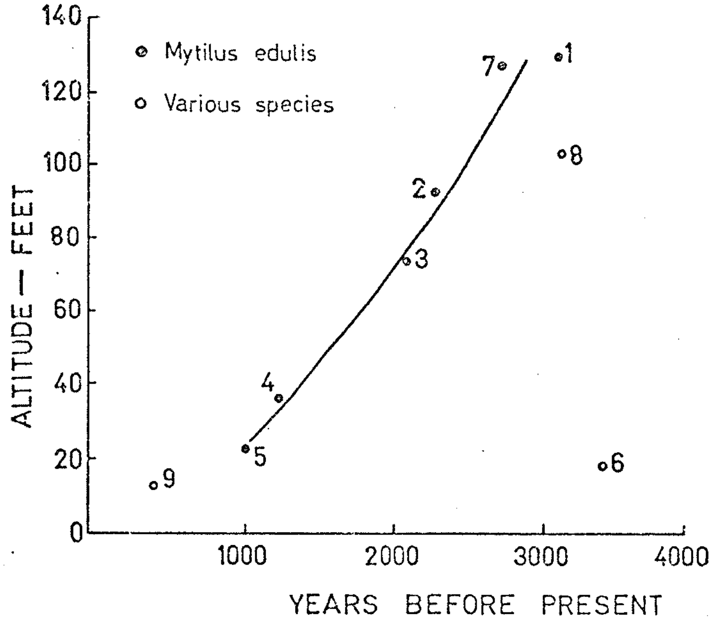

FIGURE 3.1: RADIOCARBON AGE AND ALTITUDE OF MARINE SHELLS, CHURCHILL AREA, MANITOBA. (CRAIG 1969, p.73)

TABLE 3.II

RADIOCARBON AGE OF DRIFTWOOD AND MARINE SHELLS HAYES RIVER AREA, MANITOBA

LOCALITY OF STRATIGRAPHIC SITE (FIGURES 2.1, 2.21)	ALTITUDE (FEET ABOVE SEA LEVEL)	AGE (RADIOCARBON YEARS B.P.)	LABORATORY DATING NO.*
1	31.65	2065 ± 125	GX-2061
3	25.67	1930 ± 130	GSC-1305
10	12.25	1055 ± 125	GX-2062
13	7.11	660 ± 190	GSC-1468
Craig (1969 p.69, Table I, Site 11)	375.00	7570 ± 140	GSC-878

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* GSC - Geological Survey of Canada GX - Geochron Laboratories Inc.

TABLE 3.III

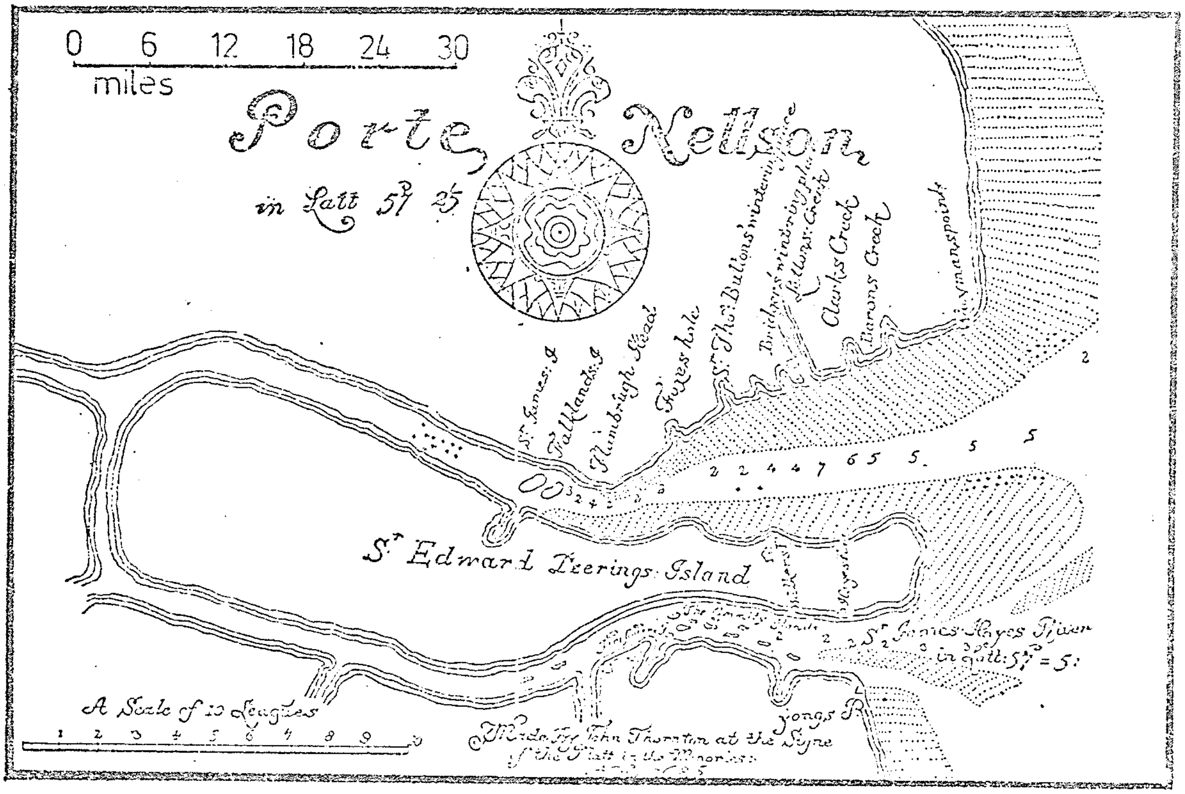
MODIFIED FIELD DATA USED FOR COMPUTATION OF EMERGENCE CURVES

SITE (SEE FIGURES 2.1, 2.21)	ALTITUDE (FEET ABOVE SEA LEVEL)	(t) AGE (RADIOCARBON YEARS SINCE DEGLACIATION)	E_a EMERGENCE ACCOMPLISHED AT (t) YEARS SINCE DEGLACIATION
Mean Sea Level at Marsh Point	0.0	7570 ± 140	375.00
13	7.11	6910 ± 190	367.89
10	12.25	6515 ± 125	362.75
3	25.67	5640 ± 130	349.33
1	31.65	5505 ± 125	343.35
Craig (1969 p.69, Table I, Site 11)	375.00	0	0

TABLE 3.IV

MODIFIED FIELD DATA FOR COMPUTATION OF UPLIFT CURVES

SITE (SEE FIGURES 2.1, 2.21)	ELEVATION (FEET) AFTER EUSTATIC SEA LEVEL CORRECTION	AGE (RADIOCARBON YEARS SINCE DEGLACIATION)	U_a UPLIFT ACCOMPLISHED AT (t) YEARS SINCE DEGLACIATION	U_r UPLIFT REMAINING AT (t) YEARS SINCE DEGLACIATION ($955-U_a$)
Mean Sea Level, Marsh Point	0.0	7570 ± 140	415.00	540.00
13	7.93	6910 ± 190	407.07	547.93
10	13.23	6515 ± 125	401.77	553.23
3	27.80	5640 ± 130	387.20	576.80
1	34.27	5505 ± 125	380.73	574.27
Craig (1969, p.69, Table I, Site 11)	415.00	0	0	955.00



From a copy in Canadian Archives

FIGURE 3.2

THORNTON'S MAP OF PORT NELSON, 1685

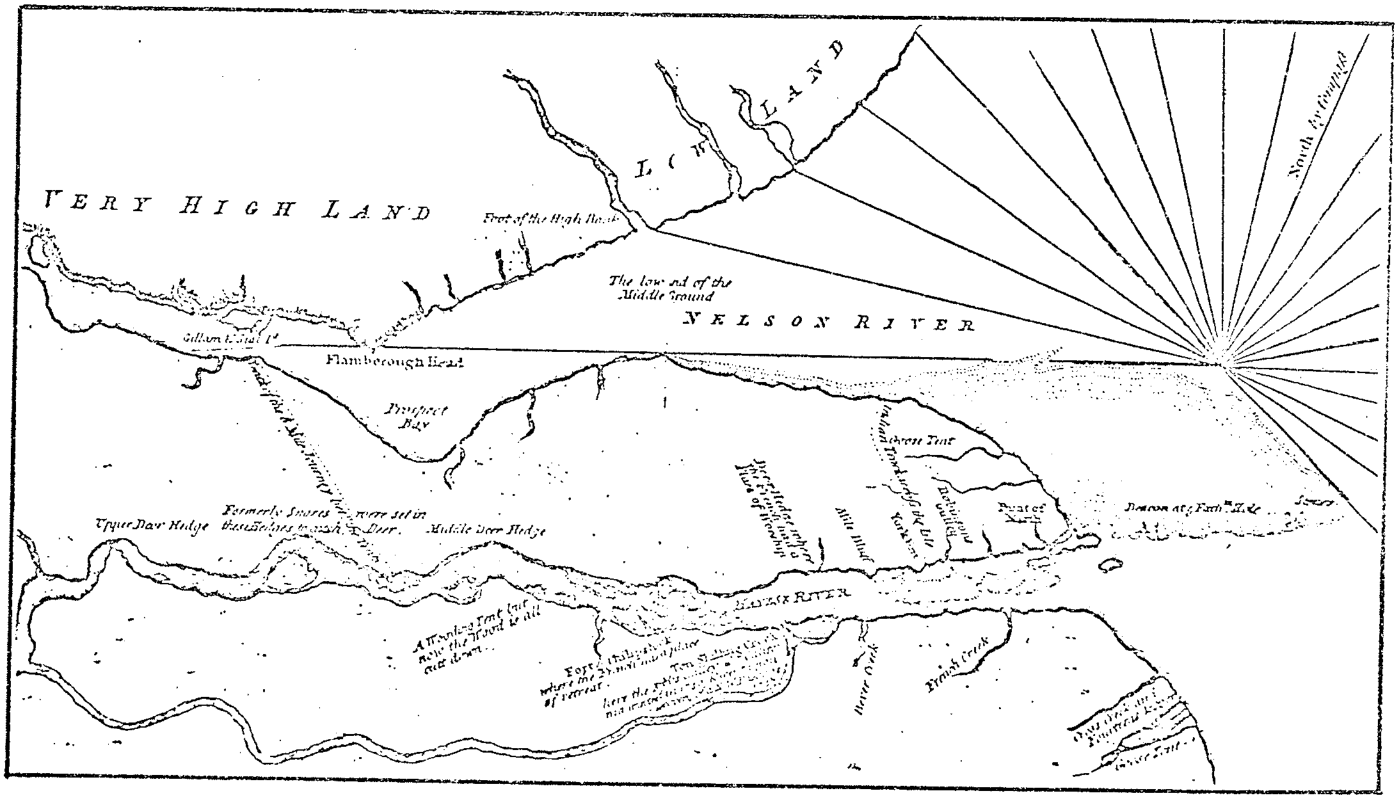


FIGURE 3.3

PORTION OF ROBSON'S SURVEY OF THE YORK FACTORY AREA, 1745

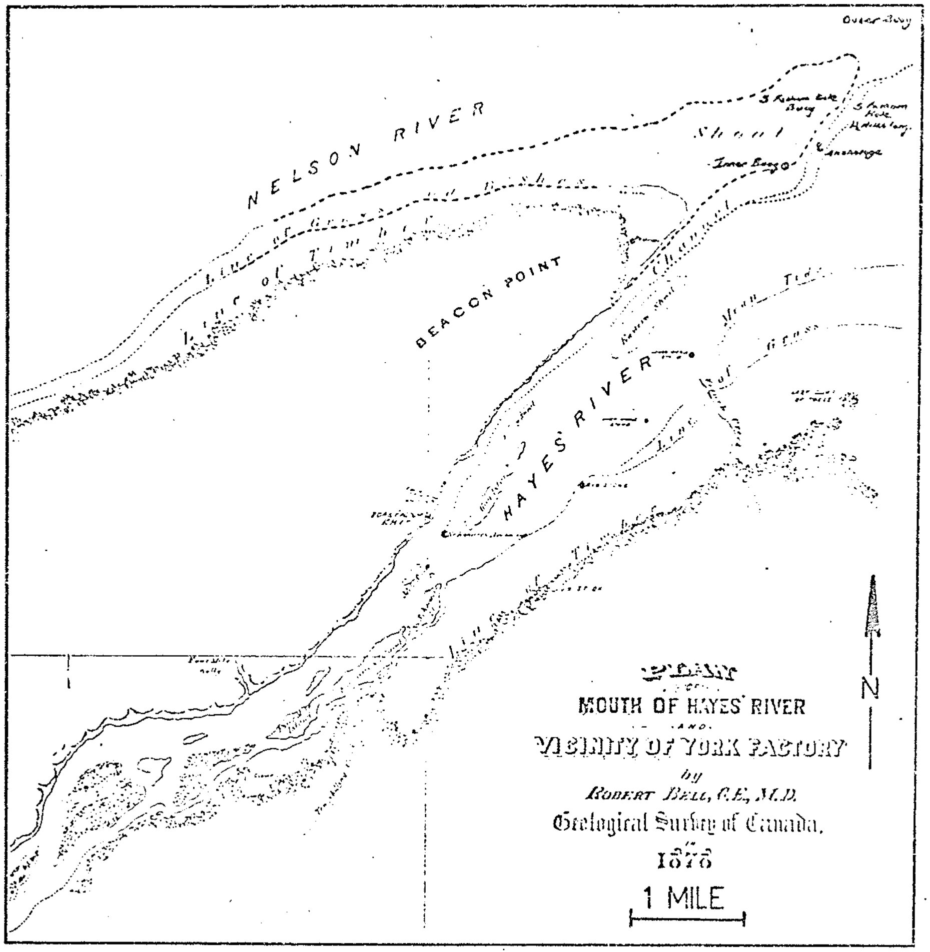


FIGURE 3.4
ROBERT BELL, 1878

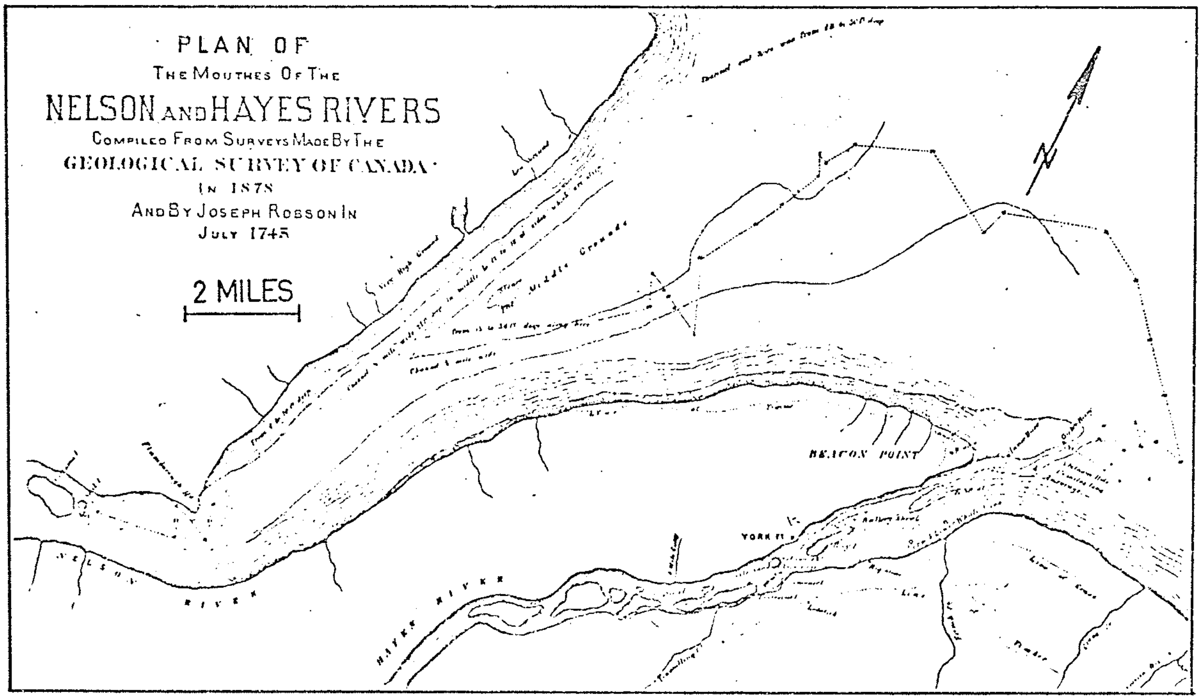


FIGURE 3.5
C.N. BELL, 1884

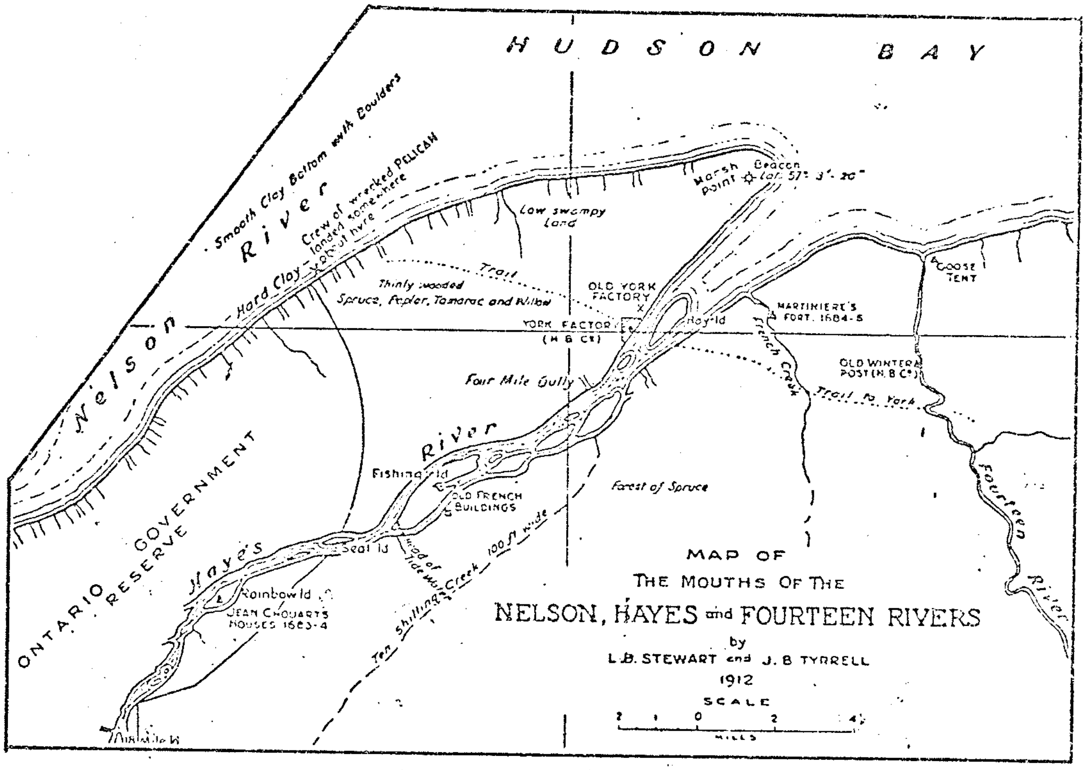


FIGURE 3.6
TYRRELL AND STEWART, 1912

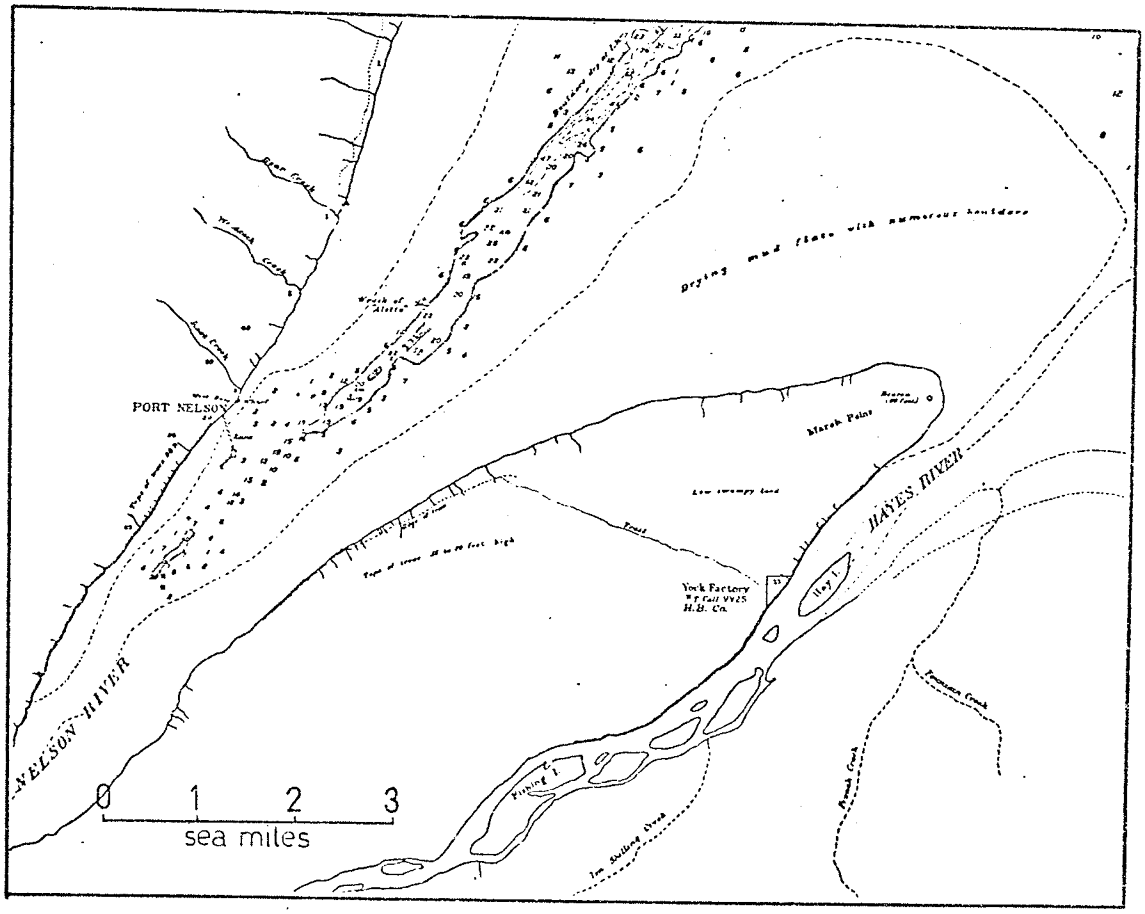


FIGURE 3.7
CAPTAIN ANDERSON, 1914

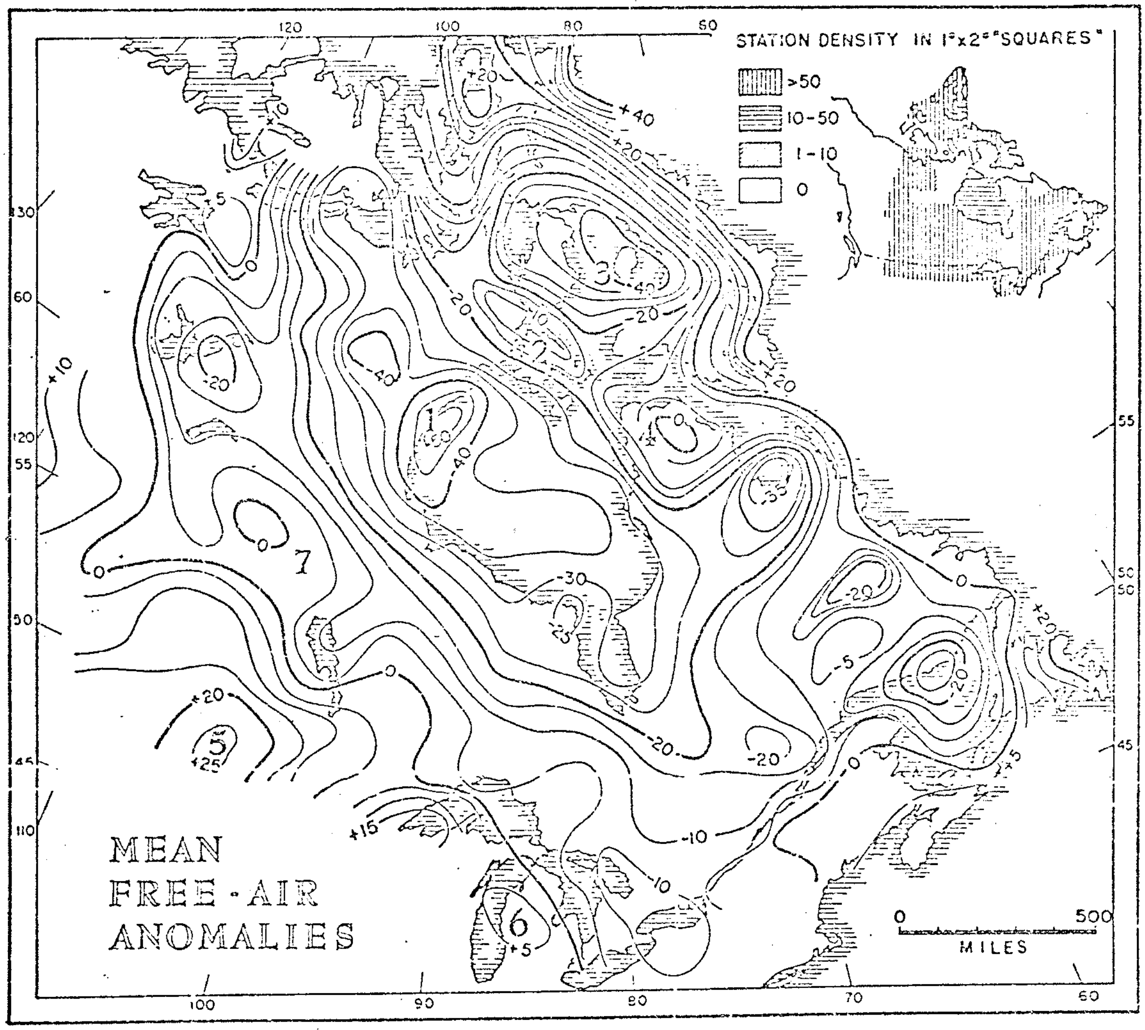


FIGURE 3.8

SMOOTHED FREE AIR ANOMALY MAP OF
CANADA AND NORTHERN UNITED STATES

Average free air anomalies in 1° x 2° 'squares' are smoothed twice by the method of averages and contoured. Number of observations for each average shown in the inset.
1) Eskimo Point; 2) Southampton Island; 3) Foxe Basin; 4) Ungava Peninsula; 5) Williston Basin; 6) Michigan Basin; 7) Flin Flon.

SOURCE: Walcott 1970, p. 717.

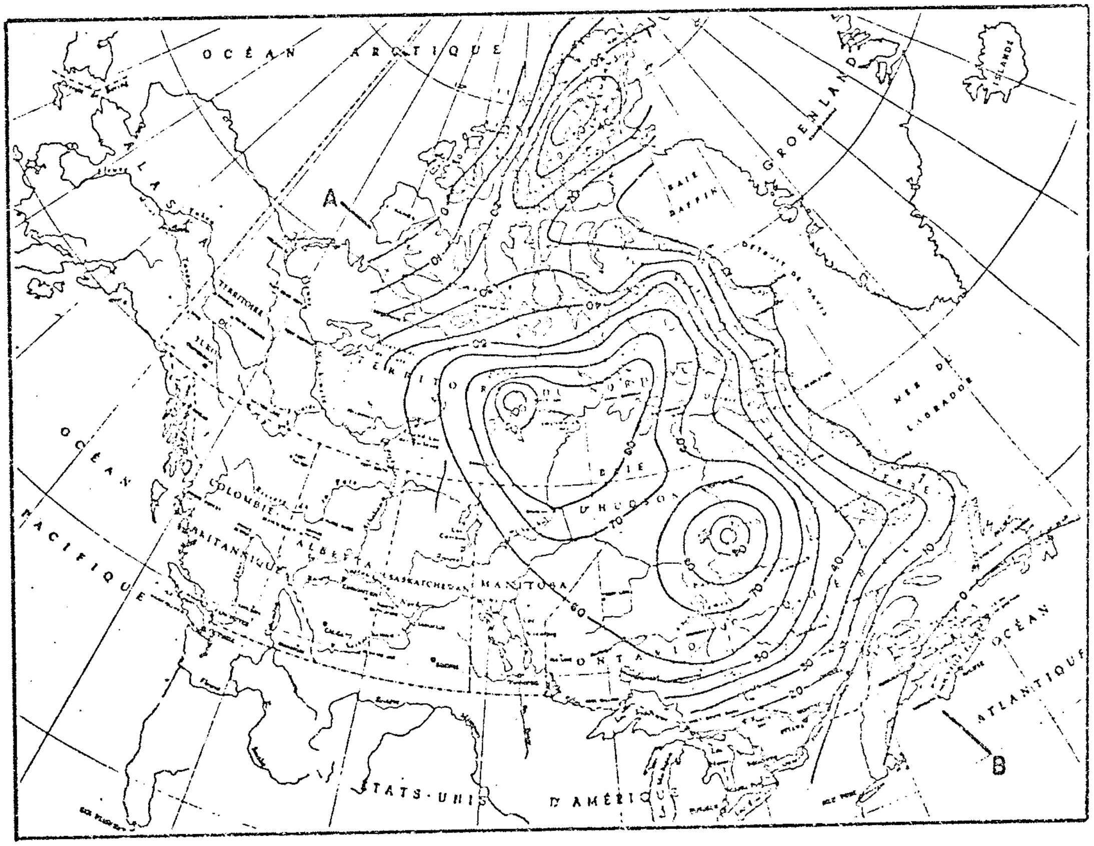


FIGURE 3.9

ISOBASE MAP FOR CANADA SHOWING THE
RELATIVE UPLIFT IN THE LAST 6,000 YEARS
(ELEVATIONS IN METRES)

SOURCE: Andrews, 1969

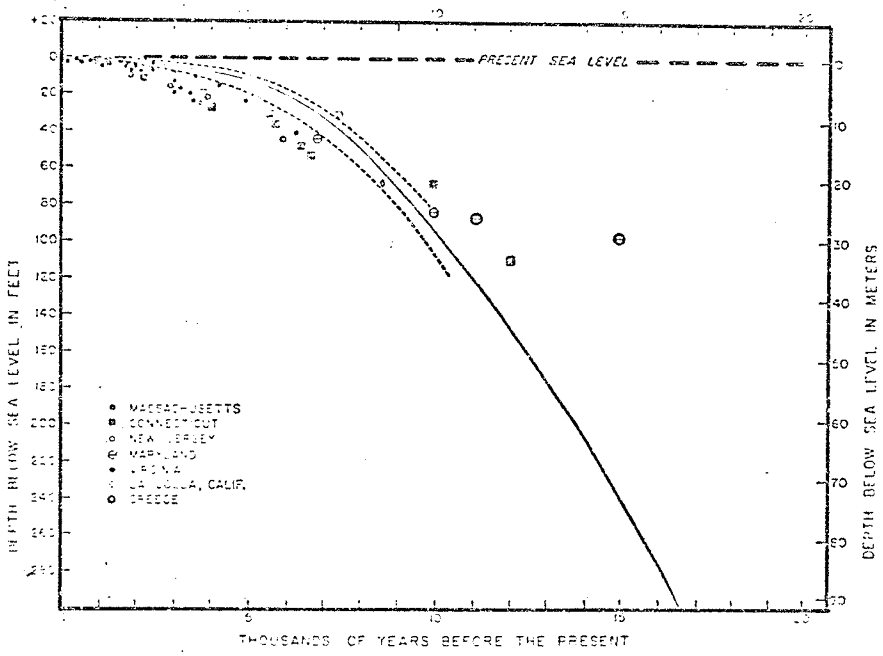


FIGURE 3.10

RISE OF SEA LEVEL

SOURCE: Shepard 1964, p. 575

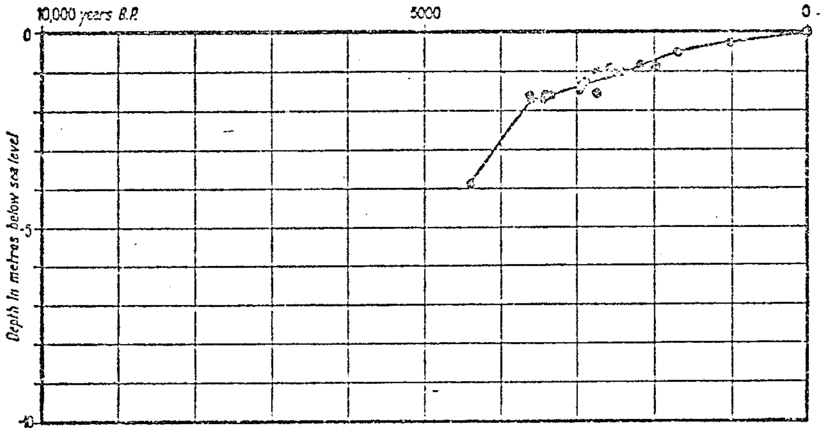


FIGURE 3.11

SEA LEVEL CHANGES

SOURCE: Scholl and Stuiver, 1965

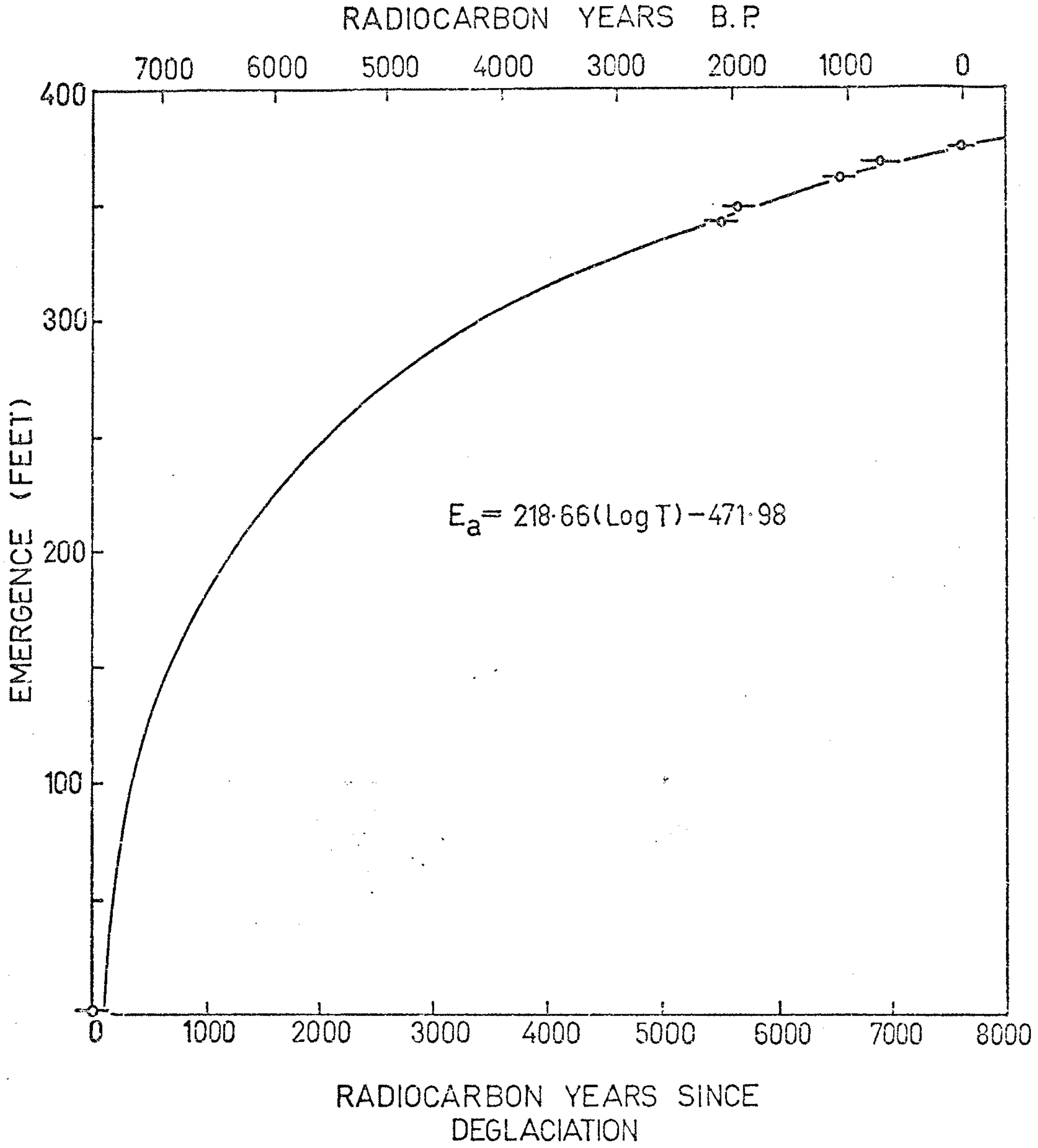


FIGURE 3.12

EMERGENCE CURVE, HAYES RIVER AREA, MANITOBA.

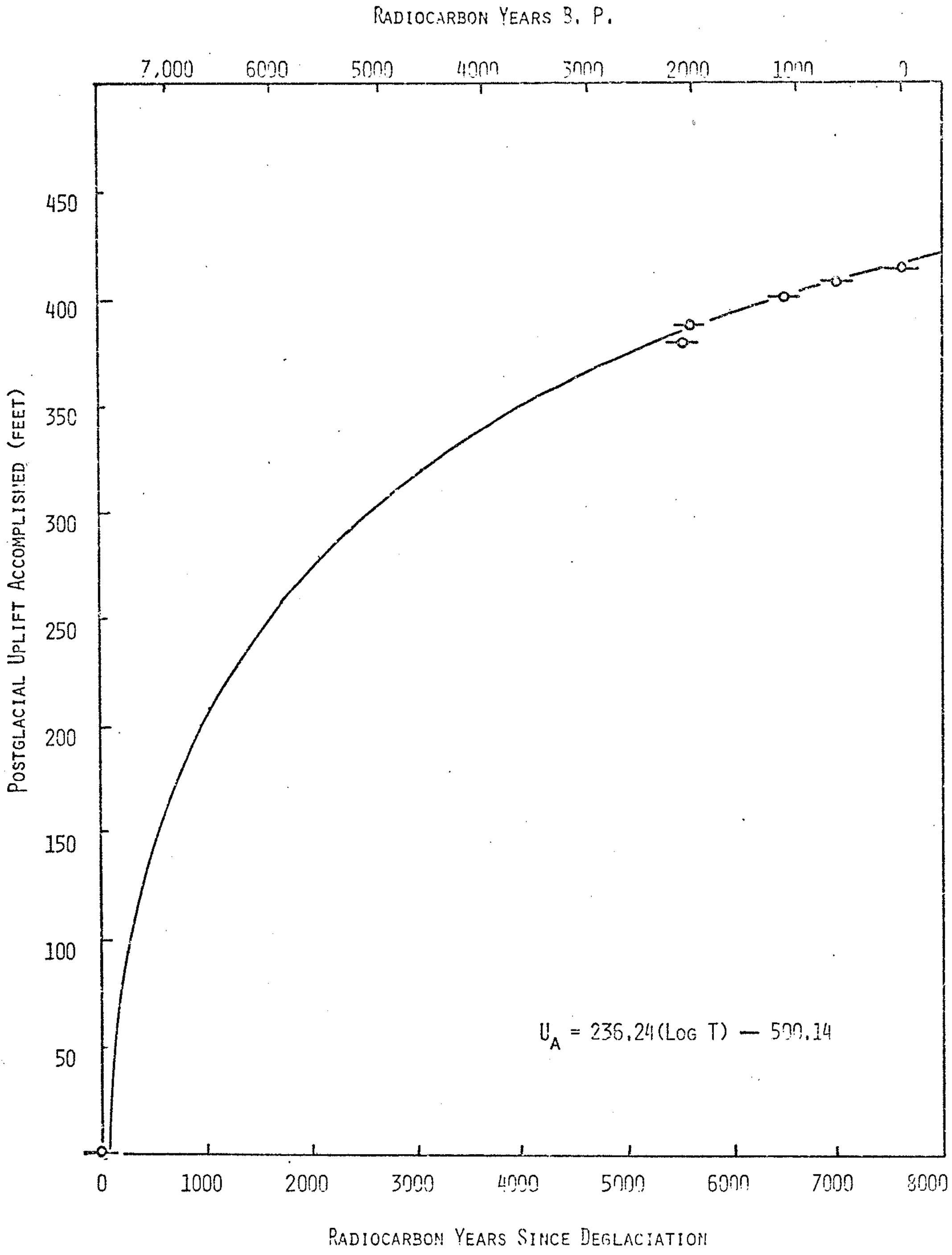


FIGURE 3.13

UPLIFT CURVE, HAYES RIVER AREA, MANITOBA.

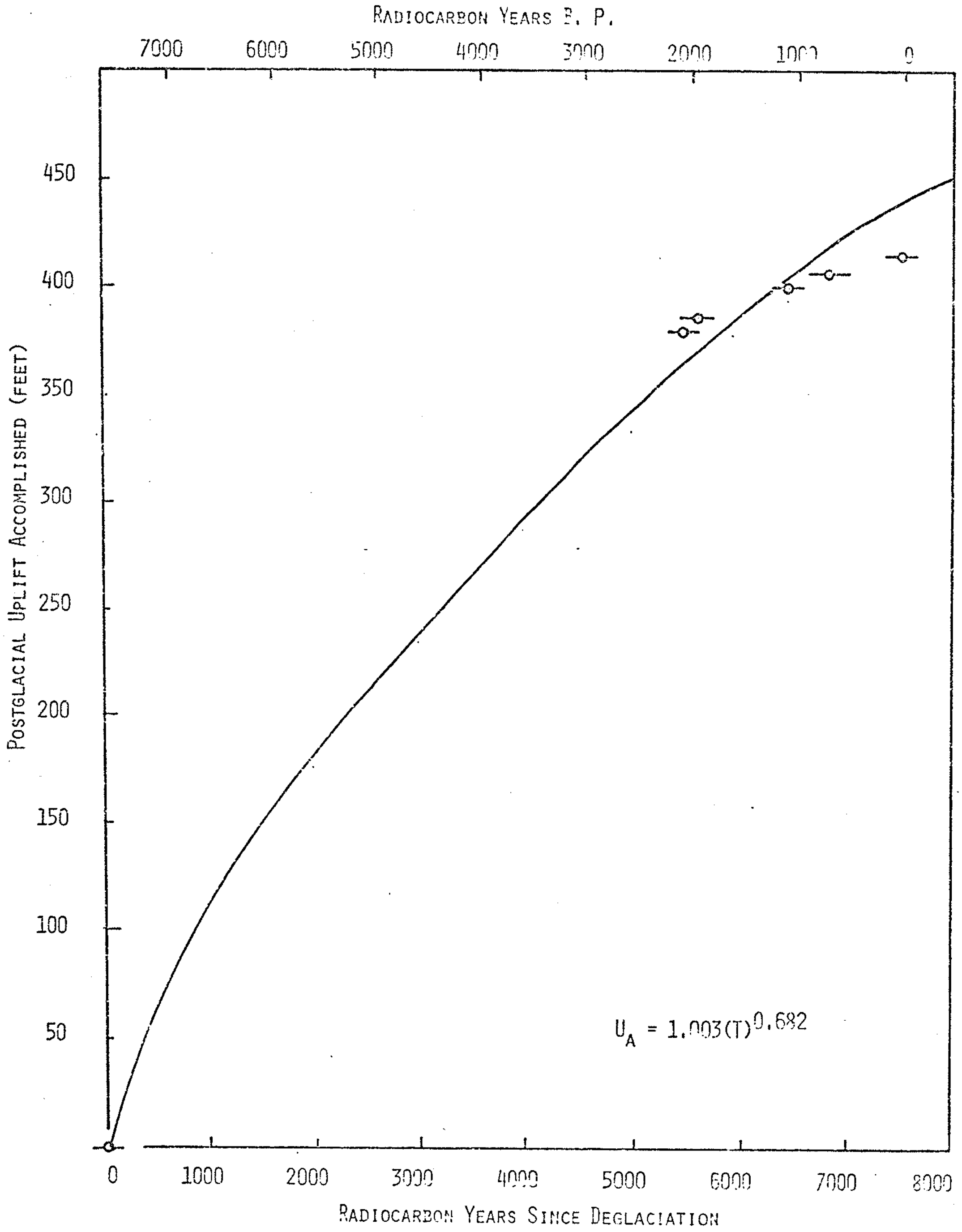


FIGURE 3.14

UPLIFT CURVE, HAYES RIVER AREA, MANITOBA.

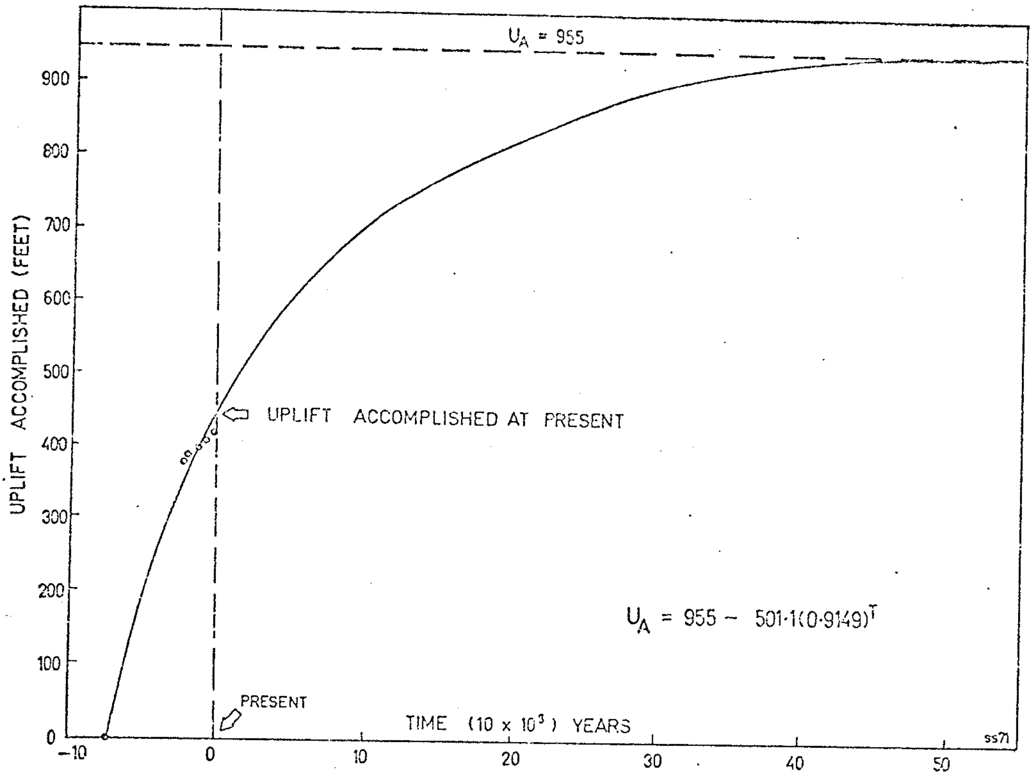


FIGURE 3.15

POSTGLACIAL UPLIFT MODEL FOR THE
LOWER HAYES RIVER AREA, MANITOBA

CHAPTER IV

CONTEMPORARY PROCESSES

The ice was here, the ice was there,
The ice was all around:
It cracked and growled, and roared and howled,
Like noises in a swound!

Samuel Taylor Coleridge 1772-1834.

4.1 COASTAL PROCESSES AND BEACH FORMATION

Direct observation of coastal processes during the 1969 and 1970 field seasons indicates that the beach presently forming at Marsh Point is not inundated during normal tidal conditions. The driftwood line is located approximately 600 feet inland of normal high water mark.[1] Inundation of this part of the backshore occurs only during periods of exceptionally high water. Consequently beach formation is associated with the occurrence of an extreme event. The latter is defined as a period of exceptional high water in association with onshore storm winds. The minimum condition for an extreme event to occur at Marsh Point, based on tidal ranges observed, is a tide of at least five feet higher than present high water mark. Such a tide completely inundates the backshore.

"Extreme Event"

Optimum conditions for the complete inundation of the backshore zone occur (a) in the latter part of each year, and (b) during the break-up period.[2] Tide gauge records from Churchill, indicate consistently higher water levels during September,

Inundation of the Backshore Zone

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[1] Arbitrarily defined as the seaward limit of grasses and sedges at Marsh Point.

[2] The mean date of break-up of Hayes River at York Factory, as defined by MacKay and MacKay (1965) is May 20th.

October and November, along the southwest coast of Hudson Bay. A relatively high frequency of NW and NNW winds and higher average monthly wind speeds are also characteristic of the latter part of the year (Figure 4.1; Table 4.I). Exceptional high water during and following the break-up of Hayes River at York Factory is known from the historic record.[3] A high frequency of NE and ENE winds is also recorded during May and June of each year (Figure 4.1). Such a wind set-up prevents ice from moving bayward. Ice in Hudson Bay is driven onshore and into the lower estuaries. The temporary barrier effect aggravates the high water in the estuaries associated with the spring run-off peak. According to MacKay and MacKay (1965) "discharge on the Hayes is less subject to the stabilizing effect of lakes; it may reach its peak more quickly and exert greater pressure on the

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[3] High water conditions during the break-up period in 1715 and 1788 caused severe damage to the fort and buildings. In 1715 James Knight reported that the garrison was forced " to leave the Factory & betake ourSelves to the woods and gett on Trees & Stages the Water Rising above nine foot upon the land & continued up for Six Days, was looking every minute when ye Factory would be tore to pieces. The Ice lay heap'd & crowded at least 20 foot higher yn the Factory...." (Quoted in Tyler, 1955). In 1788 Hayes River rose approximately 33 feet at York Factory, flooding the fort. The damage was so severe that a new location was chosen.

river's ice surface during the spring run-off. Ice disintegration is extremely rapid, and flooding in the lower stretches of the river is not uncommon."

It is difficult to ascertain the probability of an extreme event and to relate the latter to beach formation on Beacon Point. The period of observation and the tidal records represent too small a sample on which to base quantitative conclusions regarding the operation of coastal processes during the last 2,500 years. Tidal observations (1969-70) do indicate that the backshore at Marsh Point is completely inundated probably sixteen times in any one year. However, even if this frequency of inundation provides a representative estimate for the entire period of evolution of Beacon Point, the known probability is of little value unless a correlation is established between the number of periods of exceptional high water that occur, and the number of extreme events required to form any one beach ridge. Meteorological and tide gauge data indicate only that the optimum conditions for higher than usual high tides to occur which are of sufficient magnitude to permit sedimentation along the landward margin of the backshore, prevail in the latter part of each year. Whether beaches on Beacon Point originate as a result of an annual accumulation of debris, or whether they are formed at break-up, when a coincidence of high water, onshore winds, and an ice barrier offshore may be encountered, is not definitely known. The latter hypothesis is favoured however, for the following reasons.

Origin of Beach Lines on Beacon Point

(a) Infrequent exceptional high water conditions in association with storm winds, during and following the break-up of Hayes River, have had catastrophic repercussions for the inhabitants of York Factory. Twice during the 18th Century flooding as a result of ice jams in the lower estuary partially submerged the fort and buildings.

(b) The occurrence of NE/ENE winds at the time of break-up, which funnel ice back into the lower estuary or hold ice offshore, thus aggravating the high water condition associated with the spring run-off peak.

(c) Gouges and grooves observed after the break-up on Marsh Point indicate that ice overrides the backshore zone. Higher than usual water conditions in association with strong onshore winds would be required to drive these ice pans onto the landward margin of the backshore. Sporadic accumulations of ice rafted materials, mainly gravels, cobbles and isolated boulders are also found on the backshore. Deposition from ice pans is known to occur annually.

(d) Beaches are composed almost entirely of driftwood, with only sporadic amounts of sand, gravel and cobble material. Larger than usual amounts of driftwood are available during the spring flood peak. "...I have known the Ice when going out of the Rivers,[Nelson and Hayes] to appear Like a wood or grove of trees with the perdigious Quantity of wood, which has been Brought of the shores by the water and Ice...[4]

It is tentatively concluded that beach accumulation on Beacon Point has resulted from the

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[4] Williams, G. (ed) 1969. Andrew Graham's Observations on Hudson's Bay 1767-91, Hudson's Bay Record Society, Vol. XXVII, p.72. London.

infrequent occurrence of exceptional high water conditions, in association with onshore storm winds during and following the break-up period. Driftwood debris carried downstream during the spring flood peak is swept onto the backshore in front of wind driven ice pans during higher than usual tidal conditions. Minor discontinuous accumulations of driftwood observed along the backshore in front of the major driftwood line represent deposition during higher than usual high tides throughout the period of open water. These are carried back to the landward margin of the backshore when an extreme event occurs. Since the rate of decomposition of organic materials is relatively slow, reflecting the subarctic climatic regime, accumulations of driftwood do persist as topographic "highs". They provide also a distinct micro-environment with better drainage and a different thermal ground regime. The beaches

Persistence of Beaches

are colonised by shrubs and invaded by permafrost. The vegetation response and the development of permafrost emphasise the original beach form. It is the latter attributes, rather than the material composition of abandoned beach lines that enables the identification of former driftwood accumulations on Beacon Point. Present rates of postglacial uplift

(Section 3.4) are of the order of 3.5 feet per century. This rate of crustal recovery produces sufficient progression seaward of Beacon Point between extreme events so as to preserve a beach from destruction by subsequent exceptionally high water and storm conditions.

4.2 CHANNEL PROCESSES

The peninsular shape of the York Factory area reflects the boundary conditions imposed by the Nelson and Hayes Rivers. Channel processes operative in the estuaries have modified and to a large extent controlled the configuration of Beacon Point, during its evolution in the last 2,500 years. So far as channel processes are concerned, two aspects of geomorphic activity are highly significant, (1) the effects of ice, and (2) the frequency of discharge. The latter factors which reflect the subarctic climatic regime are key considerations in terms of the evolution of the present channel patterns.

4.2.1 Channel Patterns

Tyrrell (1916) observed several differences between the lower reaches of the Hayes and Nelson Rivers.

> In its lower portion the valley of Nelson river differs in some important particulars from that of the Hayes. Like in the valley of the latter stream the banks are steep and often precipitous, but unlike it the river fills the valley from bank to bank not only in the tidal portion at its mouth, but as far as I could see upwards from the summit of Gillam Island. No bottom lands of any appreciable size could be seen and there are no terraces along the sides of the valley, for the river above the head of tide water is at present actively engaged in undercutting both of its banks, and in deepening its channel from side to side....
>
> Gillam and Seal Islands, which lie just at the head of tide water in Nelson river, also differ from any of the islands in Hayes river, in that they are composed entirely of till, and rise to the full height of the adjoining plain from which they have been cut off or separated by the river, doubtless assisted in the first place by a small stream which joins the main river immediately to the west of them.
>
> The sizes of the two valleys are not at all proportional to the sizes of the two streams which flow in them, for while the Hayes river is only about one-eight of the size of Nelson river the valley in which it flows is the larger of the two.[5]

Hayes Estuary

In contrast to the Nelson estuary the lower reaches of Hayes River are characterised by a series of channel bars and islands. The sequence encountered upstream from the mouth of the Hayes is as follows:

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[5] Tyrrell, J.B. 1916, Notes on the Geology of Nelson and Hayes Rivers, Roy. Soc. Can. Trans. Ser. 3, Vol. 10, Sec. 4, p. 23.

(a) Several bars across the mouth of the river and in midchannel, which are composed mainly of gravel material, but with sporadic amounts of cobble and boulder size material on their surface.

(b) Low islands with incipient vegetation cover (e.g. Eastern Shoal, Fig. 4.2), which are still subject to periodic inundation.

(c) Low islands stabilized by grass and shrubs (e.g. Hay Island).

(d) Wooded islands (Poplars, willows) with steep banks 10-30 feet high composed of alluvial materials, dominantly silt size and with occasional layers of very fine sand (Fig. 4.3).

Upstream of York Factory the channels between the islands have silted up. Fishing Island, for example represents the joining together of two separate islands as a consequence of the infilling of the former channel between them.

The most striking differences between the lower reaches of the Nelson and Hayes Rivers are, their mean discharge relative to the size of the valleys they occupy, and the presence of the sequence of depositional forms in the Hayes estuary. In terms of the regime of a particular stream, channel form (pattern) is a semi-independent variable. Channel form may be modified by such factors as discharge, sediment size and quantity delivered to the channel, and the frequency of discharge. Consequently the evolution of channel patterns in the York Factory ares is discussed in Chapter V, following review of the above factors.

4.2.2 Hydrology

Hydrological Aspects of the York Factory Area

Both the Nelson and Hayes River hydrographs display a characteristic flood peak in late spring. In the case of the Nelson River, the storage potential of Lake Winnipeg, Cross Lake, Sipiwesk Lake and Split Lake results in a smoothing lagging outflow hydrograph (Fig. 4.4). A mean discharge of 83,600 c.f.s. is recorded for Nelson River.[6] A maximum spring flow of 175,000 c.f.s. in 53 years of record was observed in early June 1966, below Split Lake. The Hayes River on the other hand is less subject to the stabilizing effect of large lakes upstream. As a consequence the spring run-off peak is more marked. Stream gauge data is not available for the Hayes downstream of the confluence with the God's River. An indication however, of the distribution and the magnitude of the run-off may be obtained by inspection of the hydrograph for Moose River, which drains into James Bay (Fig. 4.5). Approximately 48% of the annual flow occurs in the months of May and June. As much as 35% of the total annual discharge occurs in the month of break-up (May).[7]

Run-off Patterns

---

[6] Hydrological Atlas of Canada, 1969. Preliminary Maps: Canadian National Committee for the International Hydrological Decade, Ottawa.

[7] Newbury 1968, p. 20.

The duration curve for Moose River (Fig. 4.6), considered as reasonably typical of the magnitude and frequency of discharge in the Hayes, indicates that flows of 100,000 c.f.s. or greater occur approximately 5% of the time. The capacity of the channel processes operative in the Hayes estuary will consequently reflect the highly seasonal nature of the discharge. Optimum conditions for the transportation of bed materials will coincide with the spring flood peak.

4.2.3 Ice Effects

The effects of ice in the Hayes estuary were observed by several explorers and visitors to York Factory in the 18th and 19th Centuries.

Isham's Observations (Circa 1745)

(a) Isham's observation of ice as an erosive and transporting agent, and the flooding associated with the break-up of Hayes River:

> Its a most Surprising thing and past belief to I'magine the force and the effects the Ice has in these parts and cou'd not credit such had not I been Eye witness. Large Rock stones the Ice had Lifted & Carry'd of the shores, stones of several tuns weight, has been see'n Lying upon Ice at the setting in of the Rivers, much more at the Breaking up of the River's, when the Ice is froze fast to the ground, and the Deluges or floods of water forcing such up, thereby carry's them some distance from their former beds:...as Likewise the sand and Gravel which is the occation of so many sholes...8

---

[8] Rich, E.E. 1949. James Isham's Observations On Hudson's Bay, 1743, and Notes and Observations on a book entitled "A Voyage to Hudson's Bay in the Dobbs Galley 1749". Champlain Society, Toronto.

Andrew Graham's Observations

(b) Andrew Graham's observations of the flooding accompanying the break-up of Hayes River, and the debris transported downstream on top of the ice:

> It's unknown the great Deluge that is in these parts, and the Damage that is occation'd by such Deluges or floods of water, at the Breaking up of the River's, with the Sudden thaw's in the Spring of the years,...the Ice being froze to the ground confines the water that itt has not passage to vent itt self into the Sea, which occation's a Rising of the water some fathom's Deep which in a small time spreads over the land ...Blow's the Ice up with a Noise as terrible as thunder,...Break's all the Bank's of the Rivers down,...tear's the trees Down of great Substance by the Roats,...for some Distance in Land,...I have known the Ice when going out of the Rivers, to appear Like a wood or grove of trees with the perdigious Quantity of wood, which has been Brought of the shores by the water and Ice, when these floods has happn'd, which is frequent in the shole Rivers, that abounds with Islands, tho not so Boistorious some years as others....[9]

(c) Chappell's observations of deposition from ice:

Lieut. Chappell's Observations 1817

> The continual washing of the waters on either side of the Point of Marsh has enabled the sea to encroach a great deal on the land, and thereby created many dangerous shoals in the mouths of the rivers: the navigation has, by these means been rendered extremely contracted and difficult. The breaking up of the rivers in the spring tends also, on great measure, to increase thes evils: for, in the first place, the ice being driven towards the sea with an amazing velocity, it carries every thing forcibly away, and causes a general ruin upon the banks, by cutting down large bodies of earth, and hurling trees and rocks from their places. In the second place, it frequently happens that immense stones lying at the bottom of the river become fixed into the

---

[9] Williams, G. 1969.

> ice during the winter, and the freshes, in the spring, consequently bear them away towards the sea; but the ice not being able to sustain their ponderous weight for any length of time, it naturally occurs, that those masses become disengaged, and are deposited at the mouths of the rivers...10

(d) Ballantyne's description of the over-riding of the islands in the Hayes estuary by the ice at break-up.

Ballantyne's Observations 1848

> ...the mouth of the river became so full of ice that it stuck there, and in less than an hour the water rose ten or fifteen feet to a level with the top of the bank. In this state it continued for a week; and then about the end of May, the whole floated gently out to sea...
>
> ...The islands in the middle of the stream were covered with huge masses of ice, many of which were piled up to a height of twenty feet.11

Recent observations by Newbury (1968) indicate that in the Nelson River, the annual cycle of ice formation and destruction has significant effects on the movement of water, on the movement of material, on the vegetation along the banks, and on the river channel pattern.

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[10] Chappell, Lieut. E. 1817. Narrative on a Voyage to Hudson's Bay in His Majesty's Ship Rosamund. J. Mawman London. (Reprinted by Coles Pub. Co. Toronto 1970).

[11] Ballantyne, R.M. 1848. Hudson's Bay or Every-Day Life in the Wilds of North America, Blackwood and Sons, Edinburgh and London.

The effects of ice in the Hayes estuary, though not observed directly, may be inferred from the inspection of the channel and banks after break-up. Ice effects represent a major aspect of the geomorphic activity as evidenced by the following observations.

Evidence of Ice Effects

(a) A considerable amount of the bed material and midchannel bar material is larger than the maximum size (20 mm diameter: Section 4.2.4) which may be transported by Hayes River during spring flood peaks, based on the competence parameters suggested by Lane (1955). Thus cobble and boulder size material found on the surface of the bars and on the low islands downstream of York Factory (Fig. 4.7) has originated either from the rotting of ice which was piled up on these forms during break-up, or from the direct shoving of large bed material on to the bars and low islands by ice.

(b) Vegetation trim-lines on the wooded islands of the Hayes estuary and along the tributaries of the Hayes (Ten Shilling Creek, French Creek) which have originated as a result of the clearing of vegetation by border ice along the banks.

(c) The deposition of gravel and cobble sized material along the stable, less steep southern bank of the Hayes (Fig. 4.8).

(d) The scouring action of ice moving downstream is evident from the almost vertical side walls of the larger islands upstream of York Factory. These islands possess vertical cliffs composed of alluvial materials. Historic records indicate that Hay Island, opposite York Factory was formerly overridden by ice during break-up.

(e) In the vicinity of the beacon at Marsh Point, contorted masses of willows in association with grooves and gouges on the ground surface, attest to the overriding of the banks by ice in the lower estuary. Sporadic accumulations of gravel and cobble materials are found in association with the gouges and grooves at Point of Marsh.

4.2.4 Transport, Deposition and Erosion

Stream Competence

Some measure of the competence[12] of Hayes River is required in order to ascertain the origin of the bars and islands in the estuary. Estimates of the tractive force[13] as derived from observations of the mean depth of flow and the channel slope in the vicinity of York Factory are presented in Table 4.II. The tractive force in turn provides a measure of the size of particle that is moved as bed load by the stream (Henderson 1966, pp. 416-417). In the absence of stream gauge data for the lower reaches of the Hayes River, the estimated discharge may be derived as in Table 4.III. On the basis of tractive force estimates it is concluded that:

(a) The mean diameter of particle moved during late June when the depth of flow is approximately 8.0 feet (estimated discharge 57,000 c.f.s.) is 5.0 mm.

(b) By late July when the depth of flow (Fig. 4.9) in the vicinity of York Factory is approximately 4.0 feet (estimated discharge 19,000 c.f.s.) the diameter of particle moved by the stream is of the order of 2.5 mm.

---

[12] The largest size of grain that a stream can move in traction as bed load.

[13] The force required to entrain a given grain on the bed of the stream

(c) Immediately following break-up, assuming that the mean depth of flow is approximately 30.0 feet, based on observation of the upper limit of debris accumulation on the banks, the Hayes is competent to move bed materials up to 23.0 mm in diameter.

Grab samples from midchannel bars in the lower Hayes estuary indicate that the material is predominantly of gravel size (10-50 mm in diameter). On the surface of the bars and on the stream bed material of cobble and boulder size is also present (Fig. 4.7). This material is larger than the maximum size (23.0 mm Diameter) which may be transported by the Hayes during the spring run-off peak. Thus the Hayes River for a short period of time during and following the break-up season moves the material of which the bars and low islands in the estuary are formed. The river is competent to move gravel material up to 23.0 mm in diameter during these flood peaks, but the cobble and boulder size material are moved by the ice, or deposited from rotting ice which has lodged on top of the bars and low islands. As the spring flood peak terminates and the depth of flow decreases the Hayes will move only those particle sizes which it is competent to handle. The larger particles will no longer be in transit on the bed and deposition results.

The deposition of materials is concentrated in the form of river mouth and midchannel bars. Once deposited the coarser material provides a locus for further accumulation. Once bars emerge as low islands vegetation growth traps and stabilizes finer sediment (sand and silt material). Post-glacial uplift accentuates the evolutionary sequence of bar and low island development, which is initiated as a result of the interaction of the channel variables (discharge, frequency of discharge, sediment size and the quantity of sediment delivered to the stream). The permanance of the bars and their subsequent development into islands also reflects the erodibility of the banks of the Hayes. As observed by Leopold et al (1964, p. 294) a necessary prerequisite for the stability of midchannel bars and thus their ability to divert the flow, is that the channel banks must be sufficiently erodible so that they rather than the incipient bar give way as the flow is diverted around the deposited bar.

Midchannel Bars and Islands

The erodibility and continued erosion of the northwestern bank of the Hayes River is known from the historic record. Tyrrell (1916, pp. 25-26) estimated that the rate of recession of the bank in the vicinity of York Factory was approximately 2-3

Recession of NW Bank of Hayes River

feet per year. Inspection of a photograph[14] of York Factory in the early 1930's reveals that the distance from the flagpole in front of the fort to the crest of the river bank is approximately 260 feet. Observations during the 1970 field season indicate that the distance from the flagpole to the top of the bank is approximately 200 feet. A recession of the bank in the order of 1.5 feet per year has therefore occurred during the last forty years (1930-1970).

Permafrost and Bank Retreat

Erosion of the northwestern bank is aggravated by a permafrost condition. Seasonal melting of the active layer[15] produces a condition of decreased internal friction in the bank materials, which is conducive to slope failure. The melting out of the active layer is intensified by the southern aspect of the northwestern bank and the absence of vegetation. Both factors are conducive to increased penetration of radiated heat from the atmosphere. The oversteepened nature of the bank is maintained by tidal scour in the lower estuary (Fig. 4.10).

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[14] Wilson, C. 1957. Forts on the Twin Rivers. Beaver Magazine, York Factory Edition, p. 11. Hudson Bay Company, Winnipeg.

[15] The layer of ground above the permafrost which thaws in summer and freezes in winter.

Channel soundings indicate that the main channel follows the left bank (Fig. 2.7). The development of midchannel bars and islands has been responsible for the deflection of the current against the northwestern bank. A short stretch of bank immediately downstream of York Factory, in the lee of the former docking area, has obtained a condition of relative stability, and supports a vegetation cover of grasses and willows. Elsewhere however, slumped materials have been removed either by tides or by the spring flood peaks in the channel, and the oversteepened condition of the bank and its susceptibility to erosion is perpetuated.

4.2.5 Permafrost

Permafrost is often regarded as a condition rather than a geomorphic process. The development and the presence of discontinuous permafrost in the York Factory area is an important aspect of the geomorphic activity. The principal effects of permafrost during the evolution of Beacon Point have been

Effects of Permafrost

(a) the development of peat landforms (as described in Section 2.3),

(b) the aggravation of slope failure along the northwestern bank of Hayes River,

(c) and the development of soil and vegetation patterns which reflect directly the thermal ground regime associated with the discontinuous distribution of permafrost in the area (Section 2.1: Appendix B).

Distribution of Permafrost

An important aspect of the permafrost distribution is the development of the latter condition in newly emergent habitats. Recently emerged portions of Beacon Point and the inter-beach areas do not possess a permafrost condition. In the inter-beach fen zones (Fig. 2.24) permafrost is encountered only in the micro-relief features (palsas) which rise above the general levels of the fen. The general pattern of permafrost distribution between York Factory and Marsh Point, as observed[16] along the York Factory baseline, is closely related to local terrain conditions. As a general rule, inter-beach areas where the water table is present at, or close to the ground surface, are not frozen, irrespective of the nature of the vegetation. Palsas which provide elevated and relatively well drained sites, and the beach lines (with the exception of those recently emerged at Marsh Point) are frozen. Since the beaches on Beacon Point possess limited relief, the development and persistence of permafrost in these features is important in terms of

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[16] Observations were conducted along the York Factory baseline using a portable, manually operated 6 ft. Hoffer Probe, with serated steel bit, and 3 ft. extensions.

the maintenance of the sequence of beach and inter-beach areas. Beaches forming at Marsh Point are composed predominantly of driftwood. It is likely that were it not for the selective development of permafrost in these accumulations, the sequence of beach and inter-beach zones would become obliterated, following the decomposition of the driftwood materials which produced the original topographic "high". It is the distribution of permafrost and the vegetative response that presently indicates the position of former beaches. Originally the beaches are formed by coastal processes operative at Marsh Point, but their preservation and persistence as topographic "highs" in the landscape is due to the permafrost condition which subsequently develops.

Role of Permafrost as a Geomorphic Agent

TABLE 4.1

AVERAGE WIND SPEEDS (MILES PER HOUR) RECORDED AT CHURCHILL, MANITOBA (1955-66)

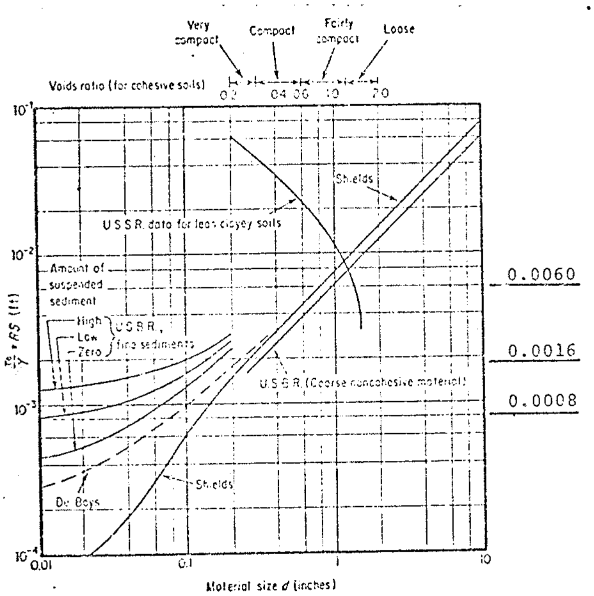
	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR
N	16.8	16.2	14.7	14.8	12.8	10.8	11.5	12.3	18.0	17.4	19.5	16.4	15.1
NNE	13.8	17.1	14.2	14.4	14.6	11.6	11.2	12.5	16.1	16.5	18.4	15.1	14.6
NE	11.9	12.7	13.1	14.0	13.9	11.1	10.4	10.4	14.5	13.7	16.9	12.9	13.0
ENE	11.6	13.2	11.8	14.8	14.5	13.0	12.3	12.8	15.1	12.7	17.8	13.1	13.6
E	12.6	13.7	13.6	14.2	14.7	14.5	12.1	12.2	16.4	12.3	13.8	13.5	13.6
ESE	11.5	12.2	15.6	16.0	15.7	17.9	15.7	15.8	14.0	16.4	11.7	13.2	14.6
SE	12.9	12.6	15.9	18.4	15.7	16.0	14.0	16.1	13.8	16.4	16.7	13.1	15.1
SSE	15.4	15.7	15.4	18.2	15.6	15.6	13.6	14.6	15.7	16.4	16.0	14.3	15.5
S	13.1	14.5	16.9	16.1	15.8	14.8	13.3	13.3	14.7	15.0	13.7	13.5	14.6
SSW	11.9	12.9	12.4	15.4	14.2	15.0	12.5	12.9	14.8	12.9	12.3	11.5	13.2
SW	12.1	12.8	12.0	13.6	14.1	14.1	13.2	12.6	13.6	11.9	13.0	12.2	12.9
WSW	12.7	13.2	11.8	13.2	13.5	14.4	13.5	13.5	13.4	12.6	12.6	12.6	13.1
W	14.0	12.2	11.4	10.6	13.1	13.8	12.5	12.9	14.2	13.3	13.3	12.5	12.8
WNW	18.1	16.1	15.1	15.5	16.8	14.9	15.5	14.2	18.4	19.0	18.5	16.9	16.6
NW	20.7	20.1	17.2	18.1	17.0	13.5	13.7	14.4	20.0	20.9	20.9	20.1	18.1
NNW	18.0	19.3	17.3	16.5	16.3	13.2	13.8	15.2	20.9	20.5	20.9	18.7	17.6
All Directions	15.8	15.6	14.5	15.7	15.1	13.5	12.8	13.5	16.4	16.4	16.9	15.3	15.1

TABLE 4.II

TRACTIVE FORCE AND PARTICLE SIZE (HAYES ESTUARY)

R	S	$\frac{\tau_0}{\gamma} = RS$	τ_0	d
30.0′ LATE MAY*	0.0002	0.0060	0.375	0.9″ (≈ 23.0 MM)
8.0′ LATE JUNE**	0.0002	0.0016	0.100	0.2″ (≈ 5.0 MM)
4.0′ LATE JULY**	0.0002	0.0008	0.050	0.1″ (≈ 2.5 MM)

*ESTIMATED **OBSERVED



R = HYDRAULIC RADIUS
≃ (D), MEAN DEPTH OF FLOW IN WIDE CHANNEL

S = CHANNEL SLOPE

τ_0 = SHEAR STRESS (TRACTIVE FORCE)

γ = SPECIFIC WEIGHT OF WATER (62.5 lb/ft^3)

d = MATERIAL SIZE (INCHES)

INSET: ALLOWABLE TRACTIVE FORCES IN COHESIVE AND NON-COHESIVE BED MATERIALS: HENDERSON, 1966, p.417, Fig. 10.5

TABLE 4.III

ESTIMATED DISCHARGE (Q), HAYES RIVER AT YORK FACTORY

	n	A	R	S	$Q^{(1)}$
LATE JUNE	0.029	18,750 SQ.FT.	8.0 FT.	0.0002	57,000 C.F.S.
LATE JULY	0.029	10,000 SQ.FT.	4.0 FT.	0.0002	19,000 C.F.S.

$$Q = V(A)$$

$$V = \frac{1.49}{n} (R)^{2/3} (S)^{1/2}$$ (Manning Equation, Henderson, 1966, p.96)

$$^{(1)}Q = \frac{1.49}{n} (A) (R)^{2/3} (S)^{1/2}$$

where Q = Discharge
n = Roughness Coefficient
V = Channel Velocity
A = Cross sectional Area of Channel
R = Hydraulic Radius
S = Channel Slope

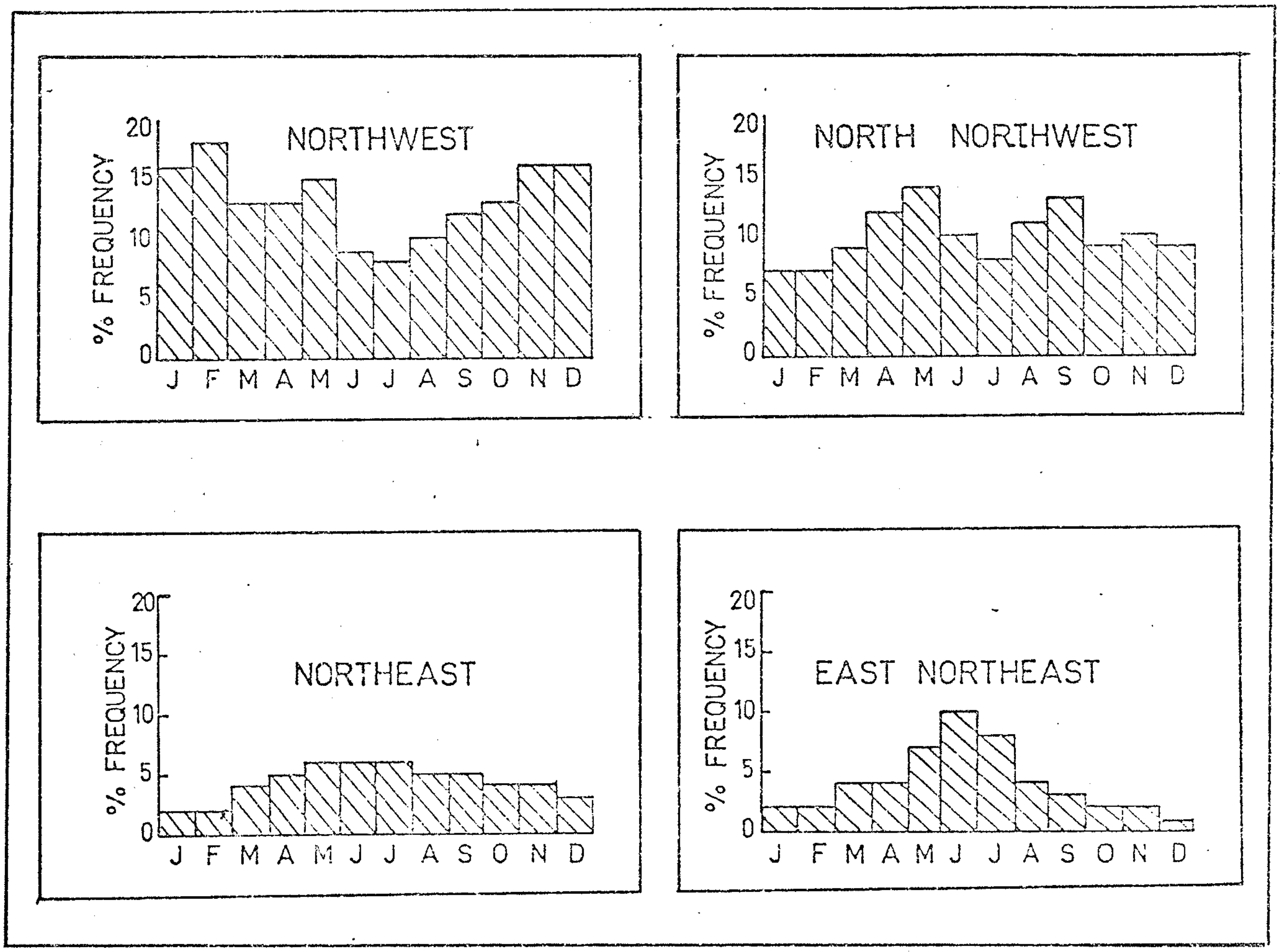


FIGURE 4.1

PERCENTAGE FREQUENCY OF
NW, NNW, NE AND ENE WINDS AT CHURCHILL, MANITOBA
(Period of Record 1955-66)

FIGURE 4.2

EMERGENT BAR (EASTERN SHOAL)
LOWER HAYES ESTUARY
WITH INCIPIENT VEGETATION COVER

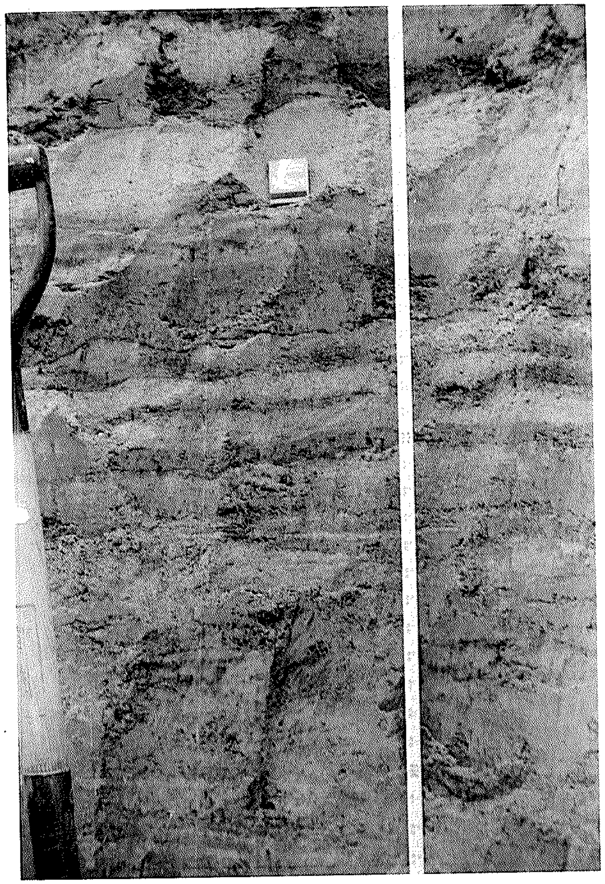


FIGURE 4.3

CLIFF BACKING BEACH AT
FOUR MILE ISLAND,
COMPOSED PREDOMINATELY OF SILT
WITH LENSES OF FINE SAND

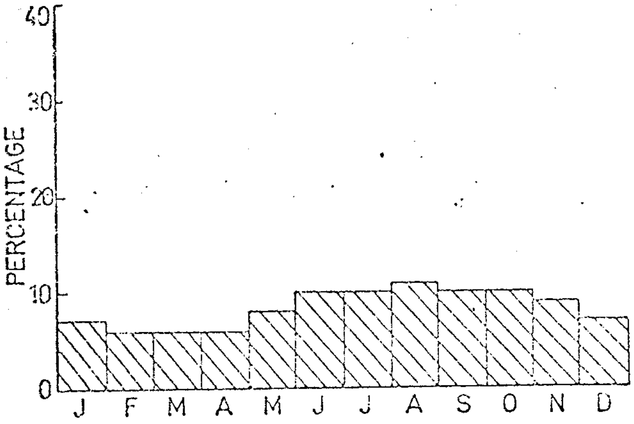


FIGURE 4.4

MONTHLY DISTRIBUTION OF RUNOFF

NELSON RIVER, VICINITY OF CROSS LAKE

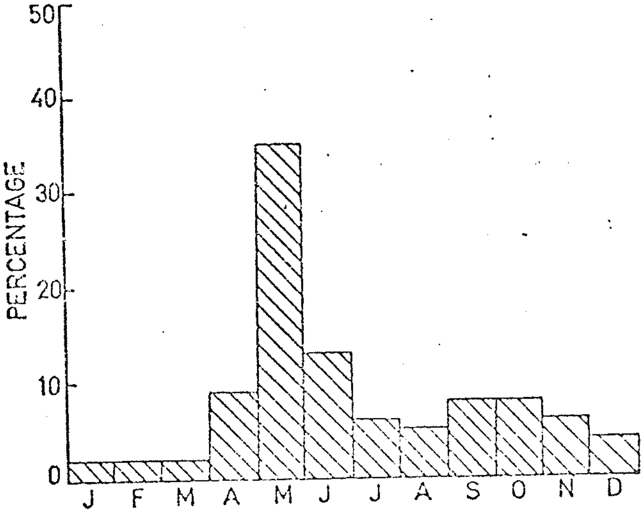


FIGURE 4.5

MONTHLY DISTRIBUTION OF RUNOFF

MOOSE RIVER AT MOOSE RIVER CROSSING

(Source: Hydrological Atlas of Canada, Preliminary Maps, 1969)

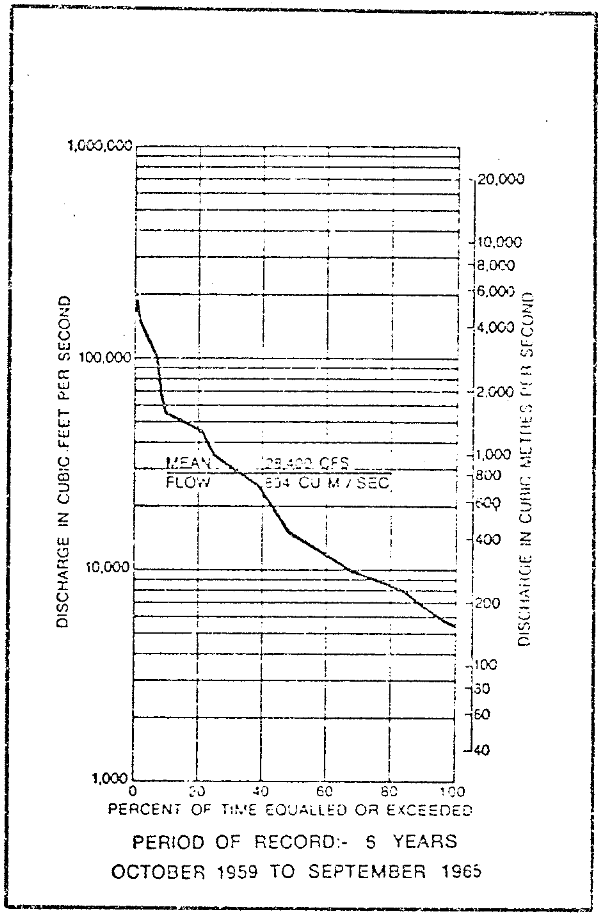


FIGURE 4.6

DURATION CURVE OF MONTHLY FLOW:
MOOSE RIVER AT MOOSE RIVER CROSSING

SOURCE: Hydrological Atlas of Canada, 1969.

FIGURE 4.7

COBBLE, GRAVEL AND COARSE SAND MATERIALS
ON THE BEACH OF HAY ISLAND

FIGURE 4.8

VEGETATION TRIM LINE, SOUTH BANK OF HAYES RIVER

Sporadic accumulations of cobble material at the top of (centre of photograph) dumped by the ice during break-up.

FIGURE 4.9

CHANNEL BAR, ONE QUARTER MILE DOWNSTREAM
OF YORK FACTORY, EXPOSED AT LOW TIDE
(JULY 1969)

FIGURE 4.10

OVERSTEEPENING OF RIVER BANK AND
REMOVAL OF SLUMPED MATERIALS BY TIDES IN THE
HAYES ESTUARY, AT THE PRESENT YORK FACTORY SITE

CHAPTER V

PROCESS AND EVOLUTION

> Nature does not reveal all her secrets at once, we may imagine ourselves uninitiated in her mysteries; we are as yet but loitering in her outer courts.
>
> Seneca

Redefinition of of Research Objective

As defined in Figure 1.1 the present analysis is concerned with the evolution of the York Factory area during the last 2,500 years. In terms of the physical boundaries this represents the tract of land between the Nelson and Hayes estuaries and the latter channels themselves downstream of Gillam Island and Fishing Island respectively. The temporal and physical boundaries defined preclude detailed discussion of the evolution of the area prior to 2,500 B.P. Interpretation of aerial photographs and a review of former investigations by Tyrrell (1913, 1916) and Newbury (1968) has enabled however a brief discussion of the origin of Beacon Point and the development of the boundary conditions inherited by 2,500 B.P. (Appendix D).

The present analysis is concerned with the change, the rate of change, and the processes responsible for the change in the landscape and channel patterns during the evolution of the York Factory area. On the basis of (a) radiocarbon dating of driftwood material extracted from the sand and gravel unit (Fig. 2.21), (b) the distribution of abandoned beach lines indicative of former shorelines, and (c) the estimated rate of recession of the northwest bank of Hayes River, the respective positions of the channel and shoreline boundaries since 2,500 B.P. may be delineated (Fig. 5.1). By 2,500 B.P. the peninsular shape of the York Factory area was already established and the estuarine framework for channel and coastal sedimentation initiated. Subsequent evolution of the area was characterised by the following developments.

Evolution of the York Factory Area

(1) Continued encroachment of the Hayes River on the northwestern bank, with corresponding aggradation of the southern bank, resulting in a continued migration of the channel to the northwest. A similar situation also occurred in the lower Nelson estuary.

(2) Continued seaward progression of Beacon Point in response to crustal rebound and sedimentation along the southwest coast of Hudson Bay. The initial rate of uplift (2,500 B.P.) was of the order of 5-6 feet/century[1] and this rate has declined exponentially to approximately 3-4 feet/century at present.

(3) The development of an evolutionary sequence of physiographic zones (beach and inter-beach areas), reflecting the continued emergence of Beacon Point.

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[1] The rate observed depends on the choice of mathematical model used to simulate the post-glacial uplift process (see Section 3.4).

(4) The development of a series of river mouth bars, midchannel bars, low islands and cliffed islands in the Hayes estuary. The persistence of the bars and islands produced in turn concentrated erosion of the northwestern bank of Hayes River.

(5) The silting up of the channels between the islands, and the coalescence of the islands upstream of York Factory.

(6) The development of an evolutionary sequence of soil and vegetation zones (Fig. 5.2), reflecting the emergence of new habitats (beach and inter-beach areas) from Hudson Bay.

(7) The development of a discontinuous pattern of permafrost, subsequent to emergence.

Evolution of Beach Systems on Beacon Point

The evolution of beach systems on Beacon Point requires special mention since their development is related to a somewhat unique combination of processes formerly and presently operative in a subarctic estuarine environment. Stages in the evolution of beach systems are represented schematically in Figure 5.3. These include the following.

STAGE (1) Deposition of Driftwood Line

The deposition at the landward margin of the backshore zone during an "extreme event" of driftwood and other debris. This provides an initial topographic "high" which persists in the landscape beacuse (a) it originates at the time of an "extreme event" (Section 4.1), thus it is located sufficiently far back from the foreshore to prevent it being destroyed by storms occurring during the period of open water on Hudson Bay: (b) The decomposition of organic materials is relatively slow in the subarctic environment: (c) Continued postglacial uplift and sedimentation produces sufficient progression seaward of Beacon Point (presently of the order of 18-20 feet per year) to preserve the driftwood line from destruction by subsequent "extreme events": (d) It is a favourable habitat for colonization by vegetation. The latter acts as a stabilising factor: (e) Flooding of the lower estuaries of the Nelson and

Persistence of Driftwood Line

Hayes Rivers following the spring break-up results in the deposition of alluvial materials adjacent to and on top of the driftwood line. The vegetation traps and stabilises these materials and a sequence of alluvial and organic layers develops.

STAGE (2)

Development of Segregation Ice in Beach Line

The driftwood line now presents a contrasting micro-environment to that of the surrounding fen, marsh and backshore. Several factors contribute to the development of a thermal ground regime which is conducive to the growth of segregation ice. (a) The driftwood lines are better drained. In the surrounding fen and backshore the water table is close to or at the surface. (b) The materials overlying the original driftwood debris are predominantly medium textured alluvial deposits (Machichi Soil Series: Appendix B, Table B-II). Such materials are frost susceptible. (c) Slow cooling of the ground (a condition regarded as necessary for the development of segregation ice[1]) is likely to occur because of the insulating character of the vegetation.

STAGE (3)

Colonisation By Spruce

With the growth of segregation ice in the beaches, up-doming occurs. The original topographic "high" is accentuated and becomes more conspicuous as a result of the colonisation by white spruce stands.

STAGE (4)

Spruce Belts 300-500'

The former beach lines are now associated with belts of mature white spruce, which occupy the crests of the ridges. Interdispersed with the spruce stands and providing a gradation into the surrounding fen are willow and tamarack with a shrub layer of alder and dwarf birch. With the development and persistence of permafrost in stages (3) and (4), continued up-doming and lateral extension of the original draftwood line occurs. Spruce belts up to 500 feet in width are typical of this latter stage of beach evolution.

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[1] Embleton, C. and C.A.M. King, 1968, p. 466.

Geomorphic Processes & Evolution

Three major groups of geomorphic processes, (1) crustal rebound, (2) river channel, and (3) coastal processes, have been operative during the evolution of the York Factory area. The channel and coastal processes have operated with a marked seasonal regime reflecting the subarctic climate of the area. The role of ice as an agent of erosion, transportation and deposition in the Nelson and Hayes estuaries and at Point of Marsh awaits further detailed investigation, particularly direct observation during and immediately following the break-up period. The area is also subject to the endogenetic process of crustal recovery. Investigations based on the physical manifestations of postglacial uplift (the sequence of abandoned beach lines) indicate that the recovery process continues today and at a rate of 3-4 feet per century. Emergence of the York Factory area cannot be regarded however as simply being a direct response to the unloading of the crust following deglaciation, since sedimentation in the estuaries of the Nelson and Hayes Rivers has also contributed to the seaward progression of Beacon Point. Data concerning the amount and the frequency of delivery of sediment by the rivers themselves is therefore required in order to ascertain the respective magnitudes of marine regression due to postglacial uplift and due to sedimentation by coastal and channel processes operative in the area.

Despite the inability to presently assess the capacity and frequency of specific processes, inspection of Figure 5.1 does indicate however, that the combined effect of the endogenetic and exogenetic processes is the extension seaward of Beacon Point at a contemporary rate of 18-20 feet per year. Initially (i.e. circa 2,500 B.P.) this rate was of the order of 70-75 feet per year.

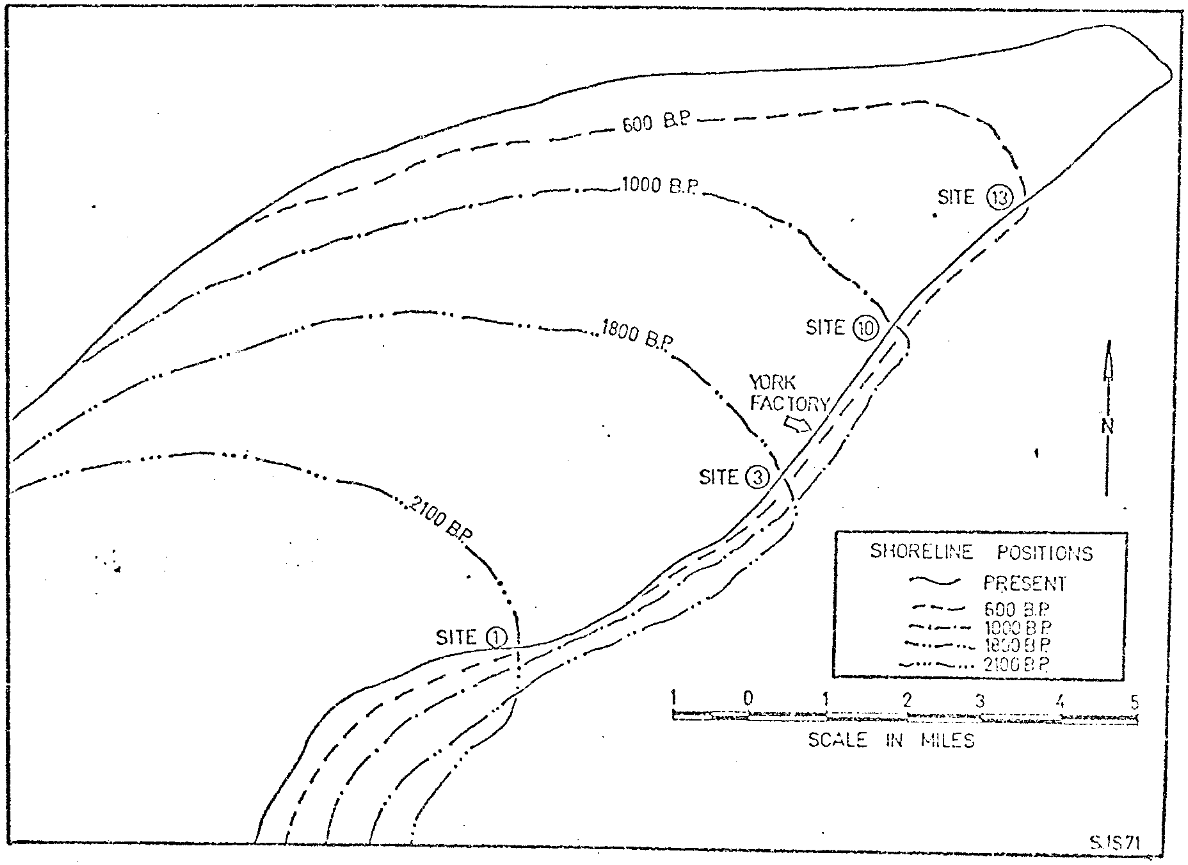


FIGURE 5.1

EVOLUTION OF THE
YORK FACTORY AREA

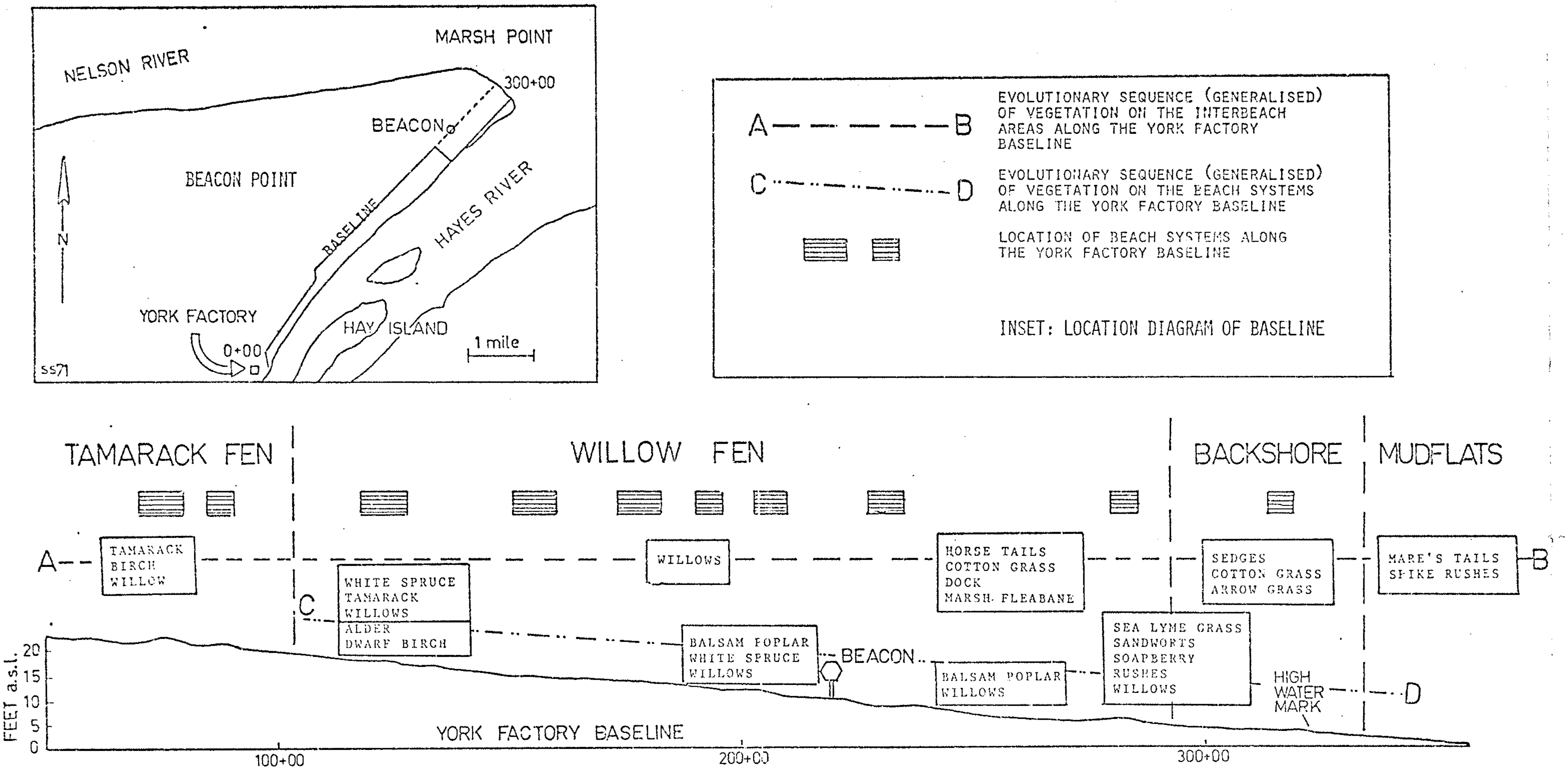
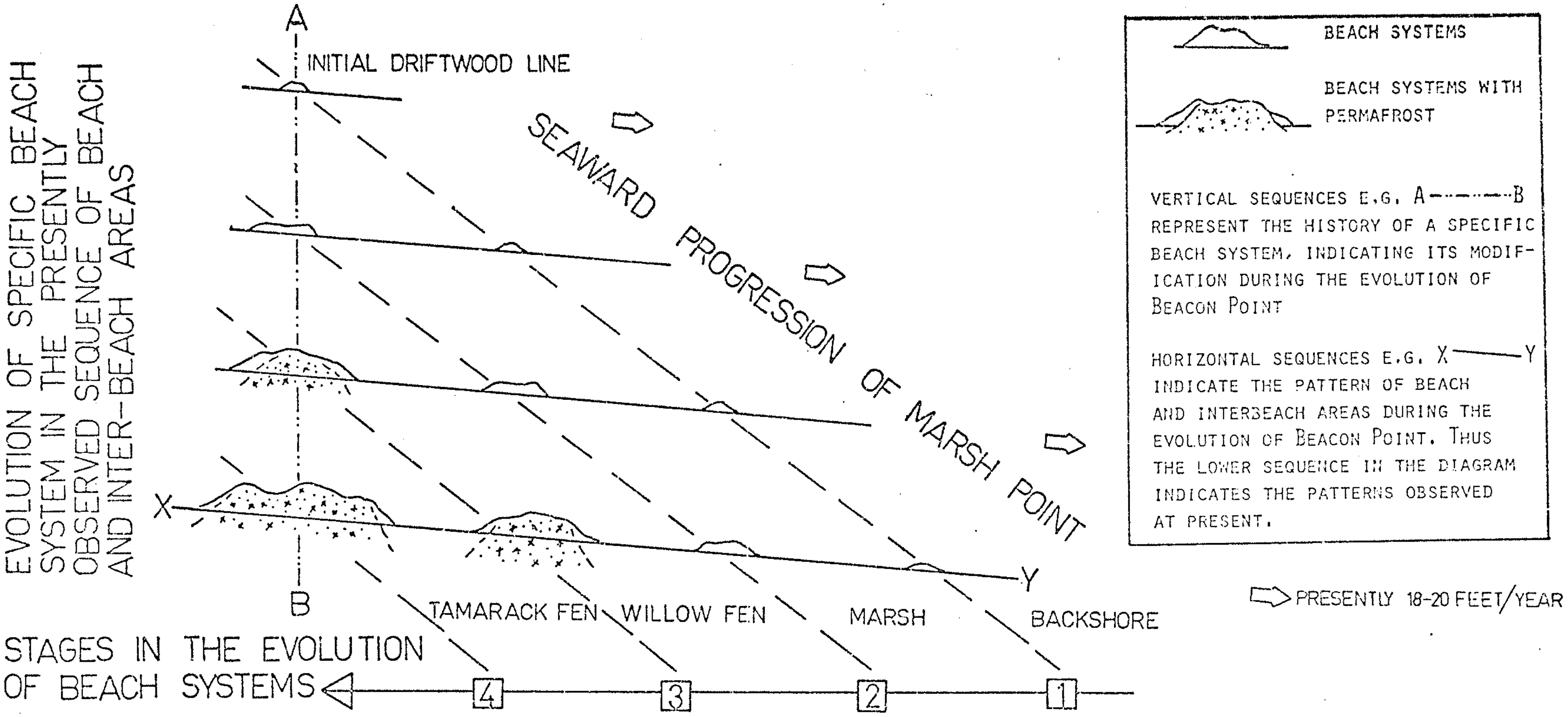


FIGURE 5.2

EVOLUTIONARY SEQUENCE OF VEGETATION PATTERNS ON BEACH AND INTER-BEACH AREAS, BEACON POINT



VERTICAL SEQUENCES E.G. A------B REPRESENT THE HISTORY OF A SPECIFIC BEACH SYSTEM, INDICATING ITS MODIFICATION DURING THE EVOLUTION OF BEACON POINT

HORIZONTAL SEQUENCES E.G. X———Y INDICATE THE PATTERN OF BEACH AND INTERBEACH AREAS DURING THE EVOLUTION OF BEACON POINT. THUS THE LOWER SEQUENCE IN THE DIAGRAM INDICATES THE PATTERNS OBSERVED AT PRESENT.

FIGURE 5.3

EVOLUTION OF BEACH SYSTEMS AND LANDSCAPE PATTERNS, BEACON POINT

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APPENDIX A

THE REGIONAL SETTING OF THE YORK FACTORY AREA

Field observations were confined to the York Factory area, thus the discussion of the events during and following the deglaciation of adjoining areas, leading to the establishment of the present postglacial landscape patterns, are based on former observations, chiefly by Tyrrell (1913, 1916), Elson (1957, 1964), Prest et. al. (1967), Newbury (1968), Craig (1969) and McDonald (1969).

A-I PHYSIOGRAPHY

The Hudson Bay region can be subdivided into several physiographic units, on the basis of inherent regional variations of climate, landforms, vegetation, soils and geological history. Robinson (1968) proposed five such subregions (Table A-I, Figure A-1). The South Coast Lowland is synonymous with the area delineated by Coombs (1954) as the Hudson Bay Lowlands. Tyrrell referred to this region as the "Archudsonian Swamp", describing it as follows:

> ....a vast level plain extends to the limit of vision. This plain which reaches to the shore of Hudson Bay, and has an area of something like 100,000 square miles is one continuous swamp covered with a thick water-soaked blanket of bog mosses....this swamp....now covers an area which once formed part of the bottom of the ancient extended basin of Hudson Bay....[1]

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[1] Tyrrell, J.B. 1916, Notes on the geology of Nelson and Hayes Rivers, Roy. Soc. Can. Trans. Ser. 3, Vol. 10, Sec. 4, p. 8.

The Hudson Bay Lowlands have been further subdivided for the purpose of regional description (Table A-I, Figure A-2). The York Factory area straddles both the Marine Clay and Coastal Zones. The former is so called because of the mantle of fine sediments deposited by rivers draining from the south and southwest of Hudson Bay into the Tyrrell Sea. Hudson Bay is a relic of the Tyrrell Sea which inundated the area during and following deglaciation. The marine transgression reached its maximum extent between 7000 and 8000 years ago (Lee, 1960). This enlarged phase of Hudson Bay (Figure A-3) is named after Joseph Burr Tyrrell (1858-1957), the famous Canadian geologist and explorer.

The Marine Clay Zone is characterised by generally flat, gently sloping, swampy, monotonous terrain, upon which is superimposed a complex network of muskeg, lakes and streams. Large rivers which cross the Lowland have downcut into the mantle of glacial, glacio-fluvial and glacio-marine sediments. Local drainage takes place slowly due to the low gradient of the flat landscape. During the snow-melt period extensive tracts of bog and muskeg are covered with an almost continuous sheet of water. The southern and southwestern limits of the Clay Zone are marked by a low discontinuous escarpment which occurs between 400 and 500 feet above sea level. A sequence of fossil shorelines, manifested in the landscape as either wave modified landforms, or as beach deposits, provide the major relief elements on this otherwise flat monotonous terrain. Micro-relief elements such as sink holes, shallow lakes, beaded stream segments and peat landforms are associated directly or indirectly with the widespread occurrence of permafrost.

The Coastal Zone includes the tidal portions of the major river estuaries and the generally continuous strip of tidal flats. The most conspicuous relief elements are the storm beaches of the Backshore Zone.[2]

A-II CLIMATIC PATTERNS

Hudson Bay has a typically Arctic climate, but inland from the southern and southeastern coast there occurs a transition to a sub-Arctic regime (Figure A-4). The York Factory lies along the boundary of the Arctic and Subarctic climatic zones. The temperature and precipitation records for Churchill, the nearest first order meteorological station, closely approximate those of the York Factory area (Figure A-5, Table A-II). Mean monthly temperatures range from -18°F in January to 54°F in July. A mean annual precipitation of sixteen inches occurs, nine inches as rain and seven inches (equivalent) as snow. Rainfall is extremely variable from

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[2] The Backshore is defined as the area extending back of normal high tide, but which is occasionally inundated by exceptional high tides and storm waves.

year to year. At Churchill the average monthly rainfall for August is 2.4 inches. In 1961 August rainfall totalled 4.9 inches, while two years later in 1963 the figure was only 0.5 inches. The greatest recorded rainfall in any month occurred in July 1934 when 7.3 inches fell, almost one half of the average annual precipitation for Churchill.[3]

Several factors combine to adversely modify the climate of the York Factory area. The location close to the cooling influence of a large expanse of cold water (or ice, depending on the season) to the north, and the intermittent penetration of the Hudson Bay Lowlands by colder arctic air, results periodically in temperatures that are typically Arctic. Wind chill, the increased cooling effect produced when low temperatures occur in association with strong winds is of particular seasonal significance. Examples of the wind chill factor at Churchill are presented in Figure A-6. Locally, the occurrence of widespread permafrost has an adverse effect on the summer temperature regime. Water from the melting snow cannot penetrate the frozen substratum. The resultant evaporation from the almost continuous water surface of the bogs and muskeg, consumes heat energy which otherwise could

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[3] Thompson, H.A. 1968, The Climate of Hudson Bay, in Science, History and Hudson Bay, (ed.) C.S. Beals, Vol. 1, Chapter 5, p. 263, Queen's Printer, Ottawa.

be used to raise the ground and subsequently the air temperatures.[4]

On the other hand, the climate of the York Factory area is often favourably modified. The southerly location of the Hudson Bay Lowlands results in the more frequent incursion of warm air masses which move north from the Gulf of Mexico, bringing higher summer temperatures than would ordinarily be expected for these latitudes. Penetration of southerly air masses for example, have raised May temperatures at Churchill to 80°F. Summer temperature peaks in the Hudson Bay Lowlands generally exceed 90°F, one year in four.[5]

In winter the upper air circulation over Hudson Bay is characterised by a persistent counter-clockwise air-flow around a low pressure vortex, centred over northeastern Baffin Island. This condition gives rise to a general northwest to southeast transfer of large masses of cold air from the Arctic. The winter wind direction frequencies for Churchill reflect this northwest flow pattern of surface winds (Figure A-7a). In winter warm southern air masses cross the North American continent well south of the Hudson Bay region. In summer low pressure systems move directly across Hudson Bay. Summer wind

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[4] Thompson, 1968, p. 267.

[5] Thompson, 1968, p. 279 and p. 284.

patterns are therefore variable, due to the intermittent invasions of warmer air from the south and west (Figure A-7b). The frequency distribution of annual wind directions (Table A-III, Figure A-8) exhibits a higher occurrence of NNW, NW and WNW winds.[6]

The high frequency of NNW, NW and WNW onshore winds in the York Factory area is reflected in the distribution of beaches and driftwood lines. These features are more strongly developed along the north and northwest side of Beacon Point.

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[6] Early explorers of the Hudson Bay region frequently remarked upon the direction of prevailing winds and currents. Charles Bell, author of "Our Northern Waters; a Report presented to the Winnipeg Board of Trade, regarding the Hudson's Bay and Straits" 1884, summarises several observations by early visitors to the region which relate to the prevailing wind direction and frequency. For example:

Parry states that in the year 1853-54 the wind blew from the NW and the NNW on 145 and 81 days respectively; on only 34 occasions did the wind blow from the SE.

Dr. Nevins, a surgeon on a Hudson's Bay Company ship wrote in 1843 that the North Westerly winds prevail in these parts, it blows from the North West quarter near nine months in twelve.

A-III BEDROCK GEOLOGY

Several structural elements in the bedrock topography of the Hudson Bay Lowlands have been identified by Nelson and Johnson (1966), Sanford, Norris and Bostock (1968), Norris and Sanford (1969). The most important of these is the Cape Henrietta Maria Arch[7] which divides the Hudson Basin (Figures A-9 and A-10) into two Phanerozoic sedimentary basins, James Bay or the Moose River Basin to the southeast, and the larger Hudson Bay Basin to the northwest. In the former Ordovician, Silurian, Devonian and Lower Cretaceous strata occur, reaching a thickness of 2,500 feet in the central part of the basin.[8] On the mainland portion of the Hudson Bay Basin rocks of Ordovician, Silurian and Devonian ages are present. A total thickness of 6,000 feet of sediments have been recorded for the central part of the basin.[9] The Cape Henrietta Maria Arch is composed of inliers of Archaean and Proterozoic rocks (Figure A-9) which are overlain by about 1,000 feet of Silurian strata. Two other minor positive[10]

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[7] Also referred to as the Patricia Arch (Nelson and Johnson 1966, p. 569).

[8] Norris, A.W. and B.V. Sanford 1969, Palaeozoic and Mesozoic geology of the Hudson Bay Lowlands, in Earth Science Symposium on Hudson Bay, G.S.C. Paper 68-53, (ed.) P.J. Hood, Queen's Printer, Ottawa.

[9] Norris and Sanford (1969), p. 169.

[10] The terms "positive" and "negative" refer to topographic high and low elements respectively in the bedrock surface of Hudson Bay Lowlands.

elements in the bedrock topography, the Cape Tatnam High and the Pen Islands High (Figure A-11), along with the Cape Henrietta Maria Arch have predetermined the gross coastal configuration of the Hudson Bay Lowlands east of the Hayes River estuary.[11]

Two negative structural elements have also been identified, the Kaskattama Trough and the Nelson River Trough (Figure A-11). The former is a complex synclinal belt between the Cape Tatnam High and the Ontario boundary, trending northeastwards with an axis approximating the Kaskattama River.[12]

The Nelson River Trough is a broad east-northeasterly trending zone opening bayward along the present Nelson River. This broad valley-like feature has influenced the development of the present day drainage patterns, since it occurs at the narrowest exposure of the Precambrian Shield, and thus provides a corridor of access for the Churchill, Nelson and Hayes Rivers which drain from the Western Interior of Canada to Hudson Bay. The Nelson Trough is also of geological significance, since it is related to the boundary zone between the Churchill and Superior geologic provinces (Figure A-12).

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11 Nelson, S.J. and R.D. Johnson, 1966, Geology of Hudson Bay Basin; Bull. Can. Petrol. Geol., Vol. 14, No. 4, p. 569 ff.

12 Nelson and Johnson (1966), p. 570.

The difference in age of the last orogeny has been the basic criterion for separating the oldest rocks peripheral to, and underlying the Hudson Bay Lowlands, into two distinct geologic provinces:

> ....the most recent orogeny in the Superior province, termed Kenoran, took place 2,390 million years ago. In the younger Churchill province on the other hand the most recent orogeny, the Hudsonian, took place 1,640 million years ago or 750 million years later.[13]

Davies et. al. (1962, p. 13ff) have summarised the characteristics of the rocks occurring in the Superior and Churchill geologic provinces:

> The Superior province is characterised by east-trending volcanic-sedimentary belts in which volcanic rocks are as abundant or more abundant than sedimentary rocks. Grade of metamorphism generally is low to moderate. The sedimentary-volcanic belts of the Churchill province trend in various directions and sedimentary rocks are more abundant than volcanic rocks. In general, also, the sedimentary rocks are more highly and extensively metamorphosed and more complexly folded...than either the volcanic or sedimentary rocks of the Superior province. The rocks underlying the Churchill province in Manitoba, are in general, lighter than those of the Superior province....
>
> The lithology of the Precambrian volcanic and sedimentary rocks is simple in general but complex in detail. Briefly the volcanic rocks consist of

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[13] Whitmore, D.R.E. and B.A. Liberty, 1968, Bedrock Geology and Mineral Deposits, in Science, History and Hudson Bay, (ed.) C.S. Beals, Chapter 9, Part II, p. 543, Queen's Printer, Ottawa.

> light to dark coloured andesites and basalts (commonly ellipsoidal), volcanic breccia (andesitic, dacitic and rhyolitic), and tuffs. Interbanded with these in places may be coarse grained massive hornblende-plagioclase rocks.... The sedimentary rocks are mainly impure quartzites and greywackes, although conglomerate, slate and arkosic rocks are also common.... Outside the volcanic-sedimentary belts, and forming the bedrock over most of the Precambrian Shield are complexes of "granite" and granite gneisses (...many or most of the rocks are not true granites but closer to granodiorites and tonalites). Sedimentary and volcanic rocks associated with these granitic rocks may be extensively granitized.[14]

The stratigraphic sequence in the Hudson Bay Lowlands consists of nearly flat to gently dipping sedimentary rocks, which overlie unconformably the Precambrian basement complex. The bedrock formations on the mainland portion of the Hudson Bay Basin include sandstones, limestones and dolomites of early Paleozoic age. The outcrops are confined to the banks of major streams, since the entire Lowlands are blanketed by Pleistocene and Recent deposits. The bedrock geology and stratigraphic succession are summarised in Figures A-13 and A-14.

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[14] Davies, J.F., Bannatyne, B.B., Barry, G.S., and H.R. McCabe, 1962, Geology and Mineral Resources of Manitoba, Manitoba Dept. Mines Nat. Resources, Winnipeg.

A-IV SURFICIAL GEOLOGY

Evidence of repeated continental glaciation is found in present day temperate areas south of the Hudson Bay region. Inter-till non-glacial deposits in Illinois and Iowa are indicative of at least four periods (Stages) of continental glaciation in North America during the Pleistocene epoch. These are the Nebraskan, the Kansan, the Illinoian and the Wisconsinan. During the final Wisconsinan glaciation several local advances and retreats (Substages) occurred. No manifestation of all four glacial periods is known for the Hudson Bay region, either because the ice sheets continued to cover much of northern Canada during the interglacial periods which occurred in lower latitudes, or because the final advances and retreats of the Wisconsinan glaciation obliterated or reworked the previous sedimentary record.

Dawson (1890) named the coalescent mass of ice which covered most of North America east of the Rocky Mountains, the Laurentide ice sheet. Several theories regarding the growth and outflow patterns of the Wisconsin-Laurentide ice sheet are summarised by Lee (1968, pp. 510-511). The growth of a single ice mass on the Labrador-Ungava plateau by a process of "instantaneous glacierization" is presently favoured. In Manitoba the traditional viewpoint of glaciation originates from Tyrrell's postulation of the existance of three centres of ice accumulation and outflow.

> In order of time therefore we would have 1st, a Patrician Period during which the ice spread out from a centre in the country between Hudson Bay and Lake Superior, northward into the basin of Hudson Bay, westward across the Hayes and Nelson rivers, and doubtless also southward towards Lake Superior and Lake of the Woods; 2nd, a Keewatin Period when the ice accumulated on a centre west of Hudson Bay and north of the Churchill river, and moved southward and southeastward down to and over the basin of Lake Winnipeg and the plains of southern Manitoba' and 3rd, a Labradorean Period during which the ice moved southwestward across the southern portion of the basin of Hudson Bay as far as Lake Winnipeg, overriding the marine deposits in the bottom of the Bay and shoving a certain portion of them to and over the country to the south of it.[15]

The single, as opposed to the multiple ice sheets viewpoint can in part be reconciled by assuming the growth of an original single ice mass, which was subsequently characterised by areas of regional advance and retreat.

The distribution of surficial deposits in the hinterland of the York Factory area is illustrated in Figure A-15. The pattern of landforms and the nature of the deposits indicate a history of glacial, glacio-fluvial, glacio-lacustrine and glacio-marine sedimentation.

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[15] Tyrrell, 1916, pp. 16-17.

A-IV-i Glacial Deposits - Till Landforms

Three till sheets have been identified in the northwest portion of the Hudson Bay Lowlands (Figures A-16 and A-17). The lower and middle tills are separated by non-glacial deposits (marine strata, peat and associated sediments, stream gravels and sand) considered to be indicative of an interglacial episode by McDonald (1969). The middle and upper tills are differentiated on the basis of their colour, texture and structure. Proglacial lake sediments have been recorded at several localities separating the upper and middle till units (Tyrrell, 1916, p. 12 ff, McDonald, 1969, p. 90).

Topographical expressions of glacial till are of limited occurrence, since glacio-lacustrine, glacio-fluvial and glacio-marine sediments have subsequently mantled the region. Morainic features (Figure A-15) have been identified largely on the basis of their morphology and their orientation relative to the assumed patterns of marginal flow. Areas of ground moraine, where not overlain by glacial-aqueous deposits have been subsequently mantled by recent accumulation of alluvial materials and organic soils.

A-IV-ii Glacio-lacustrine Deposits

Glacial Lake Agassiz[16] was impounded south and west of the York Factory area, between the retreating Wisconsin-Laurentide ice sheet and the height of land separating the Hudson Bay and the Mississippi-Missouri drainage.[17] Offshore sedimentation in a series of basins resulted in the accumulation of fine textured lacustrine deposits over a large portion of northern Manitoba (Figures A-15 and A-18). Proglacial lake sediments have been observed in the northwest Hudson Bay Lowlands; rhythmically bedded silt and sand of freshwater origin underlie the fossiliferous marine sediments deposited during the Tyrrell Sea phase. The lake sediments may represent a northern extension of Lake Agassiz (McDonald, 1969, p. 93).

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[16] The term "Lake Agassiz" refers to a series of lake phases, associated with several ice advances and retreats (substages) during the Wisconsinan Stage.

[17] The sequence of events in the history of glacial Lake Agassiz has been summarized by Elson (1955, 1957, 1967). The final drainage of the lake by way of its northern outlets to Hudson Bay, as related to the deglaciation history of northern Manitoba and the establishment of postglacial drainage in the Churchill-Nelson-Hayes Trough still awaits field investigation. Newbury (1968, p. 32 ff) has presented a tentative sequence of events following the last glaciation, leading to the development of the present Nelson River.

A-IV-iii Glacio-fluvial Deposits

Glacio-fluvial deposition during the period of final stagnation and retreat of the ice sheet in northern Manitoba is manifested by the presence of eskers, outwash complexes and spillway systems (Figure A-15). In the upper reaches of the Hayes and Gods Rivers, the eskers trend in a southwest-northeast direction. In the Fox River and lower Nelson valleys the trend changes to east-west. The distribution of eskers is almost invariably confined to an area bounded by the roughly semicircular end moraine complex in northeast Manitoba (Figure A-15). In the lower Nelson valley, north of Gull Lake, sub-parallel discontinuous eskerine ridges extend eastward from the Burntwood-Etawney end moraine, and south of Little Limestone Lake. The ridges grade into an outwash complex at the confluence of the Nelson and Limestone Rivers (Figure A-15).

Discontinuous buried channels, infilled with outwash debris, have been observed at several locations between Upper Limestone and Lower Limestone Rapids on the Nelson River (Newbury, 1968, p. 31). Higher channels have also been recorded extending upstream to the vicinity of Split Lake. The latter have been partially infilled with marine clay and alluvium. Their location in the vicinity of the eastern boundary of Lake Agassiz in the Nelson valley suggests that they are remnants of former spillway systems.

In consideration of the distribution of glacio-fluvial landforms in relation to the northern and eastern boundaries of Lake Agassiz, it is suggested that late-glacial drainage developed across, between, through and under residual blocks of stagnant ice in the Churchill-Nelson-Hayes Trough. The embayments produced by lake water in the retreating ice front, as evidenced by the distribution of lacustrine deposits, are associated with esker and spillway systems that lead away from them (Figure A-18). Elson (1967, p. 44) has postulated northern outlets of Lake Agassiz by way of the present upper reaches of the Echoing, Hayes, Bigstone and Limestone Rivers. These routes do in fact correspond with the distribution and orientation of major eskers (Figure A-18).

A-IV-iv Glacio-marine Deposits

Following deglaciation the Hudson Bay Lowlands were inundated by the Tyrrell Sea (Lee, 1960, 1968). The approximate limits of the marine transgression are shown in Figures A-3 and A-15. Radiocarbon dating of marine shells indicates that the Tyrrell Sea reached its maximum extent between 7,000 and 8,000 years ago. The Hudson Bay region was first invaded by marine water through Hudson Strait approximately 8,000 years B.P. The James Bay

Lowland was the first part of the region to become ice free (around 7,900 years B.P.). Dates approximating the time of the marine inundation become progressively younger in a clockwise direction around Hudson Bay, reflecting the nature and the time of deglaciation. Ice persisted 200 or 300 years longer in the northwest portion of the Hudson Bay Lowlands, the marine transgression not occurring until 7,600 years B.P. following a proglacial lake phase (McDonald, 1969). In the Churchill area the transgression took place 7,300 years B.P.; in the east central part of Keewatin, 7,000 years B.P. (Craig, 1969, p. 64).

During both the transgressive and regressive phases of the Tyrrell Sea, silts and clays were deposited. In the Nelson-Hayes River area the extent of the transgression is marked by wave cut and wave modified landforms at approximately 400 feet above sea level. Eskers and morainic features in the Hudson Bay Lowlands were subject to marine erosion. The Sachigo moraine (Figure A-15) and the eskerine ridges in the Lower Nelson valley display wave cut terrace features.

With the onset of postglacial rebound, marine regression occurred. Gravel, sand and boulder facies were formed as the coastline of Hudson Bay retreated towards its present position. Deposition produced a succession of beach ridges and associated features. The glaciomarine sediments have been subsequently overlain by the recent accumulation of peat and alluvial materials.

TABLE A-I

PHYSIOGRAPHIC SUBDIVISIONS OF THE HUDSON BAY REGION

REGION	SUB-REGION	ZONE	LOCALITY
Hudson Bay Region	Northwest Hills		
	West Coast Lowland		
	East Coast Upland		
	Northern Islands		
	South Coast* Lowland	Dry Zone	
		Muskeg Zone	
		Marine Clay Zone	York Factory Area
		Coastal Zone	

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* Corresponds to the Hudson Bay Lowlands (Coombs 1954), and the Archudsonian Swamp (Tyrrell 1916).

TABLE A-II

MONTHLY AND ANNUAL AVERAGES OF SNOWFALL AND TOTAL PRECIPITATION (INCHES) FOR CHURCHILL AIRPORT (1943-60)

MONTH	PRECIPITATION	NO. OF DAYS	SNOWFALL	NO. OF DAYS
January	0.50	9	5.0	9
February	0.55	9	5.5	9
March	0.65	10	6.5	10
April	1.04	12	9.9	11
May	1.20	11	6.5	10
June	1.63	9	0.7	1
July	2.03	12	T	0
August	2.40	13	0.0	0
September	2.08	14	1.4	2
October	1.50	15	9.7	11
November	1.52	17	15.0	17
December	0.89	13	8.9	13
YEAR	15.99	142	69.1	93

T = Trace

A day with snow is one in which at least 1/10th of an inch of snow has fallen.

A day with precipitation is one with 1/100th of an inch of precipitation (rain plus water equivalent of snowfall).

SOURCE: H.A. Thompson, 1968.

TABLE A-III

PERCENTAGE FREQUENCY OF WIND DIRECTIONS, CHURCHILL 1955-66.

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR
N	4	3	5	9	8	7	8	8	7	4	5	4	6
NNE	2	2	5	7	7	7	6	6	5	6	4	3	5
NE	2	2	4	5	6	6	6	4	4	3	3	1	4
ENE	2	2	4	4	7	10	8	4	3	2	2	1	4
E	2	2	5	5	5	6	4	3	3	3	3	2	4
ESE	2	1	5	5	4	7	6	5	3	5	2	2	4
SE	2	2	4	6	4	6	6	6	3	7	3	3	4
SSE	2	2	6	6	5	5	6	7	6	6	4	3	5
S	5	5	6	8	5	5	7	6	7	8	5	6	6
SSW	3	3	3	3	2	3	5	4	5	4	4	4	4
SW	5	4	4	2	3	3	6	4	5	4	5	6	4
WSW	5	4	2	1	2	4	4	5	5	5	5	5	4
W	15	11	5	2	3	4	3	6	6	7	12	15	7
WNW	24	30	18	10	9	6	7	9	10	13	16	19	14
NW	16	18	13	13	15	9	8	10	12	13	16	16	13
NNW	7	7	9	12	14	10	8	11	14	9	10	9	10
Calm	2	2	2	2	1	2	2	2	2	1	1	1	2

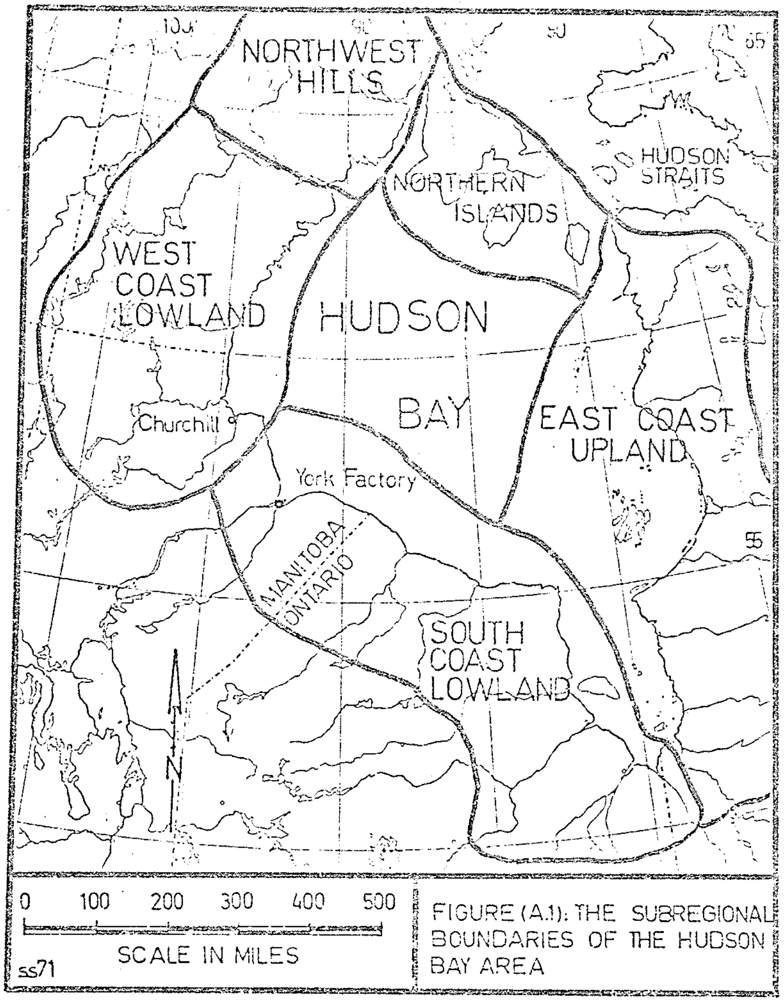


FIGURE (A.1): THE SUBREGIONAL BOUNDARIES OF THE HUDSON BAY AREA

Source: Robinson 1968.

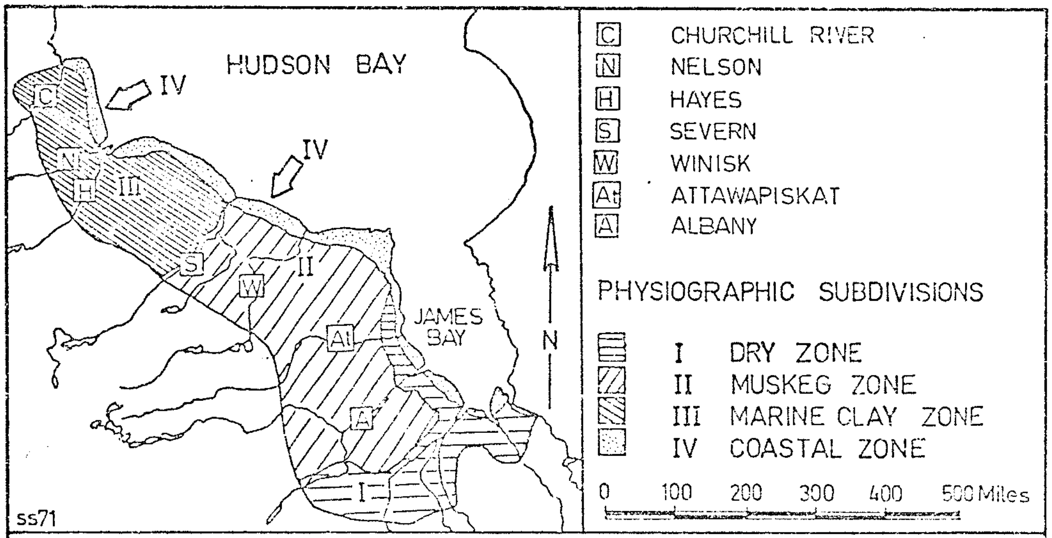


FIGURE (A.2) PHYSIOGRAPHIC SUBDIVISIONS OF THE HUDSON BAY LOWLANDS SOUTH OF 60 DEGREES NORTH (Source Coombs 1954)

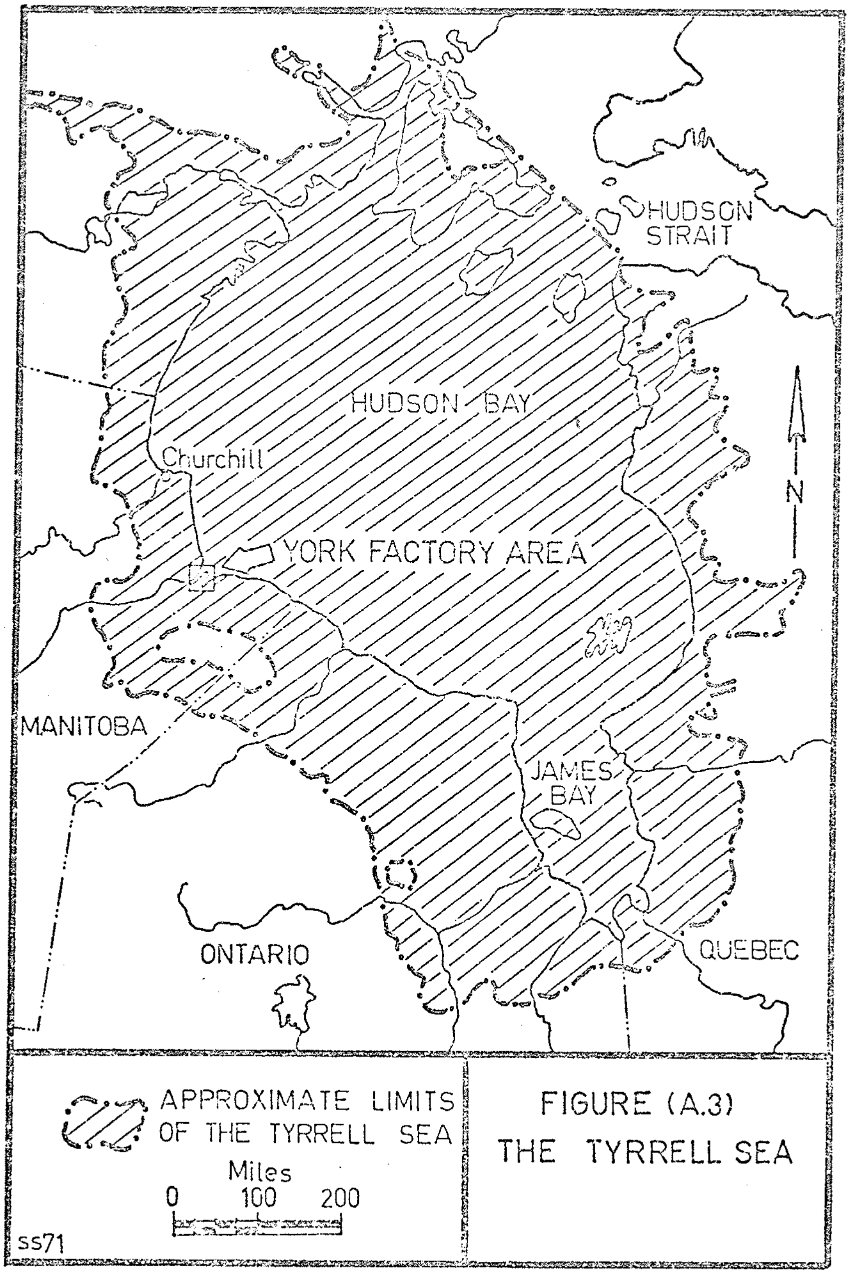


FIGURE (A.3)
THE TYRRELL SEA

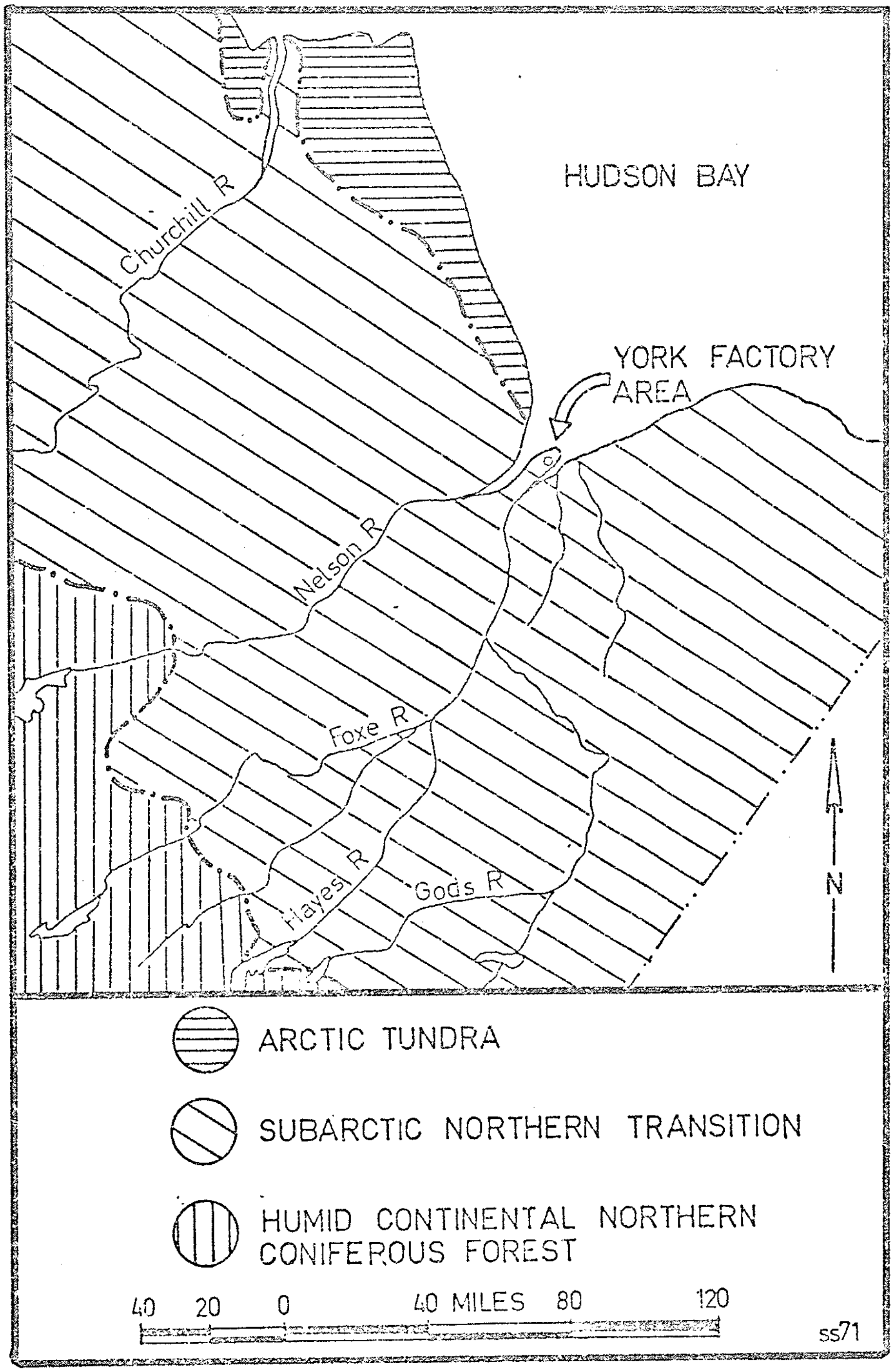


FIGURE A-4

CLIMATIC AND VEGETATION ZONES
OF NORTHERN MANITOBA

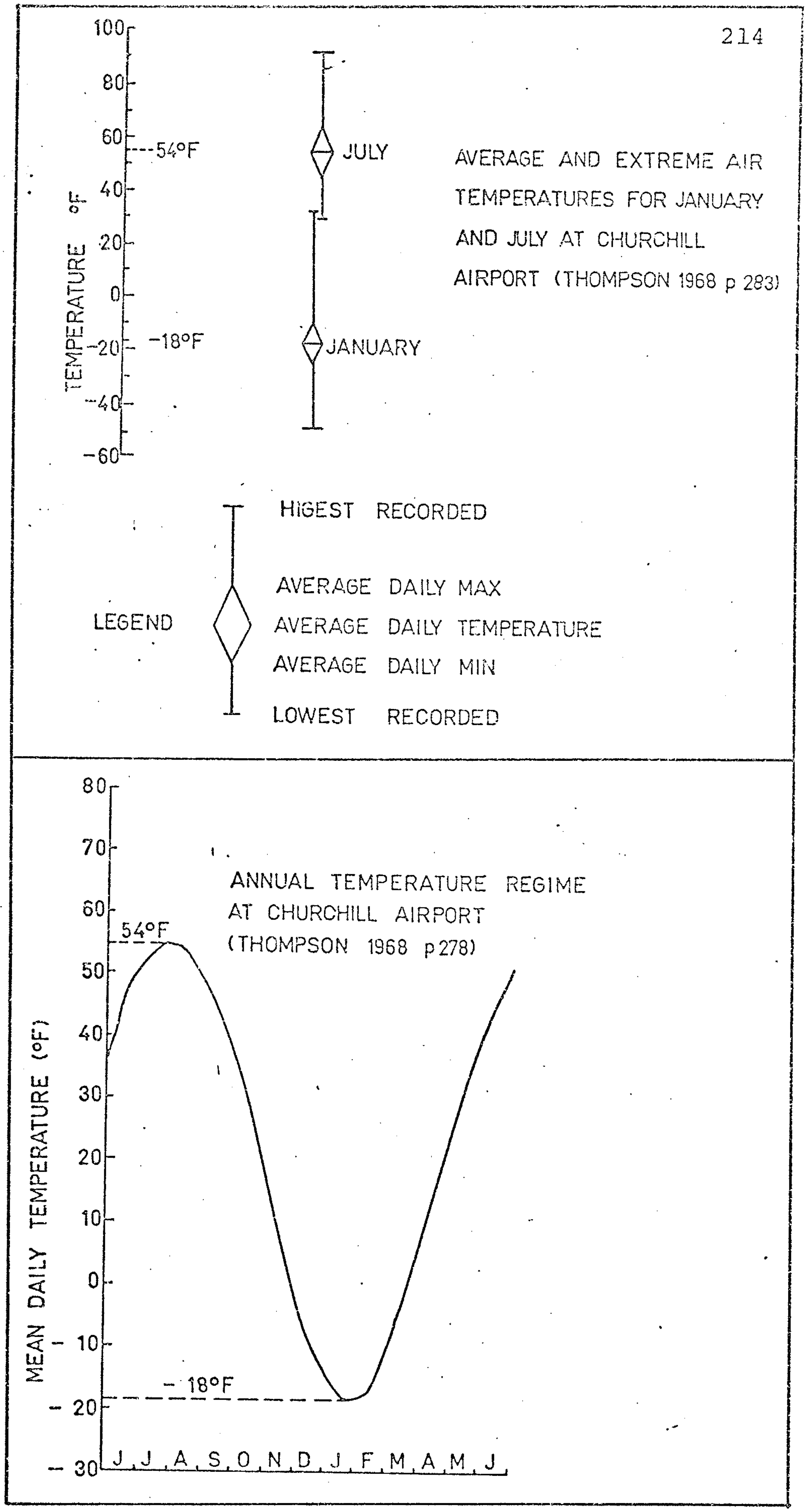


FIGURE A-5

TEMPERATURE DATA FOR CHURCHILL AIRPORT

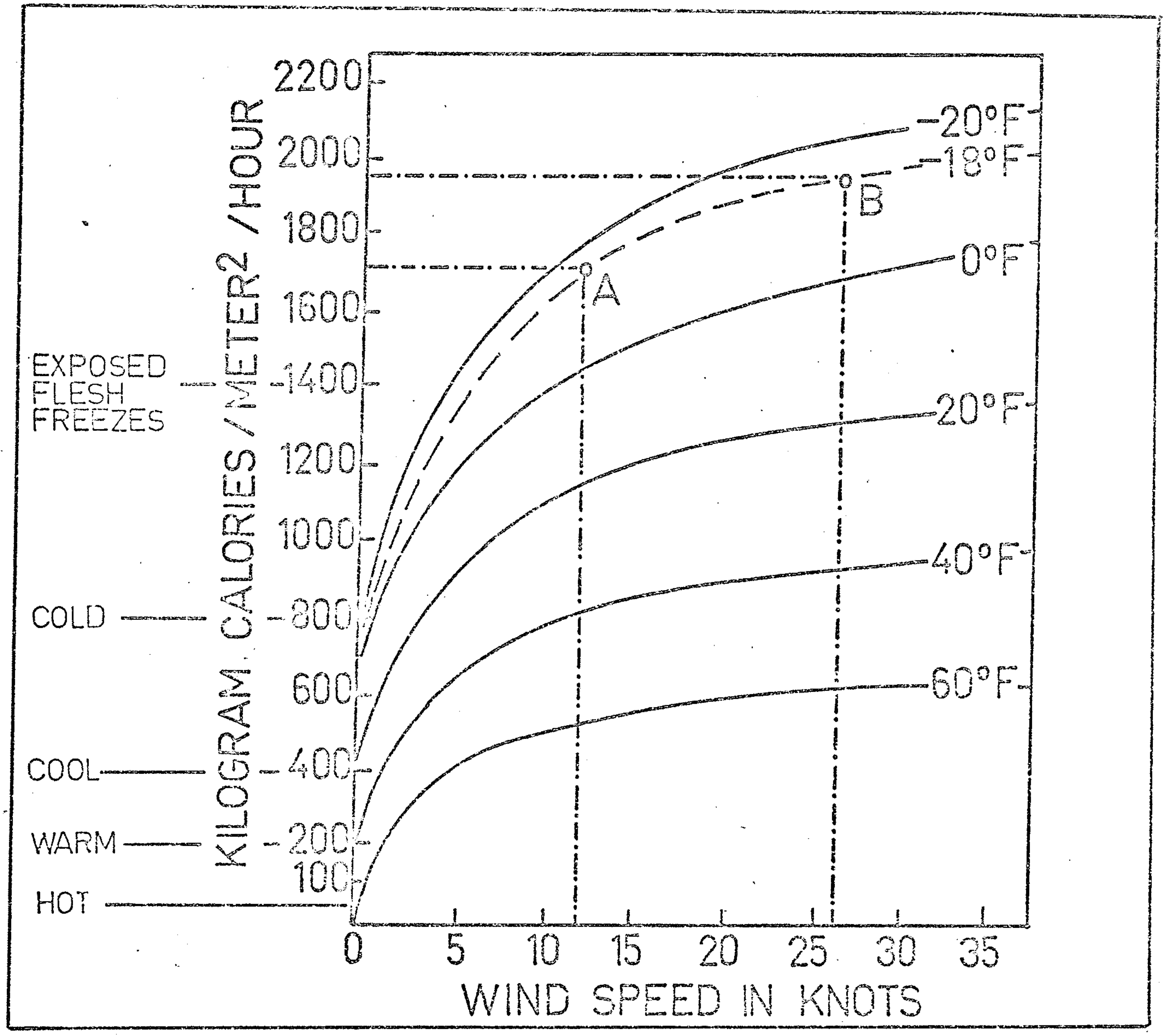
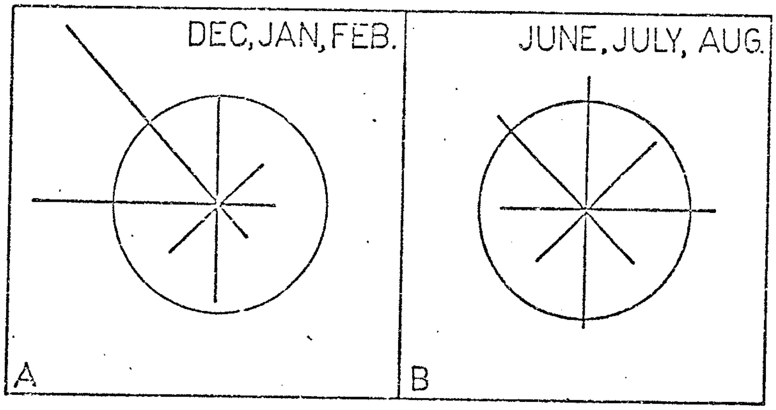


FIGURE A-6

WIND CHILL CHART INDICATING THE DEGREE OF CHILL ON EXPOSED PERSONNEL AT CHURCHILL (MODIFIED FROM THOMPSON 1968)

EXAMPLE A: Average daily January temperature for Churchill of -18°F and an average recorded wind speed for January of 14 mph (12.1 knots) results in a wind chill factor of 1700 KG.Cal/Meter^2/hour.

EXAMPLE B: Average daily January temperature for Churchill of -18°F and wind speeds exceeding 30 mph at least 5% of the winter season results in a wind chill factor of 1950 KG.Cal/Meter^2/hour.



DIRECTION FREQUENCIES OF WIND

DIRECTION FREQUENCIES OF WINDS ARE THE PERCENTAGES OF TIME (REGARDLESS OF SPEED) THAT THE WIND BLOWS FROM EACH OF THE CARDINAL DIRECTIONS. THIS PERCENTAGE IS REPRESENTED BY A LINE PROPORTIONAL IN LENGTH EXTENDING IN THE DIRECTION FROM WHICH THE WIND BLOWS. THE CIRCLE REPRESENTS THE TWELVE AND ONE HALF PERCENTAGE LEVEL (I.E. IF THE WINDS BLEW FROM THE EIGHT CARDINAL DIRECTIONS WITH EQUAL FREQUENCY, THE PERCENTAGE WOULD BE TWELVE AND ONE HALF PERCENT IN EACH CASE).

FIGURE A-7

DIRECTION FREQUENCIES OF WINTER AND SUMMER WINDS AT CHURCHILL, MANITOBA (SOURCE: THOMAS 1953)

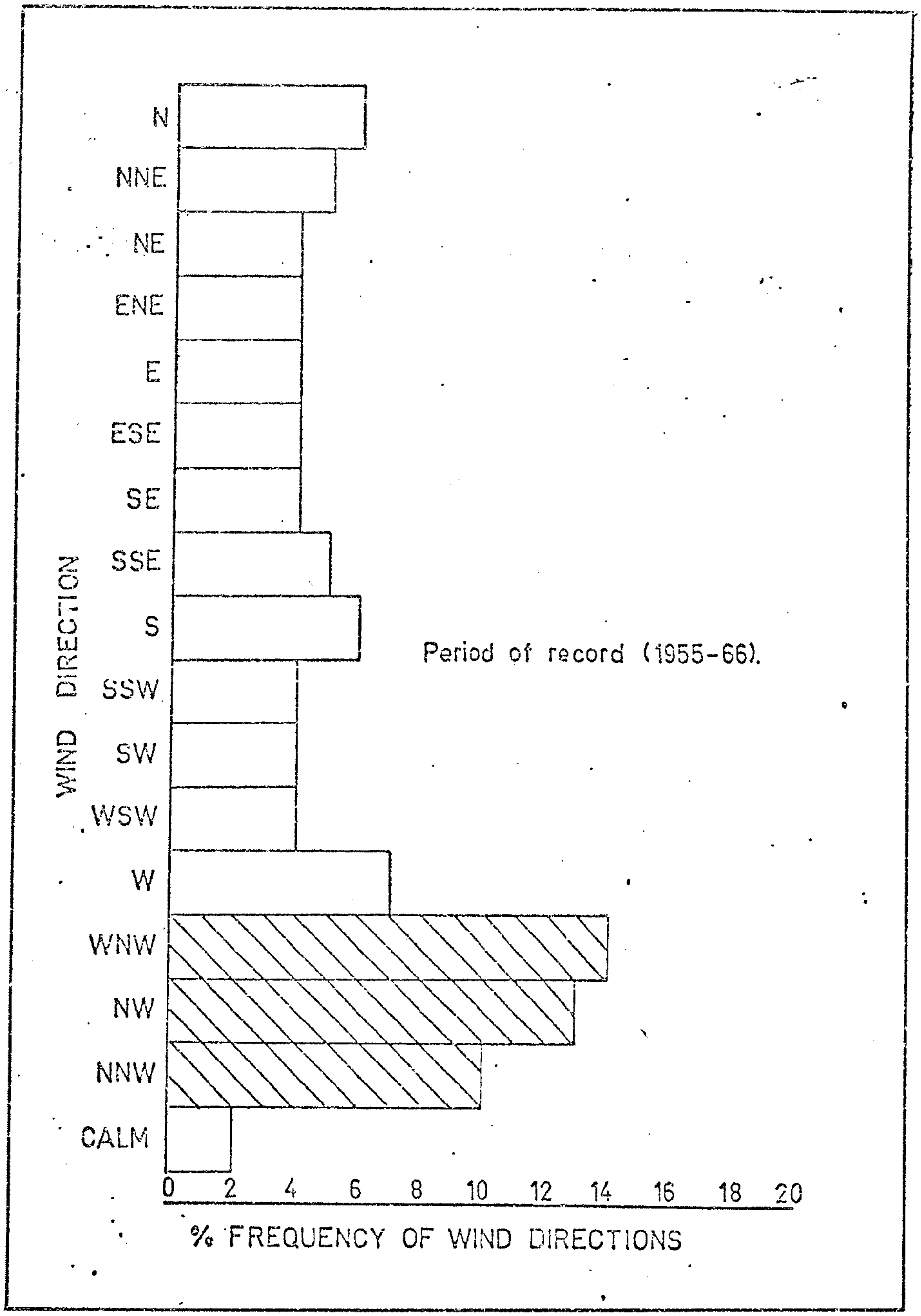


FIGURE A-8

ANNUAL FREQUENCY AND DIRECTION
OF WINDS AT CHURCHILL, MANITOBA

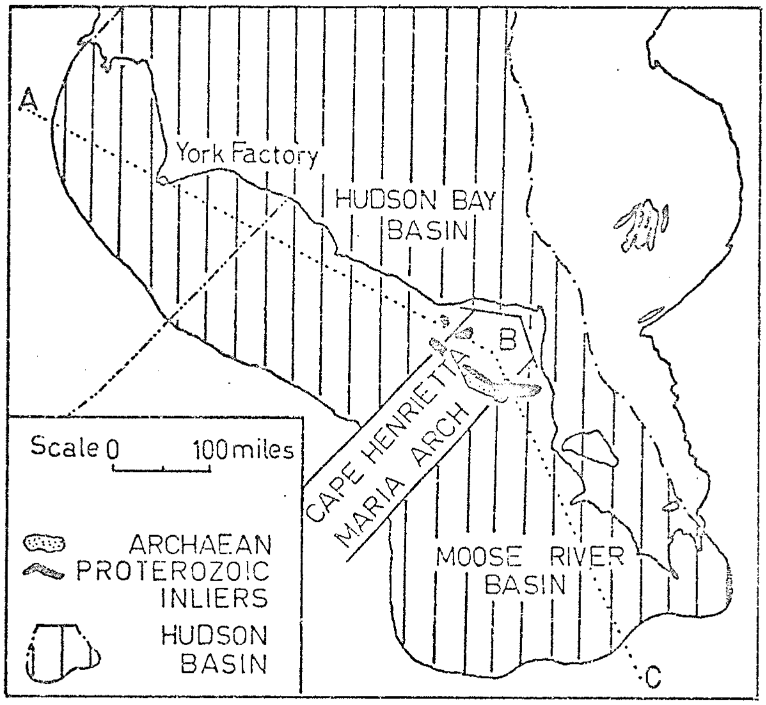


FIGURE A-9

THE HUDSON BASIN

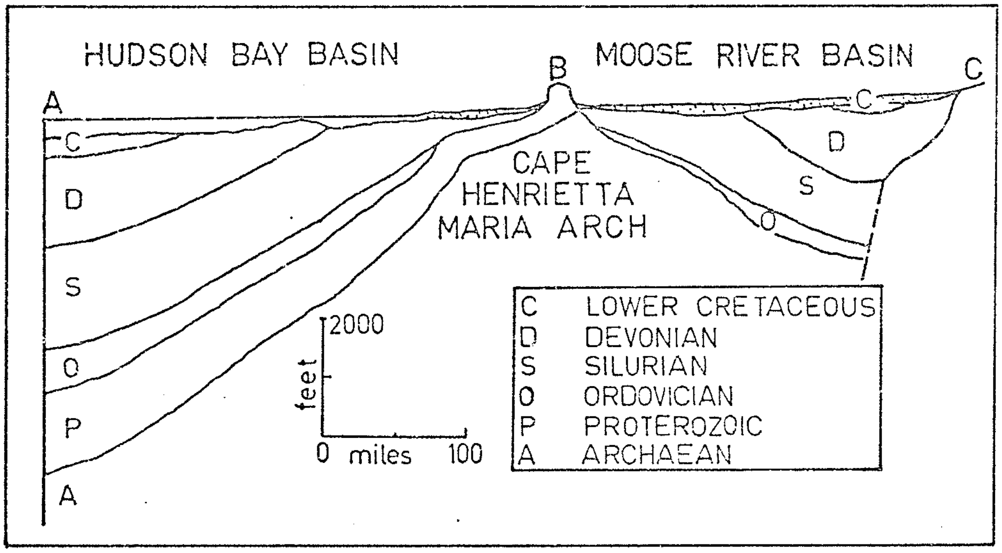
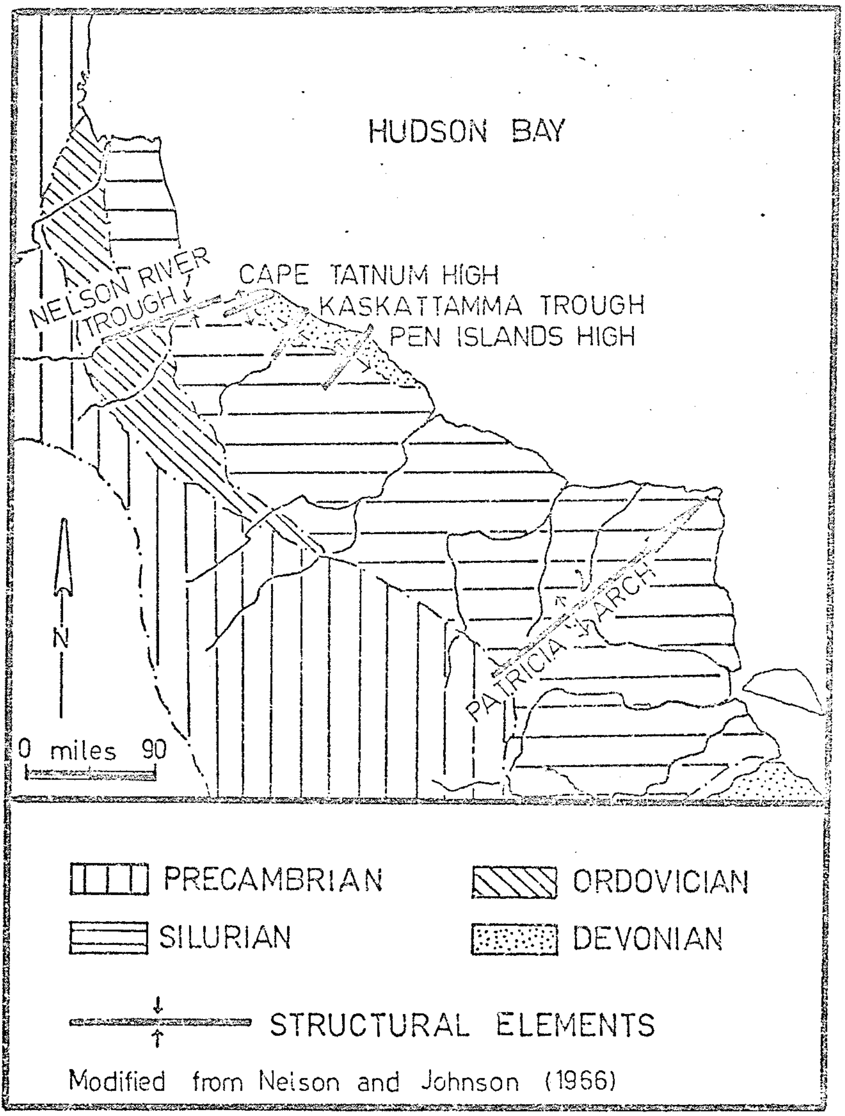


FIGURE A-10

THE CAPE HENRIETTA MARIA ARCH
(SOURCE: NORRIS AND SANFORD 1969)



Modified from Nelson and Johnson (1966)

FIGURE A-11

GEOLOGIC SKETCH MAP OF
THE HUDSON BAY LOWLANDS

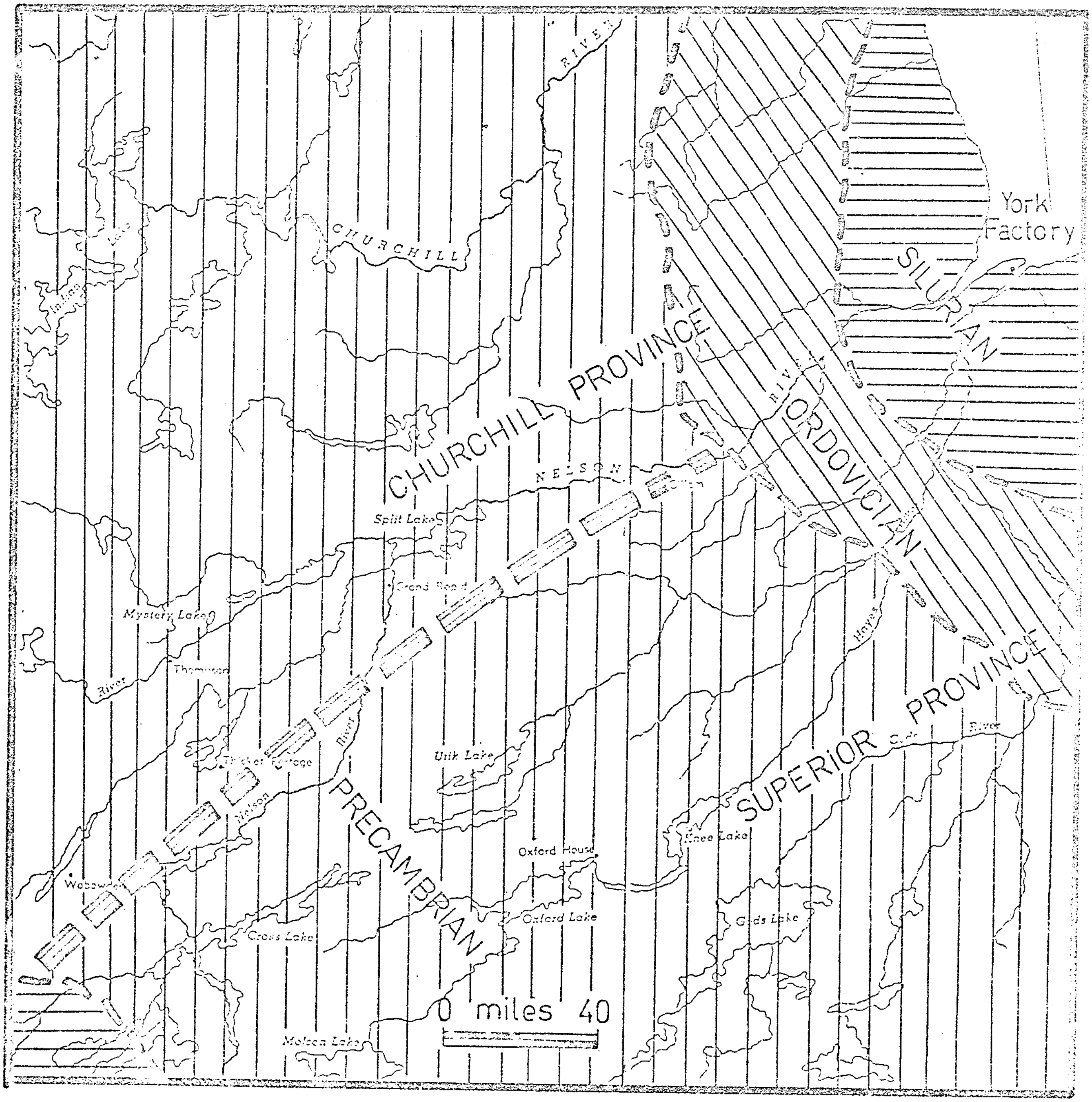


FIGURE A-12

APPROXIMATE BOUNDARY BETWEEN THE
SUPERIOR AND CHURCHILL GEOLOGIC PROVINCES,
NORTHERN MANITOBA

Source: Davies et. al., 1962.

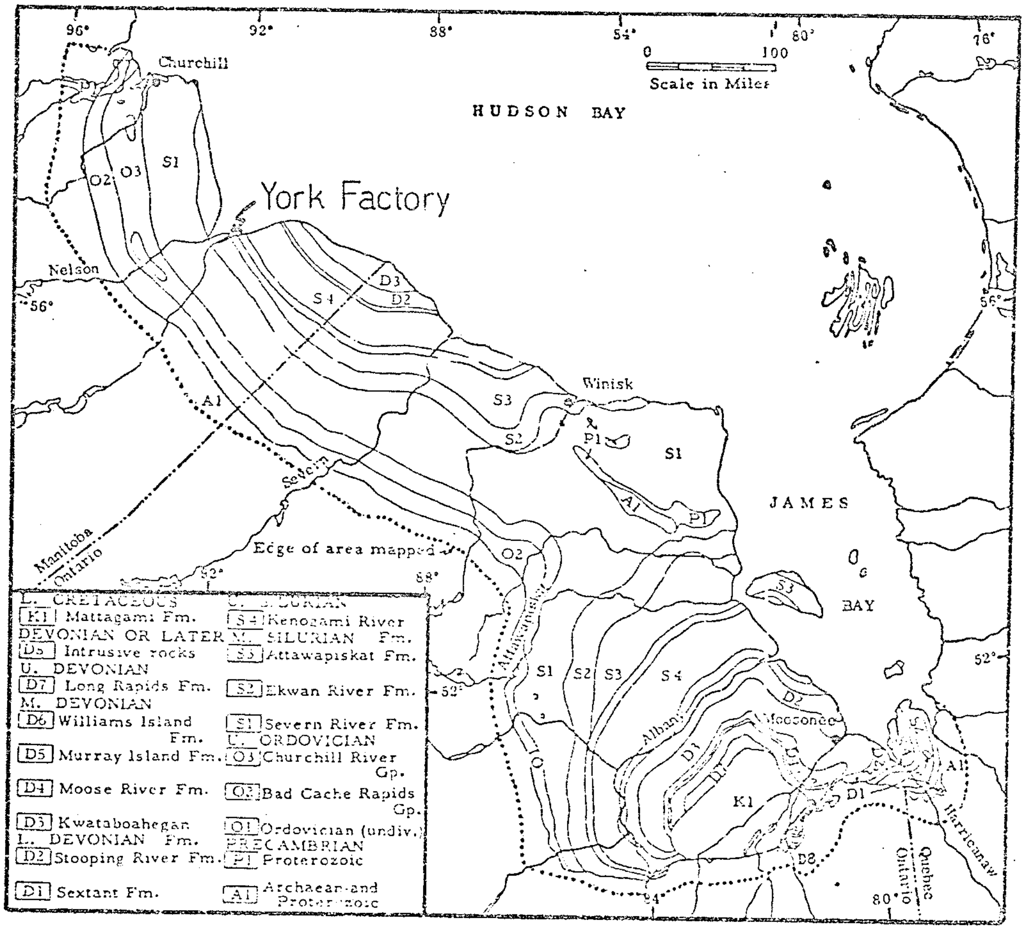


FIGURE A-13

GEOLOGICAL MAP OF THE HUDSON BAY LOWLANDS
(SOURCE: NORRIS AND SANFORD 1969)

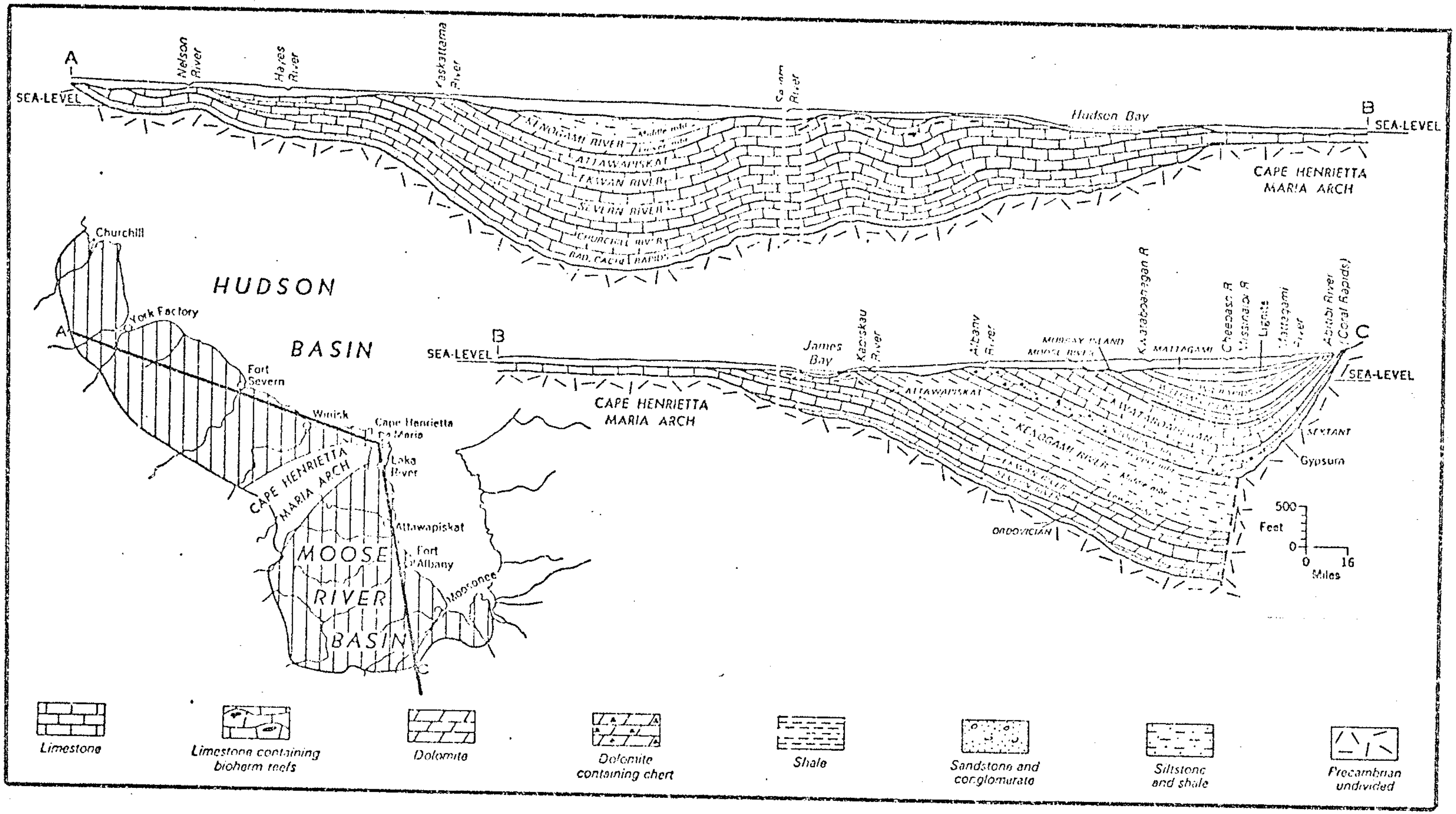
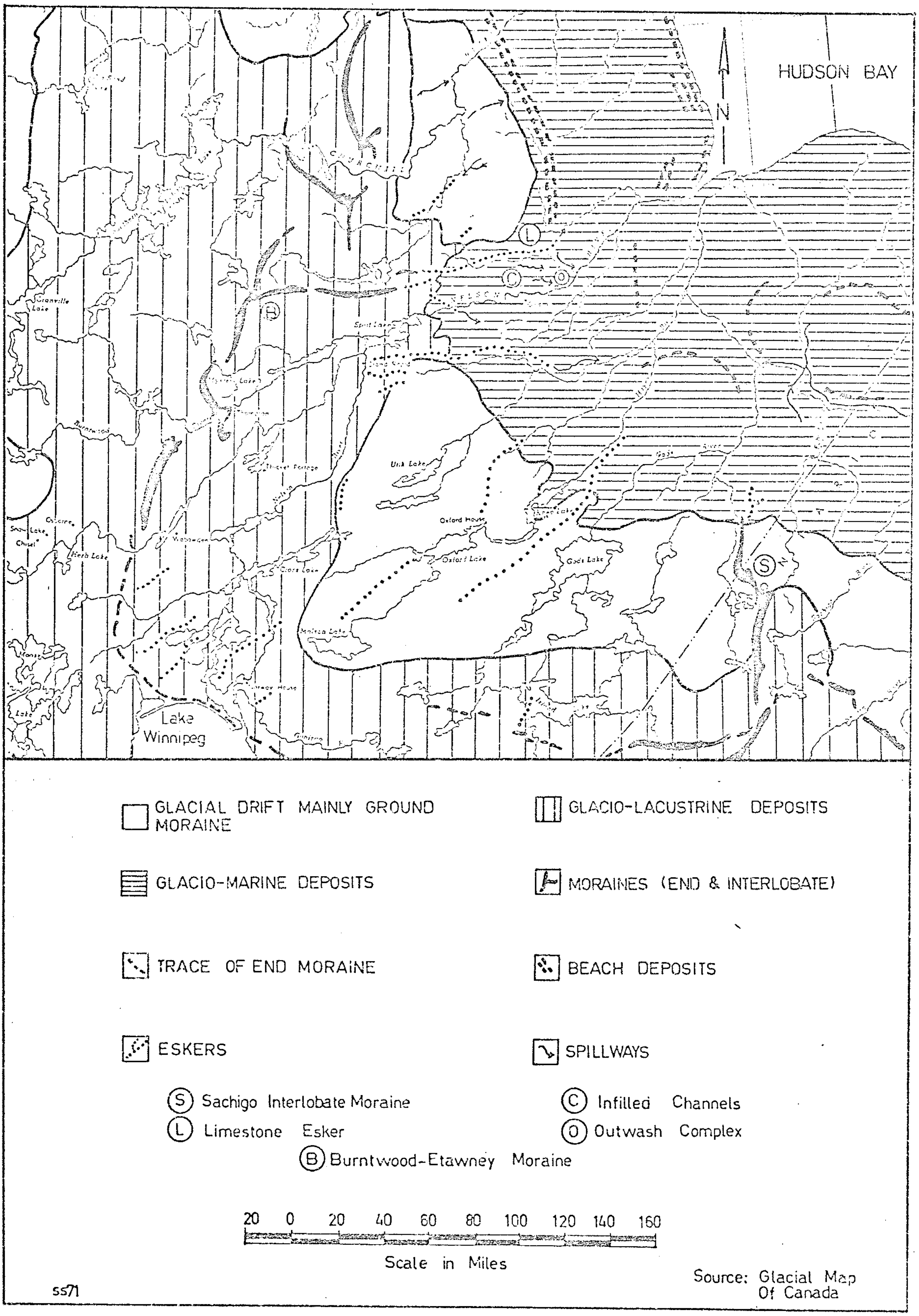


FIGURE A-14

GEOLOGICAL CROSS SECTION OF THE HUDSON BAY LOWLANDS

(SOURCE: SANFORD, NORRIS AND BOSTOCK 1968)



Source: Glacial Map Of Canada

FIGURE A-15

SURFICIAL GEOLOGY OF NORTHERN MANITOBA

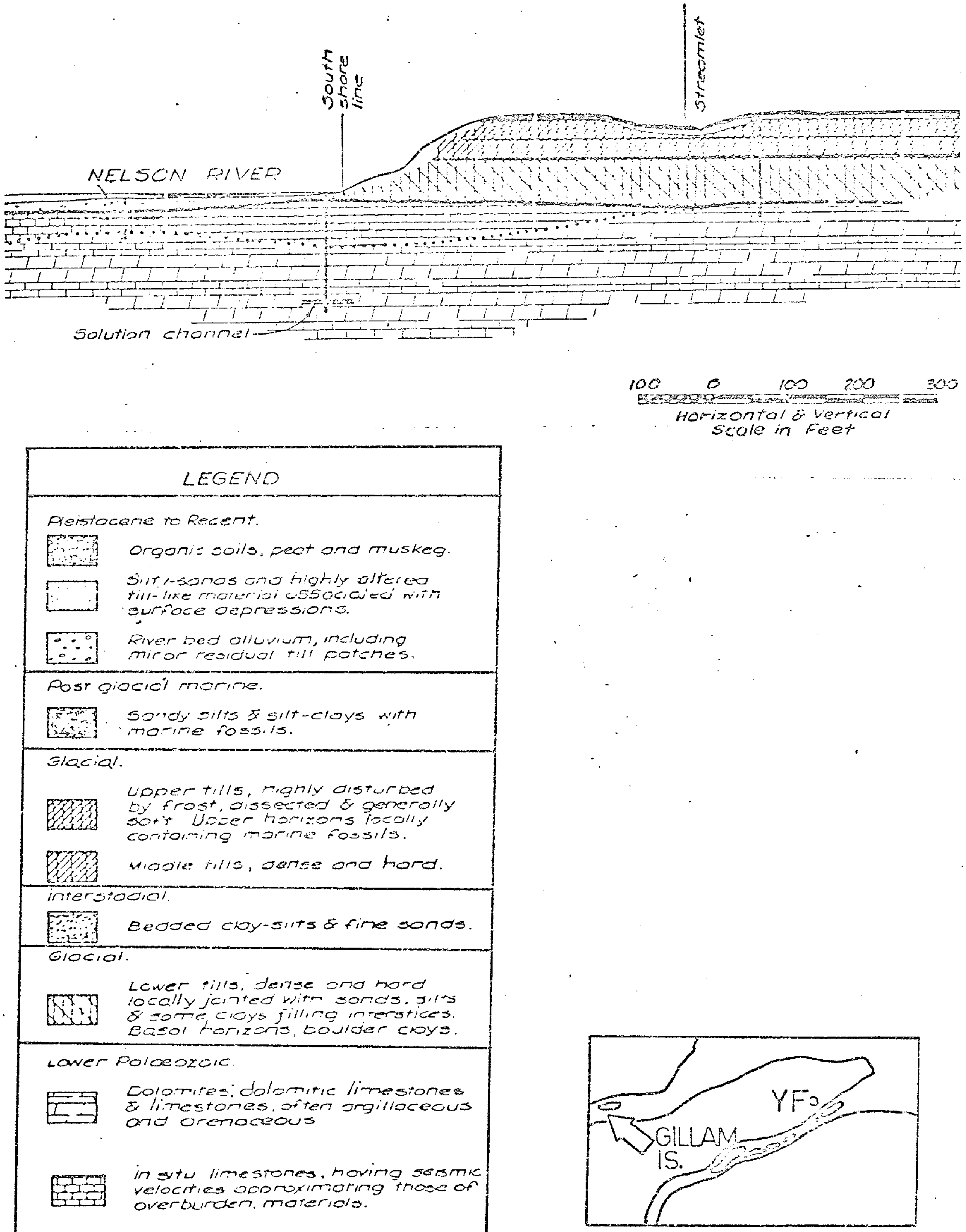


FIGURE A-16

GEOLOGICAL CROSS SECTION AT GILLAM ISLAND, NELSON ESTUARY
(SOURCE: CRIPPEN 1964)

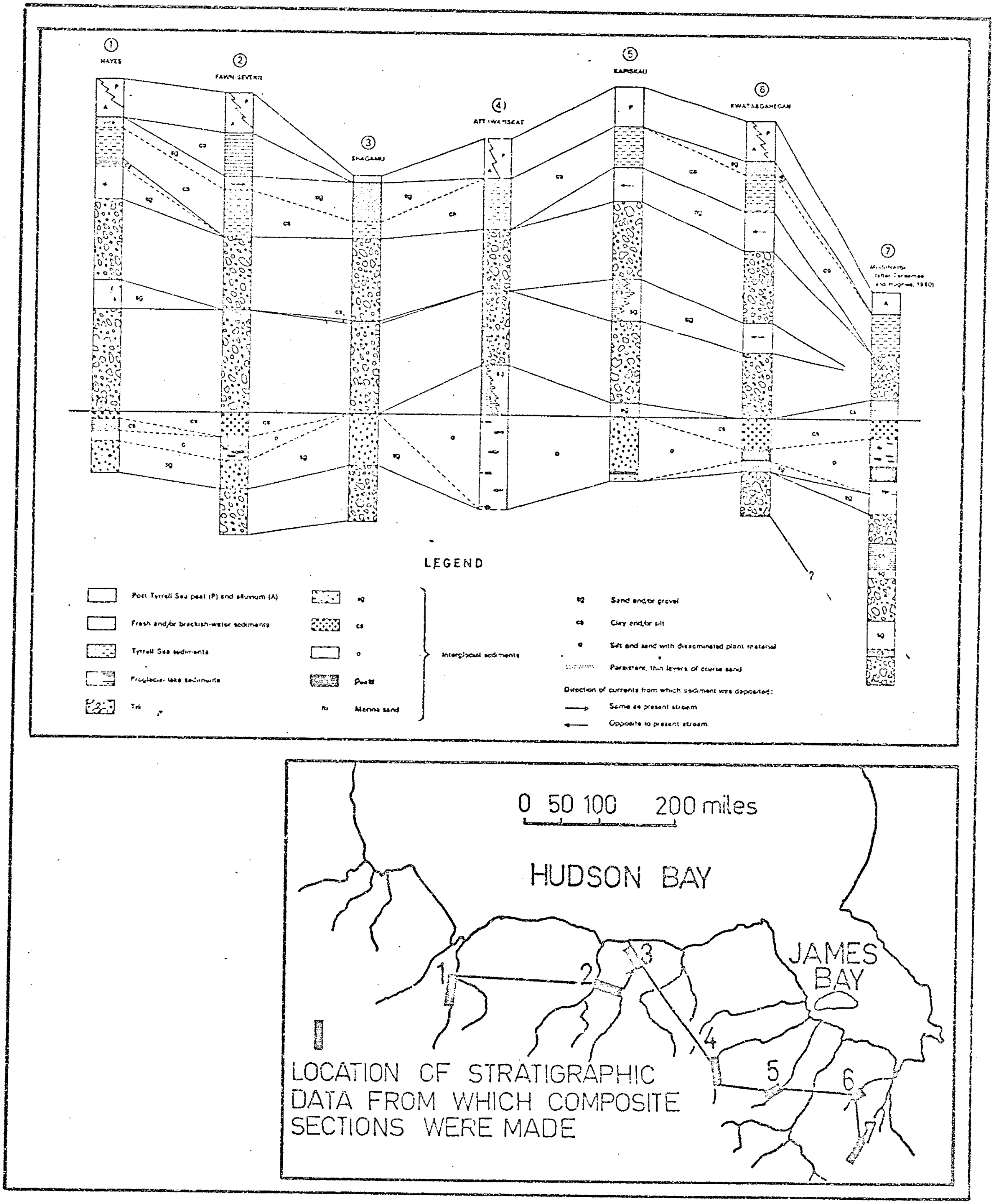


FIGURE A-17

QUATERNARY STRATIGRAPHY OF THE HUDSON BAY LOWLANDS

(SOURCE: McDONALD 1969)

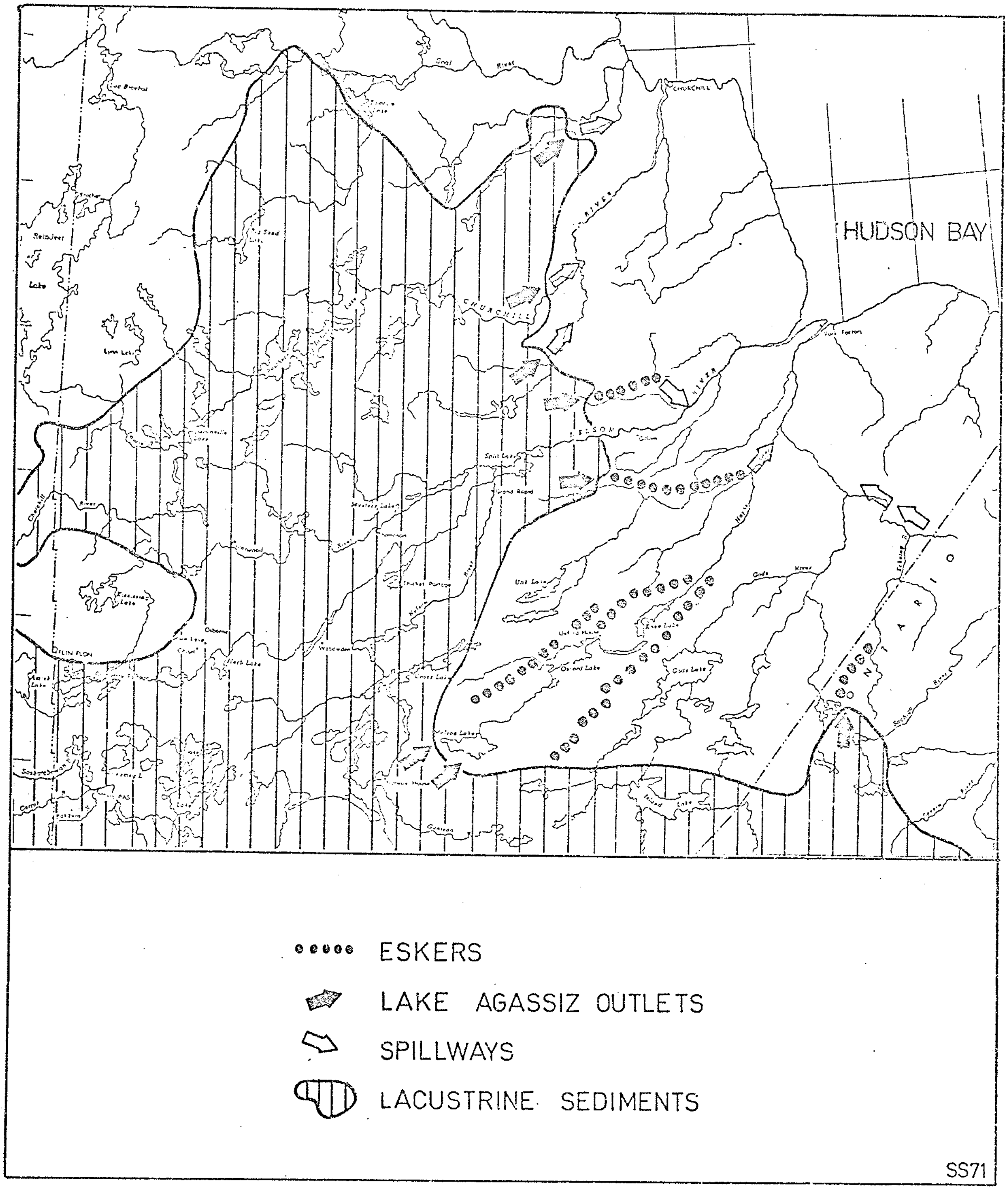


FIGURE A-18

TENTATIVE NORTHERN OUTLETS OF GLACIAL LAKE AGASSIZ

APPENDIX B

THE SOILS OF THE YORK FACTORY AREA

B-I INTRODUCTION

Data concerning the distribution and the genesis of the soils of the York Factory area are of particular value to the study of the evolution of Beacon Point. Soils reflect the climatic, vegetation, parent material, relief and drainage patterns present in an area. The soil profile possesses characteristics indicative of the nature of the former soil forming environment and of the soil forming processes presently operative, and thus indirectly provides evidence of the evolutionary landscapes that have existed during the recent emergence of Beacon Point.

Pedological investigations were conducted during the 1969 field season by Charles Tarnocai, Canada Department of Agriculture, Pedology Section. The results of these investigations and the subsequent laboratory analyses are summarised below.

B-II FACTORS AFFECTING SOIL FORMATION

The major factors affecting soil formation are climate, vegetation, parent materials, relief and drainage. On the York Factory peninsula and the surrounding area on Hudson Bay there are other local factors such as glacial rebound and permafrost, a condition which results from the subarctic climate. The type of soil formed at any one place is dependent upon the interaction of these factors and the length of time they have been operative.

B-II-i Climate

The York Factory area is characterised by short cool summers and long cold winters. The mean monthly temperatures and precipitation at Port Nelson area presented in Table B-I. The outstanding feature is the large temperature range from January to July (approximately 70°F). The area has 700 to 900 degree days above 43°F, a potential evaporation of 325 to 350 millimeters, and a frost-free season of 60 to 70 days.[1]

The annual precipitation at Port Nelson is 13.8 inches. Approximately two-thirds of this occurs during the period June to September. The average annual snowfall is 55-60 inches.

B-II-ii Vegetation

The vegetation of the York Factory area is described in Section 2.1. On mineral soils the dominant types of vegetation are salt marsh, shrub (dominated by Salix spp.), and belts of spruce forest. Due to the nature of the recent emergence of Beacon Point, vegetation displays a zonal distribution inland from Marsh Point. Frozen organic deposits, both minerotrophic and ombrotropic types, are present on Beacon Point. The

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[1] Manitoba Atlas, Edited by T.R. Weir, Department of Industry and Commerce, Province of Manitoba, 1960.

minerotrophic types are colonized by *Carex spp.*, feathermosses and Arctic willows, with white spruce (*Picea Glauca*) forming the tree layer where it is present. The ombrotrophic sites are associated with black spruce (*Picea mariana*), *Sphagnum spp.*, *Cladonia spp.*, and *Ledum groenlandicum* vegetation. Wet, unfrozen organic soils are dominated by fen type vegetation.

B-II-iii Relief

The York Factory peninsula slopes gently to Hudson Bay (approximately 3 feet per mile). Relief features include raised beaches, palsas and peat plateau, which vary in height from 2 to 6 feet.

B-II-iv Drainage

The drainage of the area is immature. Abandoned beachlines lying across the general direction of landfall, have a major damming effect on drainage. Consequently inter-beach areas are generally very poorly drained, with the exception of the palsas. The peninsula northeast of York Factory is periodically inundated by the Hayes River, during the break-up of the river in late May or early June.

B-II-v Parent Materials

The surface deposits are dominantly recent alluvium, which overlies marine sediments. On recent beaches coarse mineral material and driftwood are found, while further inland the abandoned beaches are covered with various thicknesses of recent alluvial materials. A large part of the peninsula is mantled by shallow peat, with alternate layers of alluvial sediments. Further inland where flooding does not occur, acid peat is accumulating.

B-III METHOD OF SOIL INVESTIGATION

The soil investigation was conducted in conjunction with the botanical and geomorphological studies.

A detailed soil study was carried out along a base line from York Factory to Marsh Point, as well as in areas southwest of York Factory, along the Hayes River.

During the field work the parent materials, drainage, vegetation and topography of each soil series were examined (Table B-II).The soil profile was also examined and a sample was collected for physical and chemical analysis. During the soil investigation, permafrost, chemical composition of water and soil temperature, all of which affect the soil formation, were also studied.

The pattern of physiographic features and associated vegetation was identified in the field by foot traverses and spot checks. The various soil materials, moisture classes and associated vegetation were identified on aerial photographs and served as reference points for photo interpretation. Any areas showing a consistent pattern of physiography were delineated on aerial photographs and described on the basis of the overall pattern of soil material distribution and relief (see Soil Map of the York Factory Area, Figure B-1).

B-IV DESCRIPTION OF SOIL SERIES

The descriptions of the soil series are presented in alphabetical order and generally include: a description of the soil profile type, texture, parent materials, topography, drainage and vegetation; a detailed description of a representative profile; and, a table of chemical and physical analyses of the representative profile.

B-IV-i Hayes Series

The Hayes series consists of very poorly drained Cumulo Mesisol organic soils developed on shallow to deep (16 to 52 inches) mesic fen peat with multiple layers of alluvium. The topography is level and the vegetation is dominantly *Salix spp.*, *Larix laricina*, *Carex spp.*, and moss species other than Sphagnum.

A description of a representative profile of the Hayes series follows:

Of	0 to 8 inches, dark brown (10YR 3/3, moist), moderately decomposed fen peat.
Om$_1$	8 to 11 1/2 inches, very dark brown (10YR 2/2, moist), moderately well decomposed fen peat and 3 to 4 mm thick layers of alluvium.
Om$_2$	11 1/2 to 17 inches, very dark grey (10YR 3/2, moist), moderately well decomposed fen peat mixed with alluvium.
IICg	17 to 18 inches, greyish brown (10YR 5/2, moist), coarse sand.
Om$_3$	18 to 21 inches, black (10YR 2/1, moist), moderately well decomposed fen peat.
IIICg	21 to 26 inches, greyish brown (2.5Y 5/2, moist), silt loam; mildly alkaline; very strongly calcareous.

These soils are inundated by nutrient-rich waters from the Hayes River and thus the profile is stratified with layers of alluvium.

B-IV-ii Machichi Series

The Machichi series (Table B-III) consists of imperfectly drained Cryic Cumulic Regosol soils developed on recent alluvial deposits. This soil consists of mesic surface peat with multiple peat layers throughout the profile. The cryic layer occurs within the control section. Topography is very gently sloping in the form of narrow, elongated, abandoned Hudson Bay beaches.

The vegetation is dominantly white spruce, willows and feathermosses.

A description of a representative profile of the Machichi series follows:

L-F	0 to 8 inches, black (10YR 2/1, moist), undecomposed, forest peat; non-sticky; neutral; unrubbed fiber content approximately 79 percent.
IICg	8 to 12 inches, pale brown (10YR 6/3, moist), silt loam; friable when moist, soft when dry; slightly sticky; neutral.
IIICgz$_1$	12 to 19 inches, very dark greyish brown (10YR 3/2, moist), silt loam with layers of mesic peat; frozen; friable when moist, hard when dry; segregated ice crystals; ice lenses 5 to 10 mm thick; neutral.

$IIICgz_2$ 19 to 25 inches, pale brown (10YR 6/3, moist), silt loam and multiple layers of peat; very dark grey (10YR 3/1, moist); frozen; friable when moist, hard when dry; ice lenses 1 to 1.5 cm thick; neutral.

The Machichi soils are stratified with layers of peat and mineral material as a result of the periodic inundation. The active layer of these soils consists of fibric forest peat with layers of alluvium. The frozen layer consists dominantly of alluvium mixed with organic materials. Segregated ice crystals are common throughout the frozen core and their amount increases with depth.

B-IV-iii(a) Marsh Point Series

The Marsh Point series (Table B-IV) series consists of poorly drained Rego Gleysol soils developed on strongly to extremely calcareous, medium textured deposits. Topography is level, and since these soils are generally found along the Hudson Bay shoreline, salt marsh vegetation is dominant. A description of a representative profile of the Marsh Point series follows:

Cg 0 to 10 inches, grey (5Y 6/1, moist), loam; amorphous; plastic; friable when moist, hard when dry; mildly alkaline; very strongly calcareous; clear, smooth boundary.

IICg 10 to 23 inches, greenish grey (5GY 5/1, moist), silt loam; amorphous; plastic; friable when moist, hard when dry; mildly alkaline; extremely calcareous.

Marsh Point soils have no organic surface layers. The conductivity, total soluble anions and sodium concentration are high. These soil materials were once in salt water, but they are now influenced by the river during flood time. The area around Marsh Point is greatly influenced by the tides but abundant ice-rafted materials are also found as a result of the action of the rivers. This soil is in the transitional stage (see Ten Shilling series).

B-IV-iii(b) Marsh Point Peaty Phase

These are areas of Marsh Point soils which have a 6 to 16 inch layer of fen surface peat.

B-IV-iv Prospect Bay Series

The Prospect Bay series (Table B-V) consists of imperfectly drained Cryic Cumulic Regosol soils developed on recent alluvial deposits. This soil consists of mesic surface peat with multiple peat layers throughout the profile. The cryic layer occurs within the control section. Topography is very gently sloping in the form of domes or palsas. These soils are very similar to those described under the York Fort series but differ from them by having a shallow mesic peat surface layer because the youthfulness of these palsas represents an early stage of development.

The vegetation is dominantly Carex spp., feathermosses and Arctic willows with white spruce and tamarack forming the tree layer where present.

A description of a representative profile of the Prospect Bay series follows:

L-F	0 to 5 inches, darkish brown (10YR 4/2, moist), moderately decomposed feathermoss peat with alluvium; non-sticky; mildly alkaline; unrubbed fiber content approximately 39 percent.
IICg	5 to 6 1/2 inches, very dark greyish brown (10YR 3/2, moist), silt loam; friable when moist, soft when dry; slightly sticky; neutral.
IIICg	6 1/2 to 8 inches, very dark grey (10YR 3/1, moist), silt loam; friable when moist, soft when dry; slightly sticky; neutral.

L-Fb$_1$	8 to 10 inches, very dark grey (10YR 3/1, moist), moderately decomposed feathermoss and sedge peat with alluvium; non-sticky; neutral; unrubbed fiber content approximately 53 percent.
L-Fb$_2$	10 to 12 inches, very dark grey (10 YR 3/1, moist), well decomposed sedge and feathermoss peat with alluvium; non-sticky; neutral; unrubbed fiber content approximately 23 percent.
IVCg	12 to 15 inches, very dark grey (10YR 3/1, moist), silt loam; friable when moist, soft when dry; slightly sticky; neutral.
VCgz	15 to 62 inches, olive grey (5Y 5/2, moist) to light olive grey (5Y 6/2, moist), silt loam; frozen; friable when moist, soft when dry; slightly sticky; segregated ice crystals; ice lenses; neutral.

These soils are stratified with layers of peat and mineral materials as a result of the periodic inundation. The active layer of these soils consists of mesic feathermoss peat mixed with some woody materials and layers of alluvium. The frozen layer generally consists of the same materials with segregated ice crystals. The chemical composition of these soils indicates a highly mineralized environment.

B-IV-v Rainbow Series

The Rainbow series consists of very poorly drained Cumulo Mesisol organic soils developed on shallow to deep (16 to 52 inches) dominantly mesic fen peat. These soils have 6 to 24 inches of fibric Sphagnum peat at the surface and multiple layers of alluvium below the Sphagnum peat. The topography is level and the vegetation is dominantly *Salix spp.*, *Larix laricina*, *Carex spp.*, *Sphagnum spp.*, and other moss species.

A description of a representative profile of the Rainbow series follows:

Of	0 to 12 1/2 inches, very dark grey (10YR 3/1, moist), undecomposed, loose, spongy sphagnum peat; extremely acid.
Om_1	12 1/2 to 20 1/2 inches, very dark greyish brown (10YR 3/2, moist), moderately decomposed fen peat with thin layers of alluvium; neutral.
Om_2	20 1/2 to 31 1/2 inches, dark grey (10YR 41/, moist), well decomposed fen peat, with 5 to 8 mm thick layers of alluvium; neutral.
IICg	31 1/2+ inches, grey (5Y 5/1, moist), silt loam, single grained; slightly sticky; mildly alkaline; very strongly calcareous.

These soils are found around York Factory and further inland on the peninsula. These areas are not inundated by nutrient-rich waters from the Hayes River and thus provide an environment suitable for the growth of Sphagnum moss.

B-IV-vi Recent Beaches

These well to imperfectly drained recent beaches have formed mainly on the Nelson River side of the peninsula. They consist of alternate layers of mineral and driftwood materials.

B-IV-vii Seal Creek Series

The Seal Creek series (Table B-VI) consists of poorly drained Cryic Sphagno-Fibrisol organic soils developed on shallow to deep (24 to 64 inches) fibric Sphagnum peat. The cryic layer occurs within the control section. The topography is level in the form of peat plateaus. The vegetation is dominantly black spruce, _Ledum_, _Sphagnum_, and _Rubus chamaemorus_.

A description of a representative profile of the Seal Creek series follows:

Of	0 to 12 inches, yellowish brown (10YR 5/4, moist), undecomposed, loose, spongy Sphagnum peat; extremely acid; unrubbed fiber content approximately 100 percent.

Ofz$_1$	12 to 15 1/2 inches, dark yellowish brown (10YR 4/4, moist), undecomposed frozen, Sphagnum moss peat; segregated ice crystals 1 to 2 mm thick; extremely acid; unrubbed fiber content approximately 87 percent.
Ofz$_2$	15 1/2 to 21 inches, very dark brown (10YR 2/2, moist), undecomposed frozen, woody peat mixed with Sphagnum peat; segregated ice crystals 1 to 2 mm thick; extremely acid; unrubbed fiber content approximately 98 percent.
Omz	21 to 33 inches, very dark brown (10YR 2/2, moist), moderately well decomposed, frozen, sedge peat with thin alluvial layers; slightly sticky; ice lenses 3 to 5 mm thick; neutral; unrubbed fiber content approximately 43 percent.
IICgz	33 to 48 inches, grey (10YR 6/1, moist), silt loam; frozen; friable when moist, soft when dry; contains 3 to 5 mm thick ice lenses and some thin layers (5 mm) of peat; mildly alkaline.

The Seal Creek series is one of the dominant soil types in the peat plateaus. The active layer of this soil consists of fibrous Sphagnum moss peat. The frozen layer generally consists of the same material underlain by alluvial layers and mesic peat. Because these areas are not inundated by floods, the water supply is from precipitation only, thus maintaining the acid environment. Ice crystals 1 to 2 mm in thickness are found throughout the frozen core. Here again, larger ice lenses were generally found at the lower depths. The chemical composition of this soil is characteristic of low nutrient organic soils found in northern Manitoba. They are extremely acid in reaction and low in exchangeable calcium and magnesium. In the frozen layer, however, values are much higher.

B-IV-viii Ten Shilling Series

The Ten Shilling series (Tables B-VII, B-VIII, B-IX) consists of imperfectly drained Gleyed Cumulic Regosol soils developed on strongly to extremely calcareous, medium textured, (Figure B-2) recent alluvial deposits. The topography is level and these soils are generally found on the slightly better drained sites along the Hayes River. The dominant vegetation is white spruce, willows and feathermosses.

A description of a representative profile of the Ten Shilling series follows:

L-F 0.17 to 0 feet, very dark grey (10YR 3/1, moist), mesic forest peat with thin layers of alluvium; neutral; moderately calcareous; abrupt, smooth boundary.

Cg_1 0 to 0.17 feet, pale brown (10YR 6/3, moist), silt loam; single grained; slightly sticky; mildly alkaline; very strongly calcareous; clear, smooth boundary.

Cg_2 0.17 to 0.54 feet, very greyish brown (10YR 3/2, moist), silt loam with thin layers of peat; single grained; slightly sticky; mildly alkaline; very strongly calcareous; clear, smooth boundary.

Cg_3 0.54 to 0.67 feet, pale brown (10YR 6/3, moist), loam; single grained; non-sticky; mildly alkaline; very strongly calcareous; clear, smooth boundary.

Cg_4 0.67 to 2.0 feet, very dark greyish brown (10YR 3/2, moist), sandy loam with thin layers of peat; single grained; non-sticky; mildly alkaline; very strongly calcareous; clear, smooth boundary.

Cg_5	2.0 to 4.0 feet, light yellowish brown (10YR 6/4, moist), silt loam; thin 5 to 10 mm thick layers of organic matter; single grained; non-sticky; moderately alkaline; very strongly calcareous; abrupt, smooth boundary.
Cg_6	4.0 to 6.0 feet, pale brown (10YR 6/3, moist), loam; thin 3 to 5 mm thick layers of organic matter; single grained; non-sticky; mildly alkaline; extremely calcareous; abrupt, smooth boundary.
Cg_7	6.0 to 7.1 feet, grey (5Y 5/1, moist), silt loam; cross bedded; very thin, 2 to 3 mm thick layers of organic matter; weak fine platy; slightly sticky; mildly alkaline; extremely calcareous; abrupt, smooth boundary.
Cg_8	7.1 to 10.5 feet, grey (5Y 6/1, moist), sandy loam; cross bedded; single grained; non-sticky; mildly alkaline; very strongly calcareous; abrupt, smooth boundary; stone line at 10.5 feet.

IICg_1 10.5 to 12.0 feet, olive grey (5Y 5/2, moist), loam; strong, coarse subangular blocky; slightly sticky; moderately alkaline; very strongly calcareous; clear, smooth boundary.

IICg_2 12.0 to 14.0 feet, olive grey (5Y 5/2, moist), silt loam; strong, coarse subangular blocky; slightly sticky; moderately alkaline; extremely calcareous; clear, smooth boundary.

IICg_3 14.0 to 16.0 feet, grey (5Y 5/1, moist), loam; strong, coarse subangular blocky; slightly sticky; moderately alkaline; extremely calcareous; clear, smooth boundary.

IICg_4 16.0 to 18.0 feet, greenish grey (5GY 5/1, moist), silt loam; weak, coarse subangular blocky; slightly sticky; moderately alkaline; extremely calcareous; clear, smooth boundary.

$\mathrm{IICg}_5\mathrm{z}$ 18.0 to 19.5 feet, dark grey (N4, moist), silt loam; frozen amorphous; segregated ice crystals; slightly sticky; moderately alkaline; extremely calcareous.

These soils have a thin peat surface layer but the peat accumulation seldom exceeds 10 inches in thickness as a result of frequent flooding. The flooding has retarded continuous organic matter production by covering the peat with mineral sediments during the periods of inundation. As a result of these floods, the profiles are stratified with bands of peat. Gleying and iron staining are characteristic of these soils. Since the profile was examined at the river bank, the permafrost was found at a depth of 18 feet. According to test coring farther from the river bank, seasonal frost was found at depths of 8 to 41 inches, the residual thaw zone was found at 41 to 76 inches and frozen ground was found below 76 inches from the surface on July 4, 1969.

Based on the physical and chemical characteristics, this profile can be divided into three main zones or stages according to the evolution of the land and the origin of the deposits.

1. Alluvial zone, above the stone line. The profile is characterized by fluctuation of total sand and silt content while the clay fraction varies very little. The upper part of this zone

contains peat layers of varying thickness. The low conductivity and low sodium and salt concentration characteristic of the upper part show a slight increase in the lower part, just above the stone line. This would indicate that this stage of deposition was under the influence of river waters. In the upper part, the increasing thickness of the peat layers and the decreasing thickness of the alluvial layers show that the land slowly emerged from the flood level due to glacial uplift. On the other hand, the lower part of this zone, above the stone line shows slight sea water influence.

2. Transitional zone, below the stone line to an approximate depth of 18 feet. This stage is characterized by fluctuation of sand and silt content but at a much lower rate than above the stone line. There is an increase in conductivity and sodium and soluble salt concentration. This would indicate that this transitional zone was under the influence of brackish water.

3. Marine zone, below depths of 18 feet. This zone is characterized by a sharp decrease in total sand, an increase in clay and a large concentration of sodium. This would indicate that these materials were deposited by the sea water.

B-IV-ix Woodcock Series

The Woodcock series (Table B-X) consists of poorly drained Cryic Fibrisol organic soils developed on shallow to deep (24 to 64 inches) fibric forest peat. The cryic layer occurs within the control section. The topography is level in the form of peat plateaus. The vegetation is dominantly black spruce, Ledum and Cladonia.

A description of a representative profile of the Woodcock series follows:

Of_1	0 to 9 inches, very dark greyish brown (10YR 3/2, moist), undecomposed, forest peat, containing a high amount of fine roots, feathermoss and Cladonia plant materials; non-sticky; extremely acid; unrubbed fiber content approximately 96 percent.

Of_2	9 to 13 inches, very dark greyish brown (10YR 3/2, moist), undecomposed, woody peat mixed with some Sphagnum peat; non-sticky; extremely acid; unrubbed fiber content approximately 92 percent.
Ofz	13 to 17 inches, dark greyish brown (10YR 4/2, moist), undecomposed frozen woody peat mixed with some Sphagnum peat; non-sticky; ice lenses 3 to 5 mm thick; extremely acid; unrubbed fiber content approximately 90 percent.
IICgz	17 to 37 inches, dark grey (10YR 4/1, moist), silt loam, frozen; friable when moist, soft when dry; contains thin layers of peat; ice lenses approximately 1 to 1.5 cm thick; mildly alkaline.

The Woodcock series is one of the dominant organic soils on the peat plateaus. The active layer of this soil concists of fibrous woody peat, high in fine roots and other plant remains. The frozen layer generally consists of the same materials underlain by alluvial layers and mesic peat. Because these areas are not inundated by floods, the water supply is from precipitation only, thus maintaining the acid environment.

Ice crystals 1 to 2 mm in thickness are found throughout the frozen core. Here again, large ice lenses are generally found at the lower depths.

The chemical composition of this soil is similar to that of the Seal Creek soil, extremely acid in reaction and low in exchangeable calcium and magnesium.

B-IV-x York Fort Series

The York Fort series (Table B-XI) consists of imperfectly drained Cryic Cumulo Mesisol organic soils developed on shallow to deep (16 to 52 inches) mesic fen peat. This soil consists of multiple layers of alluvium, more than 2 inches (5 cm) thick. The cryic layer occurs within the control section. The topography is very gently sloping in the form of domes or palsas.

The vegetation is dominantly *Carex spp.*, feathermosses and Arctic willows with white spruce and tamarack forming the tree layer where present. The surface of many of these palsas consists of exposed peat and is nearly devoid of living vegetation.

A description of a representative profile of the York Fort series follows:

Of	0 to 7 inches, dark yellowish brown (10 YR 4/4, moist), weakly decomposed feathermoss peat and sedge peat; non-sticky; medium acid; unrubbed fiber content approximately 66 percent.
Om	7 to 15 inches, very dark grey (10YR 3/1, moist), moderately decomposed sedge peat, somewhat horizontally matted or layered; non-sticky; unrubbed fiber content approximately 57 percent.
Omz	15 to 20 inches, very dark brown (10YR 2/2, moist), well decomposed, frozen, sedge peat with layered alluvium; slightly sticky; segregated ice crystals 1mm thick; neutral; unrubbed fiber content approximately 30 percent.
IICgz	20 to 28 inches, dark greyish brown (2.5Y 4/2, moist), silty clay loam; frozen; friable when moist, soft when dry; contains thin layers of peat; ice lenses approximately 3 mm thick; mildly alkaline.
Omz	28 to 37 inches, dark grey (10YR 4/1, moist), well decomposed, sedge peat with alluvium; frozen; slightly sticky; contains 1 to 1.5 cm thick ice lenses; mildly alkaline.

IIIcgz	37 to 46 inches, olive grey (5Y 4/2, moist), silty clay loam, frozen; friable when moist, soft when dry; contains 3 to 5 cm thick ice lenses and some thin layers (5mm) of peat; mildly alkaline.
IVCgz	46 to 65 inches, greenish grey (5GY 5/1, moist), silty clay; frozen; friable when moist, slightly hard when dry; 3 to 5 cm thick ice lenses; mildly alkaline.

The York Fort series is the dominant soil type in the minerotrophic palsas of the York Factory peninsula. This area is periodically inundated with nutrient-rich and sediment-rich water from the Hayes River.

The active layer (that layer subject to annual thawing) consists of moderately decomposed sedge and feathermoss peat, generally 12 to 18 inches thick. The frozen layer consists of moderately decomposed sedge peat materials with multiple layers of alluvium. Alluvium is also present with the organic layers as is indicated by an increase in ash content with increasing depth. Ice crystals, 1 to 2 mm in thickness, are common throughout the frozen core. The number of ice crystals increases with depth and generally the alluvial layers contain higher amounts of ice than the adjacent peat layers. Ice lenses up to two inches thick were found at the lower depths.

The chemical composition is very different from that of any other cryic organic soil examined to date in northern Manitoba. These soils are neutral to mildly alkaline in reaction (pH 7 to 7.5) and the dominant exchangeable cations are calcium and magnesium. These soils are found throughout the peninsula with Rainbow soils.

B-V CHEMICAL COMPOSITION OF WATER

The water analysis is presented in Table B-XII and the distribution of sodium, calcium and pH according to their location on the York Factory peninsula is shown in Figure B-3.

The highest concentration of nutrients, especially sodium, was found at site 8 on Marsh Point under salt marsh vegetation. The soils on this site are Rego Gleysol with no surface peat. Site 1, along the base line, is a strongly minerotrophic, rich fen, and the associated soils are Cumulo Mesisol and Cryic Cumulic Regosol. This site is frequently inundated by the Hayes River.

The samples from sites 4, 5, 7 and 9 are under the influence of mineral rich ground waters, and Sphagnum mosses are usually found on hummocks, slightly above the water level. Organic soils associated with these sites are Cryic Cumulo Mesisol and Cumulo Mesisol.

Site 6, located on the bog pool, shows the lowest concentration of nutrients. These values, however, are higher than those from ombrotrophic bogs found further inland as they probably receive some minerotrophic water from below. The vegetation consists of black spruce, *Ledum*, *Sphagnum* and *Cladonia spp.*, the associated organic soils are Cryic Fibrisol and Cryic Sphagno-Fibrosol.

High values for sodium, calcium and magnesium are typical of sites close to the sea and of areas which are frequently inundated by the rivers. Hayes River, sampled at low tide, showed moderate amounts of calcium, probably because these waters were derived dominantly from non-calcareous peatland.

B-VI GLOSSARY

Active Layer (seasonal frost) is the top layer of ground, subject to seasonal freezing and thawing. In arctic and sub-arctic regions where annual freezing penetrates to the permafrost table, suprapermafrost and the active layer are identical.

Clear Ice is transparent and contains only a moderate number of air bubbles.

Cloudy Ice is relatively opaque because of entrapped air bubbles or for other reasons.

Frost Table is the surface, usually irregular, which represents the penetration at any time in spring or summer of thawing of the seasonally frozen ground. It may also refer to the top surface of the seasonally frozen ground above the permafrost.

Frozen Layer is the range of depths within which the soil is frozen. The frozen layer may be bounded both top and bottom by unfrozen soil, or at the top by the ground surface.

Ground Ice is a body of more or less clear ice within frozen ground. Generally the term is used to include all ice in the frozen ground.

Ice Coatings on Particles are discernible layers of ice found on or below the large soil particles in a frozen soil mass. They are sometimes associated with hoarfrost crystals which have grown into voids produced by freezing action.

Ice Crystal is a very small individual ice particle visible in the face of a soil mass. Crystals may be present alone or in combination with other ice formations.

Ice Lenses are lenticular ice formations occurring essentially parallel to each other in the soil and generally normal to the direction of heat loss, commonly in repeated layers.

Ice Segregation is the growth of ice as distinct lenses, layers, veins, and masses in soils, commonly but not always oriented normal to direction of heat loss.

Permafrost is perennially frozen earth materials whose temperature remains below 0°C continuously for a number of years.

Permafrost Table is the surface which represents the upper limit of permafrost.

Residual Thaw Zone is a layer of unfrozen ground between the permafrost and the seasonal frost. This layer does not exist where annual frost extends to permafrost.

TABLE B-I

MONTHLY AND ANNUAL DAILY MEAN TEMPERATURES AND PRECIPITATION AT PORT NELSON*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Daily mean temperature (°F)	-17	-14	- 2	17	33	45	55	53	44	30	10	- 9	21
Precipitation (inches)	0.60	0.46	0.58	0.88	0.85	2.07	1.64	2.08	1.79	0.96	1.04	0.81	13.76

* COMPILED FROM VOLUME I OF CLIMATIC SUMMARIES FOR SELECTED METEOROLOGICAL STATIONS IN THE DOMINION OF CANADA, ISSUED BY THE METEOROLOGICAL DIVISION OF THE DEPARTMENT OF TRANSPORT, CANADA (11 YEAR PERIOD).

TABLE B-II

SOIL LEGEND OF THE YORK FACTORY AREA

PARENT MATERIAL	NATURAL DRAINAGE	SOIL NAME AND DOMINANT TEXTURE	SYMBOL	PROFILE TYPE	DOMINANT VEGETATION	TOPOGRAPHY
Moderately to strongly calcareous, medium textured, recent alluvial deposits	Imperfect	Ten Shilling Series	T	Gleyed Cumulic Regosol	White spruce and willows	Level
	Imperfect	Machichi Series	M	Cryic Cumulic Regosol	White spruce and willows	Very gently sloping, low narrow ridges
	Imperfect	Prospect Bay Series	P	Cryic Cumulic Regosol	Arctic willows, sedges, some white spruce	Very gently sloping, low domes or palsas
	Poor to very poor	Marsh Point Series	Mp	Rego Gleysol	Sedges, tamarack and willows	Depressional to level
Mixed mesic forest and fen peat, 16 to 52 inches thick with layers of alluvium	Imperfect	York Fort Series	Y	Cryic Cumulo Mesisol	Feathermosses and some willow	Very gently sloping, low domes or palsas
	Poor to very poor	Hayes Series	H	Cumulo Mesisol	Tamarack, willows and mosses other than Sphagnum	Depressional to level
	Poor to very poor	Rainbow Series	R	Cumulo Mesisol	Tamarack, some willow and Sphagnum mosses	Depressional to level
Fibric forest peat with a cryic layer within the control section	Imperfect to poor	Woodcock Series	W	Cryic Fibrisol	Black spruce, Ledum sp., & Cladonia sp.	Level, peat plateau
Fibric Sphagnum peat with a cryic layer within the control section	Imperfect to poor	Seal Creek Series	S	Cryic Sphagno-Fibrisol	Black spruce, Sphagnum mosses	Level, peat plateau

TABLE B-III

ANALYSIS OF MACHICHI SERIES (CRYIC CUMULIC REGOSOL)

Hor.	Depth inches	% Ash	% Org. C	% Total N	C/N Ratio	pH in KCl	C.E.C. m.e.	Exchangeable Cations m.e./100 gms					% $CaCO_3$ Equiv.	% Calcite	% Dolomite
								Ca	Mg	K	Na	H			
L-F	0- 8	36.88	41.9	1.66	25.2	7.13	120.3	121.80	10.78	0.33	0.43	-	3.87	1.05	2.60
IICg	8-12	83.37	10.5	0.43	24.4	7.10	29.3	78.98	8.48	0.29	0.47	-	28.56	10.48	16.65
$IIICgz_1$	12-19	88.64	6.96	0.34	20.5	7.20	11.2	62.41	8.48	0.19	0.39	-	25.31	6.38	17.42
$IIICgz_2$	19-25						alluvium								

TABLE B-IV

ANALYSIS OF MARSH POINT SILT LOAM

CHEMICAL CHARACTERISTICS

Hor.	Depth inches	pH (0.01N $CaCl_2$)	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org. C	% Total	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms.				
										Ca^{2+}	Mg^{2+}	K+	Na+	H+
Cg	0-10	7.65	31.50	13.91	16.19	-	0.11	-	8.32	-	-	-	-	-
IICg	10-23	7.70	40.37	22.32	16.61	-	0.04	-	3.52	-	-	-	-	-

SOLUBLE ANIONS AND CATIONS

Hor.	Depth inches	Cond. mmhos/cm	SO_4^{2-} me/l	Cl^- me/l	HCO_3^- me/l	Total Anions me/l	Ca^{2+} me/l	Mg^{2+} me/l	Na+ me/l	Total Cations me/l
Cg	0-10	3.28	7.15	23.75	5.36	36.26	8.10	5.00	23.48	36.58
IICg	10-23	5.78	13.56	49.50	4.08	67.08	16.00	12.20	37.83	66.03

PARTICLE SIZE CHARACTERISTICS

Hor.	Depth inches	Stones		Sand Fraction %					Total Sand %	Silt %	Clay %	Textural Class
		Dominant Size	%	V.C.S.	C.S.	M.S.	F.A.	V.F.S.				
Cg	0-10	-	0	-	-	-	6.50	31.73	38.23	48.51	13.26	L
IICg	10-23	-	0	-	-	-	1.43	26.53	27.97	57.03	15.00	SiL

TABLE B-V

ANALYSIS OF PROSPECT BAY SERIES SILT LOAM

Hor.	Depth Inches	% Ash	% Org. C	% Total N	C/N Ratio	pH in KCl	C.E.C. m.e.	Exchangeable Cations m.e./100 gms.					% $CaCO_3$ Equiv.	% Calcite	% Dolomite
								Ca	Mg	K	Na	H			
L-F	0 - 5	68.94	14.60	0.29	50.3	7.40	32.8	78.17	7.07	0.33	0.22	-	29.90	13.41	15.18
IICg	5 - 6½	92.92	6.96	0.27	25.8	7.00	19.6	71.10	3.83	0.25	0.20	-	25.81	9.91	14.65
IIICg	6½- 8	88.60	10.40	0.45	23.1	7.12	42.7	81.20	7.67	0.33	0.38	-	25.53	9.03	15.18
L-Fb$_1$	8 -10	-	27.20	1.27	21.4	6.90	69.6	67.26	7.67	0.31	0.28	-	6.12	0.00	5.64
L-Fb$_2$	10 -12	-	27.30	1.05	27.9	7.10	41.7	77.72	10.50	0.28	0.41	-	8.51	0.00	7.83
IVCg	12 -15	-	10.90	0.50	21.8	6.98	15.7	80.39	4.24	0.23	0.28	-	26.68	10.05	15.32
VCgz	15 -62	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE B-VI

ANALYSIS OF SEAL CREEK SERIES (CRYIC SPHAGNO-FIBRISOL)

Hor.	Depth inches	% Un-rubbed Fiber	% Pyro-phos. Sol.	% Ash	% Org. C	% Total N	C/N Ratio	pH in KCl	C.E.C. m.e.	Exchangeable Cations m.e./100 gms.				
										Ca	Mg	K	Na	H
Of	0 -12	100.0	0.037	0.08	54.88	0.41	133.8	2.70	106.90	6.06	4.24	1.50	1.96	101.00
Ofz_1	12 -15½	86.7	0.020	2.68	54.44	0.51	106.7	3.16	104.80	25.75	4.84	1.07	1.63	85.90
Ofz_2	15½-21	98.3	0.082	4.60	60.64	0.80	75.8	3.90	88.96	27.27	7.57	0.69	1.79	58.20
Omz	21 -33	43.3	-	25.10	39.68	1.21	32.8	6.70	100.60	68.47	12.12	0.27	1.14	5.15
IICz	33 -48					alluvium								

TABLE B-VII

ANALYSIS OF TEN SHILLING SILT LOAM

Hor.	Depth feet	pH (0.01N $CaCl_2$)	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.	% Total	C/N Ratio	C.E.C. m.e.
L-F	0.17- 0	7.10	6.31	0.79	5.09	37.12	1.27	29	82.10
Cg_1	0 - 0.17	7.45	30.73	11.16	17.60	4.37	0.20	22	17.30
Cg_2	0.17- 0.54	7.50	35.32	14.04	19.62	6.36	0.34	19	25.06
Cg_3	0.54- 0.67	7.50	33.45	16.88	14.78	-	-	-	9.72
Cg_4	0.67- 2.0	7.60	27.91	14.98	11.91	-	-	-	7.20
Cg_5	2.0 - 4.0	8.00	39.30	18.65	19.01	-	-	-	4.12
Cg_6	4.0 - 6.0	7.70	41.32	26.18	13.95	-	-	-	5.82
Cg_7	6.0 - 7.1	7.75	42.81	19.27	21.68	-	-	-	7.96
Cg_8	7.1 -10.5	7.70	34.38	22.39	11.04	-	-	-	5.98
$IICg_1$	10.5 -12.0	7.90	33.94	20.49	12.39	-	-	-	4.44
$IICg_2$	12.0 -14.0	7.90	41.48	25.71	14.53	-	-	-	5.18
$IICg_3$	14.0 -16.0	8.00	40.21	21.41	17.32	-	-	-	4.44
$IICg_4$	16.0 -18.0	8.05	45.42	31.54	12.79	-	-	-	6.00
$IICg_5z$	18.0 -19.5	8.30	48.32	25.38	21.80	-	-	-	6.76

TABLE B-VIII

ANALYSIS OF TEN SHILLING SILT LOAM
CHEMICAL CHARACTERISTICS, SOLUBLE ANIONS AND CATIONS

Hor.	Depth feet	Cond. mmhos/cm	SO_4^{2-} me/1	Cl^- me/1	HCO_3^- me/1	Total Anions	Ca^{2+} me/1	Mg^{2+} me/1	Na+ me/1	Total Cations me/1
L-O	0.17- 0	0.92	-	-	-	-	-	-	-	-
Cg_1	0 - 0.17	0.86	-	-	-	-	-	-	-	-
Cg_2	0.17- 0.54	0.76	-	-	-	-	-	-	-	-
Cg_3	0.54- 0.67	0.76	-	-	-	-	-	-	-	-
Cg_4	0.67- 2.0	0.52	-	-	-	-	-	-	-	-
Cg_5	2.0 - 4.0	0.52	-	-	-	-	-	-	-	-
Cg_6	4.0 - 6.0	1.82	21.15	1.50	2.81	25.46	15.50	5.60	1.52	22.62
Cg_7	6.0 - 7.1	2.31	26.90	0.80	4.08	31.78	18.10	10.90	3.30	32.30
Cg_8	7.1 -10.5	1.76	17.90	0.55	4.08	22.53	14.30	4.35	1.41	20.06
$IICg_1$	10.5 -12.0	4.27	55.75	1.80	3.83	61.38	28.00	14.60	17.39	59.99
$IICg_2$	12.0 -14.0	4.37	52.05	1.90	5.10	59.05	20.50	15.70	21.74	57.94
$IICg_3$	14.0 -16.0	5.78	63.20	3.40	3.57	70.17	26.60	17.00	33.04	76.64
$IICg_4$	16.0 -18.0	5.17	52.40	6.70	3.32	62.42	14.00	10.00	39.13	63.13
$IICg_5z$	18.0 -19.5	4.80	22.10	22.55	9.69	54.34	1.30	3.00	46.96	51.26

TABLE B-IX

ANALYSIS OF TEN SHILLING SILT LOAM
PARTICLE SIZE CHARACTERISTICS

Hor.	Depth feet	Stones		Sand Fraction %					Total Sand %	Silt %	Clay %	Textural Class
		Dominant Size	%	V.C.S.	C.S.	M.S.	F.S.	V.F.S.				
L-H	0.17- 0	-	0	-	-	-	-	-	-	-	-	-
Cg_1	0 - 0.17	-	0	-	-	-	6.54	31.56	38.10	51.07	10.83	SiL
Cg_2	0.17- 0.54	-	0	-	-	-	0.97	15.38	16.35	69.18	14.47	SiL
Cg_3	0.54- 0.67	-	0	-	-	0.64	4.53	40.37	45.54	44.51	9.94	L
Cg_4	0.67- 2.0	-	0	-	0.60	8.48	18.55	25.39	53.02	38.94	8.04	S.L.
Cg_5	2.0 - 4.0	-	0	-	0.24	0.42	3.03	19.62	23.30	63.92	12.78	SiL
Cg_6	4.0 - 6.0	-	0	-	0.12	0.41	1.92	40.09	42.54	48.75	8.71	L
Cg_7	6.0 - 7.1	-	0	-	-	-	0.63	15.90	16.53	71.37	12.09	SiL
Cg_8	7.1 -10.5	-	0	-	0.51	1.39	13.68	39.63	55.20	34.80	10.00	S.L.
$IICg_1$	10.5 -12.0	1/8"	0.9	0.43	0.44	1.03	7.86	27.24	37.01	48.09	14.90	L
$IICg_2$	12.0 -14.0	1/8"	2.1	0.29	0.53	1.04	8.50	23.04	33.41	51.37	15.22	SiL
$IICg_3$	14.0 -16.0	-	0	-	0.15	0.30	1.50	39.64	41.58	46.42	12.00	L
$IICg_4$	16.0 -18.0	-	0	0.16	0.52	1.08	3.29	24.39	29.45	56.68	13.87	SiL
$IICg_5z$	18.0 -19.5	-	0	-	-	-	-	6.87	6.87	70.62	22.51	SiL

TABLE B-X

ANALYSIS OF WOODCOCK SERIES (CRYIC FIBRISOL)

Hor.	Depth inches	% Un-rubbed Fiber	% Pyro-phos. Sol.	% Ash	% Org. C	% Total N	C/N Ratio	pH in KCl	C.E.C. m.e.	Exchangeable Cations m.e./100 gms.				
										Ca	Mg	K	Na	H
Of$_1$	0- 9	96.7	0.102	2.52	54.70	0.75	72.9	2.99	70.0	16.05	1.51	0.79	0.98	53.90
Of$_2$	9-13	92.7	0.076	2.10	54.32	0.73	74.4	2.62	80.0	8.18	1.81	1.08	0.98	78.50
Ofz	13-17	90.5	0.010	2.66	56.72	0.97	58.5	2.93	94.4	26.05	7.27	0.46	0.82	82.10
IICgz	17-37					alluvium								

TABLE B-XI

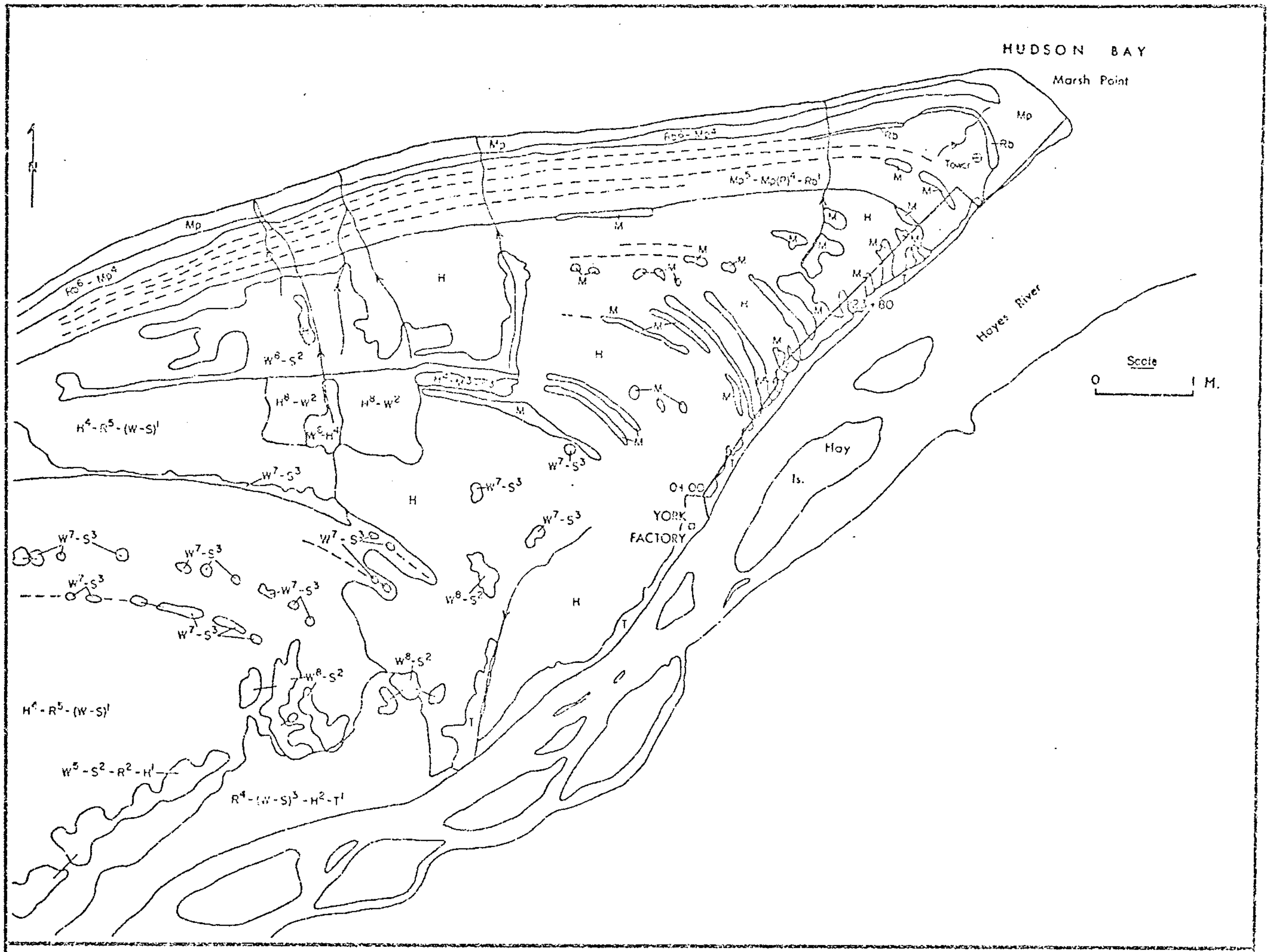
ANALYSIS OF YORK FORT SERIES (CRYIC CUMULO MESISOL)

Hor.	Depth inches	% Un-rubbed Fiber	% Pyro-phos. Sol.	% Ash	% Org. C	% Total N	C/N Ratio	pH in KCl	C.E.C. m.e.	Exchangeable Cations m.e./100 gms.				
										Ca	Mg	K	Na	H
Of	0- 7	66.1	0.053	10.83	49.3	1.85	26.6	5.6	102.40	62.41	81.50	1.09	1.30	15.45
Om	7-15	56.8	0.227	17.43	43.6	1.83	23.8	-	128.97	79.38	53.63	0.50	0.82	17.45
Omz	15-20	30.2	0.110	46.21	24.6	1.13	21.8	7.0	80.26	53.63	12.42	0.44	0.65	10.85
IICgz	20-28		-			alluvium								
Omz	28-37	28.3	-	57.11	-	-	-	7.5	-	-	-	-	-	-
IIICgz	37-65					alluvium								

TABLE B-XII

CHEMICAL PROPERTIES OF WATER SAMPLES

Sample No.	Date	pH	Conductivity M/Mhos	Ca ppm	Mg ppm	Na ppm	Zn ppm
YF 1	5/7/69	7.40	0.28	48	11	16	0.20
YF 4	28/6/69	6.70	0.11	20	6	4	0.05
YF 5	26/7/69	5.59	0.16	8	4	12	0.45
YF 6	27/7/69	5.65	0.07	5	2	5	0.35
YF 7	28/7/69	6.80	0.21	27	1	9	0.35
YF 8	29/7/69	6.70	4.47	98	75	850	0.20
YF 9	29/7/69	7.10	0.21	24	7	7	0.07
YF 10	29/7/69	7.90	0.13	25	4	6	0.05



	SOIL NAME	PROFILE TYPE
H	Hayes Series	Cumulo Mesisol
M	Machichi Series	Cryic Cumulic Regosol
Mp	Marsh Point Series	Rego Gleysol
Mp(p)	Marsh Point Peaty Phase	Rego Gleysol
P	Prospect Bay Series	Cryic Cumulic Regosol
R	Rainbow Series	Cumulo Mesisol
Rb	Recent Beach	
S	Seal Creek Series	Cryic Sphagno-Fibrisol
T	Ten Shilling Series	Gleyed Cumulic Regosol
W	Woodcock Series	Cryic Fibrisol
Y	York Fort Series	Cryic Cumulo Mesisol

---- Beaches

—— York Factory Baseline

FIGURE B-1

SOILS OF THE YORK FACTORY AREA

SOURCE: Tarnocai 1970

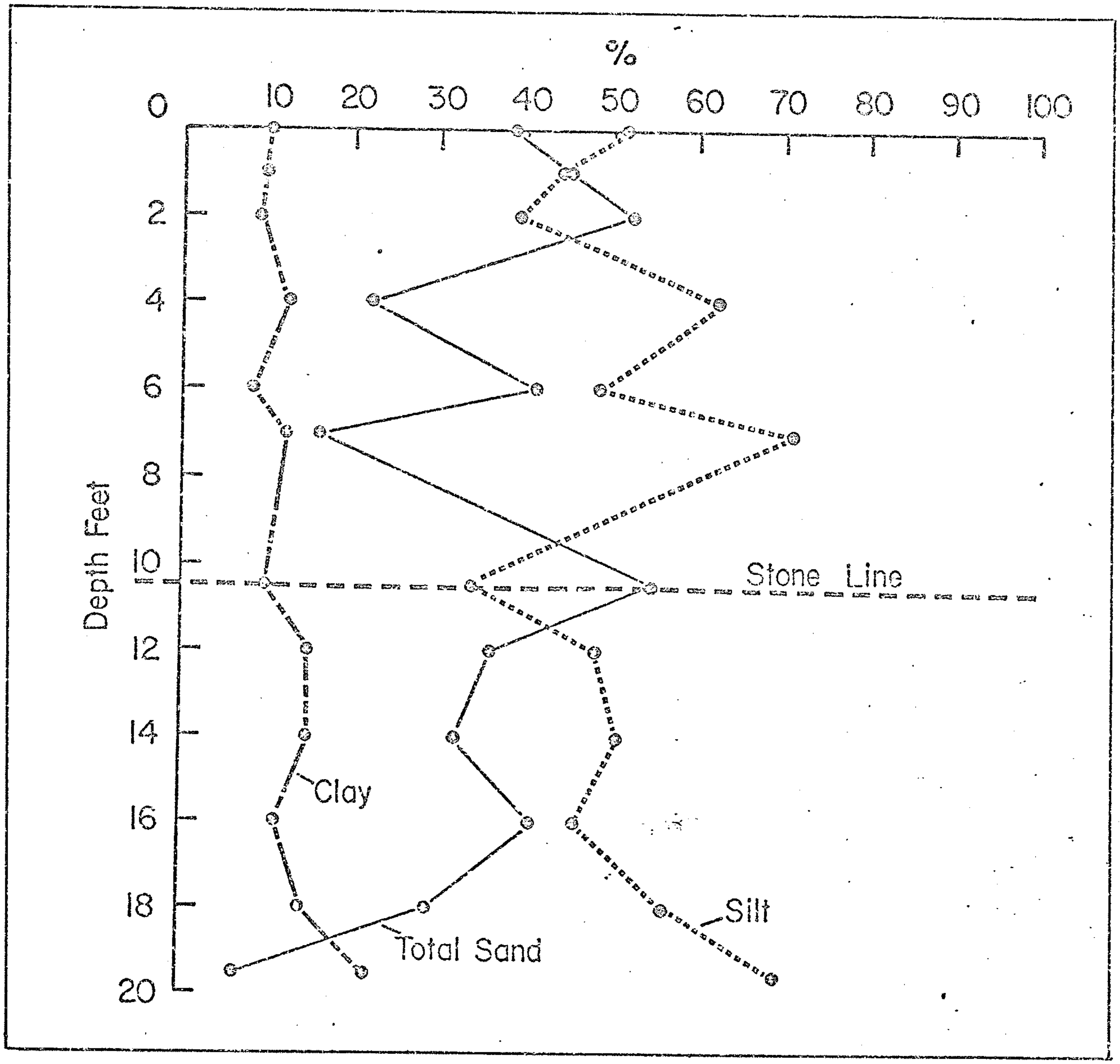


FIGURE B-2

PARTICLE SIZE ANALYSIS OF TEN SHILLING SILT LOAM

SOURCE: Tarnocai 1970

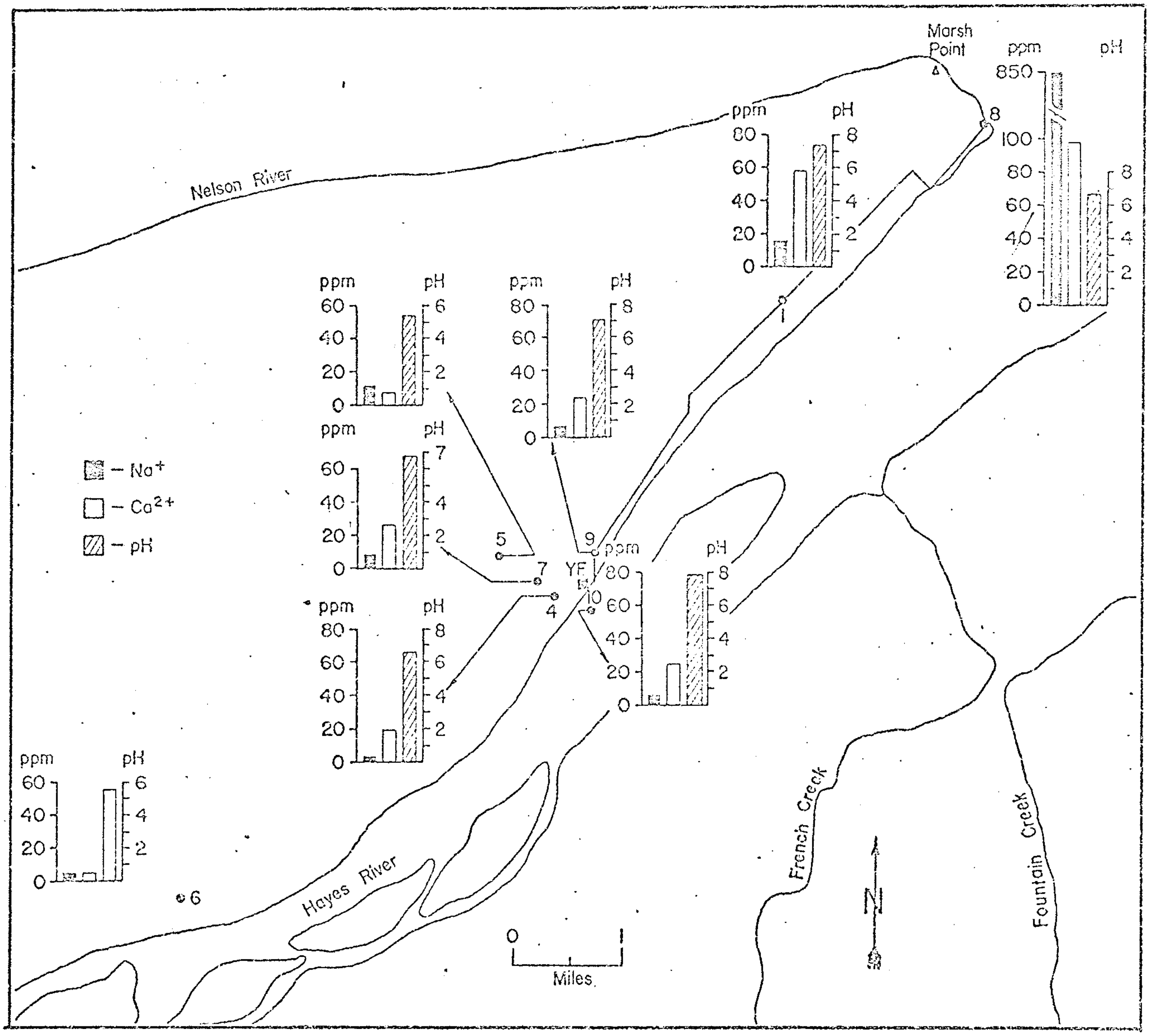


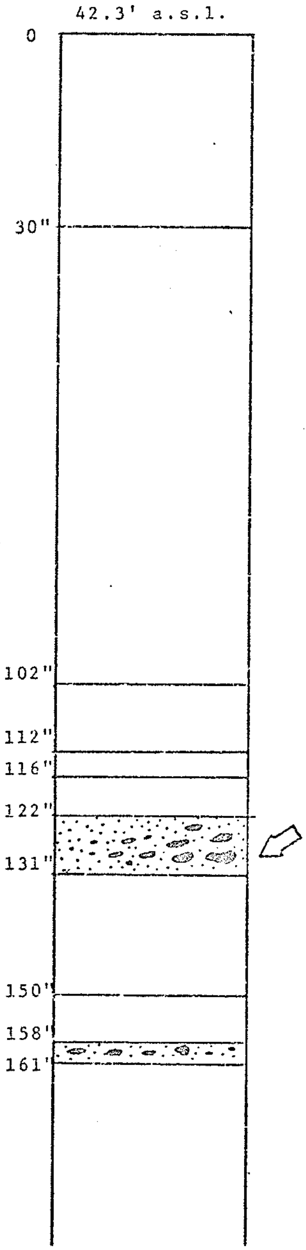
FIGURE B-3

LOCATION OF SAMPLE SITES AND DISTRIBUTION OF SODIUM, CALCIUM AND pH IN WATERS OF THE YORK FACTORY AREA

SOURCE: Tarnocai, 1970

APPENDIX C

STRATIGRAPHIC SITES

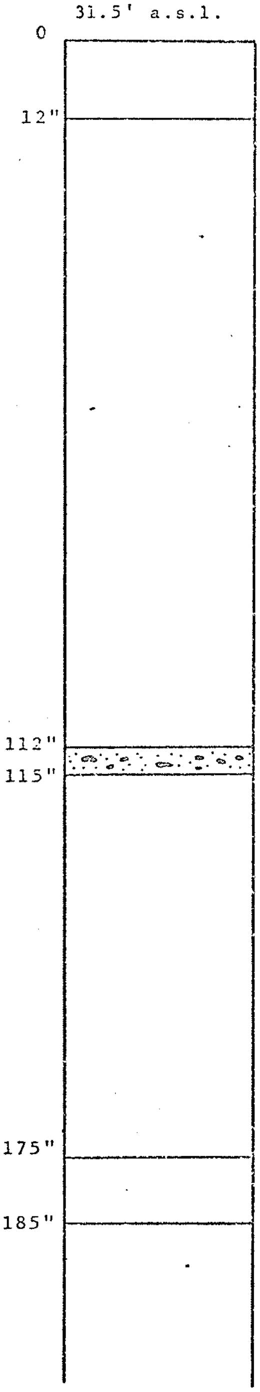


UNIT	THICKNESS	DESCRIPTION
10	30"	Peat, fibrous.
9	62"	Silty overbank deposits with distinct organic layers. Towards base of unit layers of very fine X-bedded sand
8	10"	Silty clay/sandy clay
7	4"	Coarse sand
6	6"	Clayey sand/sandy clay
5	9"	Coarse sand, gravels, some cobble material
4	19"	Very fine sand, silty sand Random inclusions of clay
3	8"	silty/sandy clay
2	3"	Gravel: coarse sand matrix
1		Blocky sandy clay, oxidised along joints Transition to marine fossiliferous clay

⇦ RADIOCARBON DATED WOOD 2065±125 YEARS B.P. (GX-2061)

FIGURE C-1

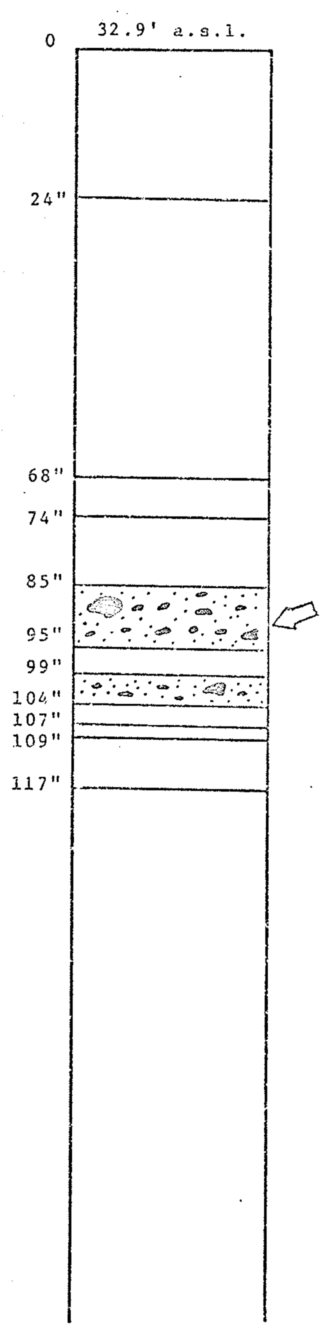
STRATIGRAPHIC SUCCESSION AT GANDER CREEK (SITE 1)



UNIT	THICKNESS	DESCRIPTION
6	12"	Peat, fibrous
5	100"	Horizontally bedded overbank deposits, predominantly silt: clay and organic layers: sporadic pockets of clay
4	3"	Gravels/cobbles, coarse sand
3	60"	Clayey sand Sandy clay
2	10"	Transition zone, sandy clays, partially oxidised
1		Marine fossiliferous clay

FIGURE C-2

STRATIGRAPHIC SUCCESSION AT FOUR MILE GULLY (SITE 2)

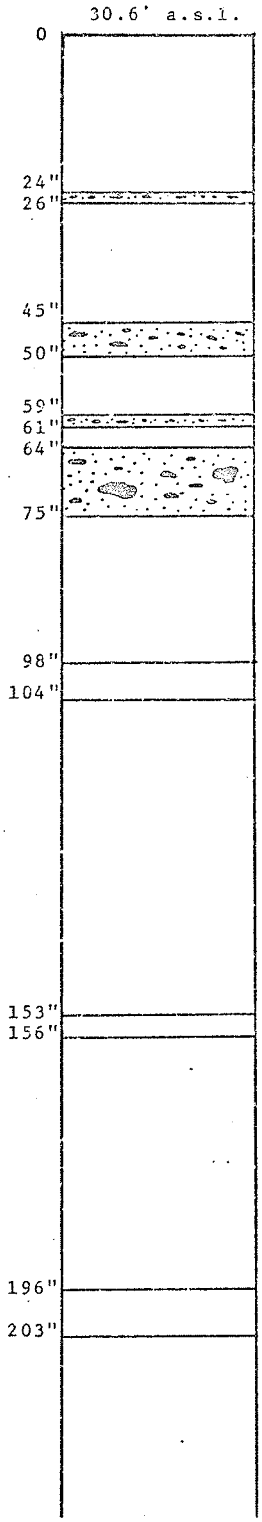


UNIT	THICKNESS	DESCRIPTION
11	24"	Peat
10	44"	Alluvial overbank materials, predominantly silt: some clay and organic layers
9	6"	Coarse sand and gravel
8	11"	Very fine sand
7	10"	Gravel, cobbles,occasional boulders, coarse sand matrix
6	4"	Very fine sand: organic material
5	5"	Sand and gravel: no cobbles
4	3"	Coarse sand
3	2"	Clayey sand
2	8"	Fine/medium sand, clay inclusions
1		Transition zone to marine fossiliferous clays, sandy clay/clay, blocky, oxidation along joints

⇦ RADIOCARBON DATED DRIFTWOOD 1930±130 YEARS B.P. (GSC-1305)

FIGURE C-3

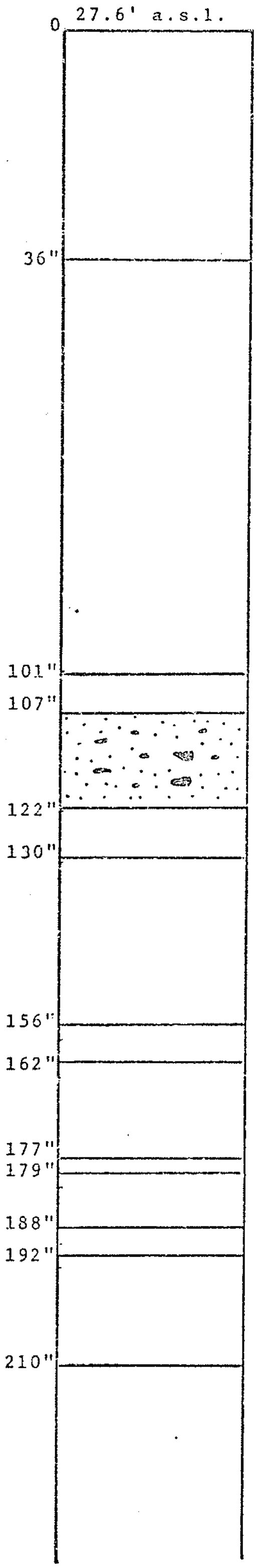
STRATIGRAPHIC SUCCESSION AT MILE SANDS (SITE 3)



UNIT	THICKNESS	DESCRIPTION
15	24"	Peat, fibrous
14	2"	Gravel
13	19"	Overbank deposits, predominantly silt with organic layers
12	5"	Sand and gravel
11	9"	Clayey sand: silty sand X-bedded towards base of unit
10	2"	Gravel
9	3"	Clayey sand
8	11"	Gravel, cobble and boulder material in coarse sand matrix
7	23"	Clayey sand
6	6"	X- bedded fine sand
5	49"	Sandy clay/clayey sand,blocky structure
4	3"	Very fine sand
3	40"	Sandy clay/clayey sand,blocky structure
2	7"	Very fine sand
1		Transition zone to marine fossiliferous clay, mainly blocky sandy clay material

FIGURE C-4

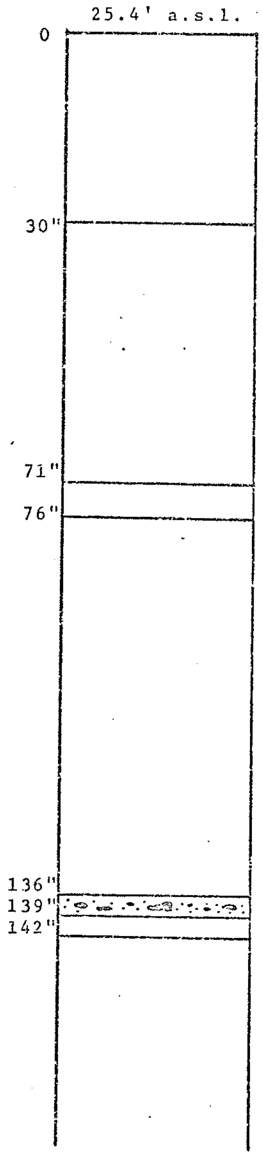
STRATIGRAPHIC SUCCESSION AT MILE SANDS (SITE 4)



UNIT	THICKNESS	DESCRIPTION
12	36"	Peat, fibrous
11	65"	Overbank deposits, predominantly silt: organic and clay layers
10	6"	Very fine/fine sand
9	16"	Silty sand layer with gravels and some cobble material
8	8"	Very fine/fine sand
7	28"	Sandy clay/clayey sand, pockets of pure sand, structure blocky
6	6"	Fine sand. X-bedded
5	15"	Sandy clay/clayey sand
4	2"	Very fine/fine sand
3	9"	Sandy clay/clayey sand, pockets of pure sand
2	4"	Very fine/fine sand
1		Transition zone to marine fossiliferous clay, sandy clay material, partially oxidised

FIGURE C-5

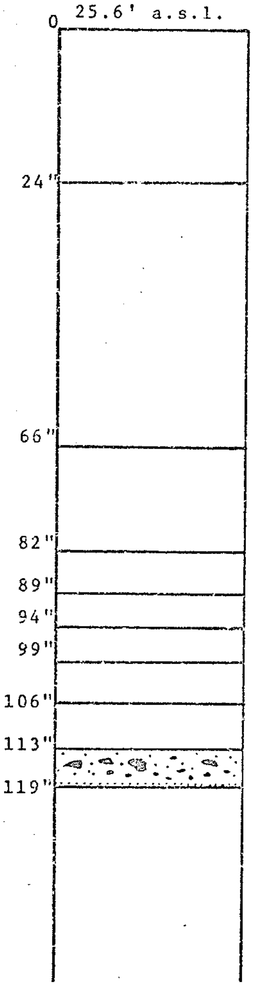
STRATIGRAPHIC SUCCESSION AT FORT SITE (SITE 5)



UNIT	THICKNESS	DESCRIPTION
7	30"	Peat, undecomposed vegetation
6	46"	Overbank alluvial deposits, predominantly silt, organic and clay layers
5	5"	Sandy silt layer
4	60"	Fine Sand, with random pockets of clay: X-bedded sand
3	3"	Gravel, some cobbles, sand matrix
2	3"	Fine/medium sand
1		Transition zone of partially oxidised blocky sandy clay Marine fossiliferous clay

FIGURE C-6

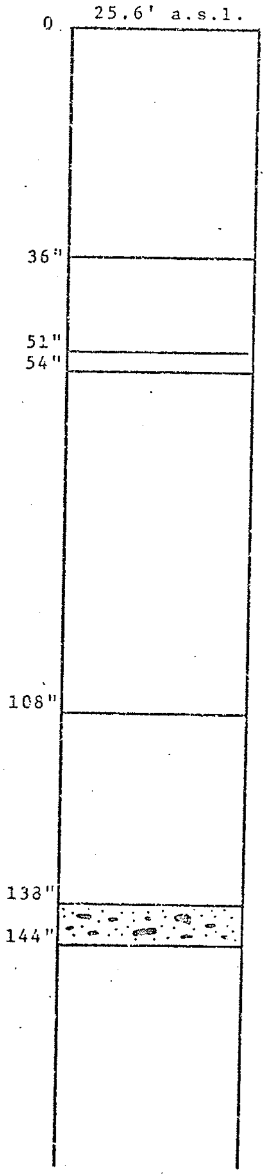
STRATIGRAPHIC SUCCESSION AT CHAIN SITE (SITE 6)



UNIT	THICKNESS	DESCRIPTION
10	24"	Peat, Undecomposed root systems, entrapped alluvial materials
9	42"	Overbank deposits, predominantly silt: organic and clay layers
8	16"	Silty sand/fine sand
7	7"	Fine/Very fine sand
6	5"	Clay/sandy clay
5	5"	Fine/very fine sand
4	7"	Clay/sandy clay
3	7"	Fine/very fine sand
2	6"	Gravel: cobbles, coarse sand with distinct layer of very fine sand at base of unit
1		Transition zone, sandy blocky clay Marine fossiliferous clay

FIGURE C-7

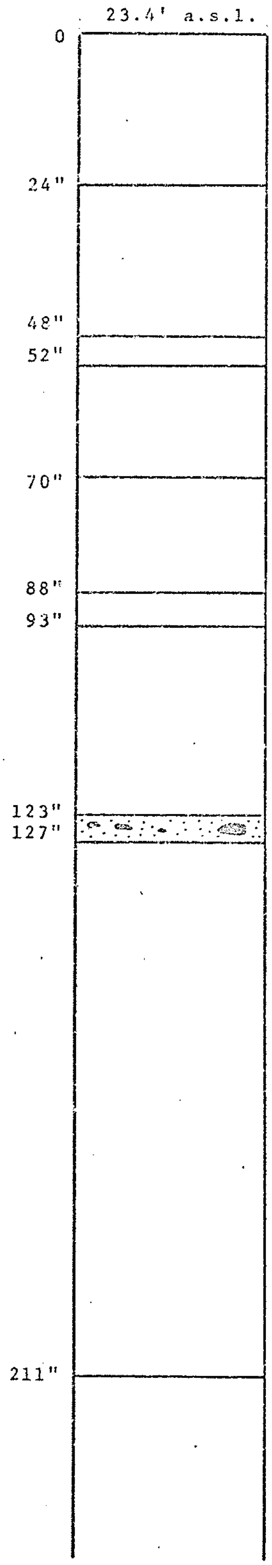
STRATIGRAPHIC SUCCESSION AT ROBINSON'S GULLY (SITE 7)



UNIT	THICKNESS	DESCRIPTION
7	36"	Peat, undecomposed vegetation, roots and stumps
6	15"	Alluvial overbank deposits, predominantly silt, organic layers
5	3"	Very fine/fine sand
4	54"	Clayey sand/sandy clay, blocky when dry
3	30"	Very fine/fine X-bedded sand layers and pockets of clay: Predominantly Clayey sand material
2	6"	Gravels, coarse sand
1		Transition zone of blocky sandy clay Marine fossiliferous clay

FIGURE C-8

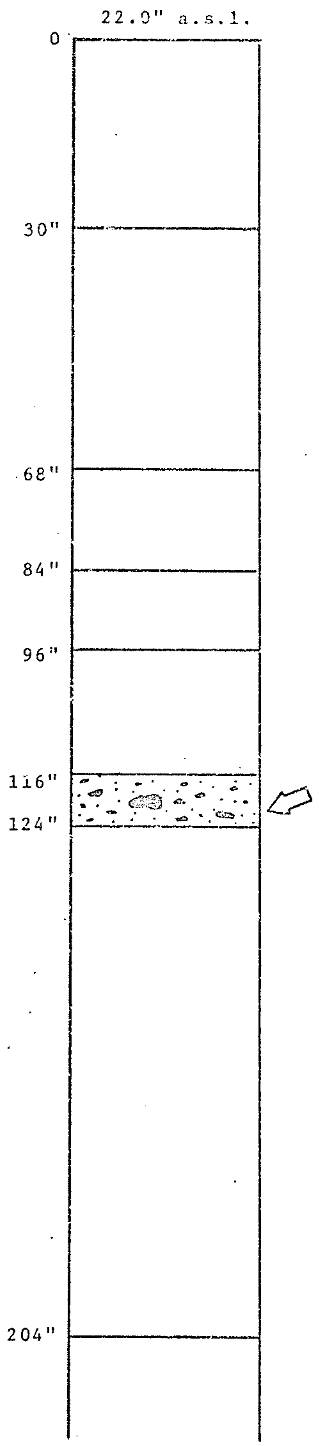
STRATIGRAPHIC SUCCESSION AT
ROBINSON'S GULLY (SITE 8)



UNIT	THICKNESS	DESCRIPTION
9	24"	Peat, fibrous, undecomposed root systems
8	24"	Overbank deposits, silt, organic and fine sand layers
7	4"	Very fine/fine sand
6	18"	Clayey silt/silty clay
5	18"	Clay, some pockets of fine sand
4	5"	Fine sand, X-bedded
3	30"	Clayey sand/sandy clay, blocky structure, lenses of silt material
2	4"	Gravels/cobbles: sand matrix
1	84"	Blocky clayey sand Sandy Clay, partially oxidised
		Marine fossiliferous clay

FIGURE C-9

STRATIGRAPHIC SUCCESSION AT CARIBOU CREEK (SITE 9)

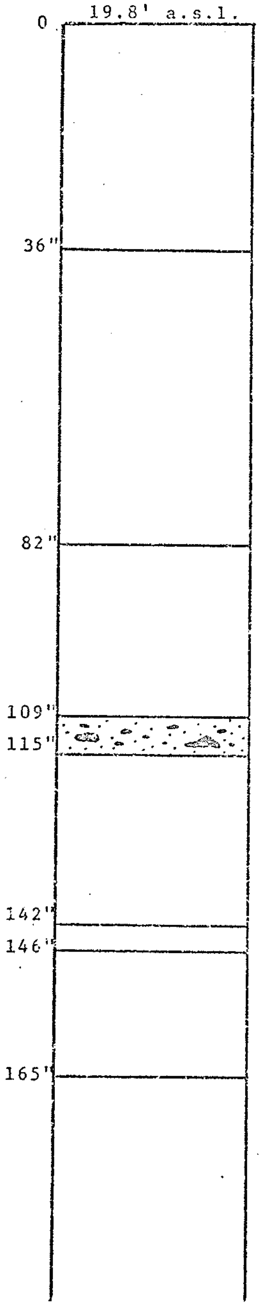


UNIT	THICKNESS	DESCRIPTION
8	30"	Peat, fibrous, roots and stumps, entrapped alluvial materials
7	38"	Overbank deposits, dominantly silt: organic and clay layers Increase in silt content towards the base of unit
6	16"	Sandy silt/silty sand
5	12"	Silty sand: lenses of clay incorporated
4	20"	Sandy clay/ clayey sand: sharp boundary to
3	10"	Gravels: some cobbles
2	80"	Blocky sandy clay, transition zone
		Marine fossiliferous clay

⇦ RADIOCARBON DATED DRIFTWOOD 1955±125 YEARS B.P. (GX-2062)

FIGURE C-10 .

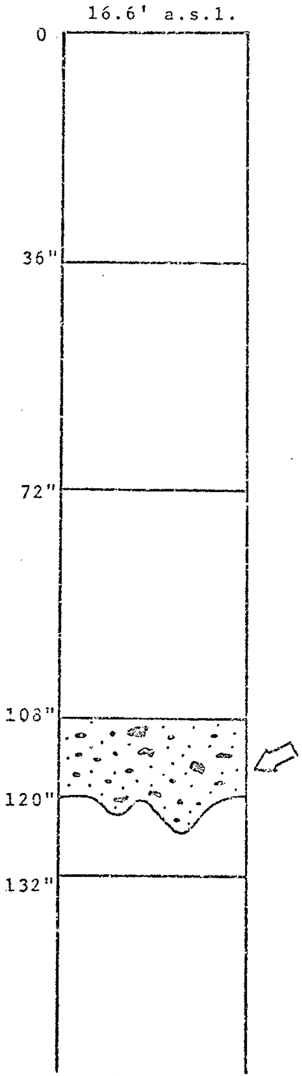
STRATIGRAPHIC SUCCESSION AT RAVEN CREEK (SITE 10)



UNIT	THICKNESS	DESCRIPTION
8	36"	Peat, fibrous: Undecomposed root systems, tree stumps: trapped silty materials
7	46"	Overbank deposits, dominantly silt: clay and organic layers 6" layer fine sand at base of unit
6	27"	Sandy clay Clayey sand
5	6"	Gravels: cobbles; coarse sand
4	27"	Blocky sandy clay/clayey sand
3	4"	Fine sand
2	20"	Transition zone of blocky partially oxidised sandy clay material
1		Marine fossiliferous clay

FIGURE C-11

STRATIGRAPHIC SUCCESSION AT SQUIRREL CREEK (SITE 11)

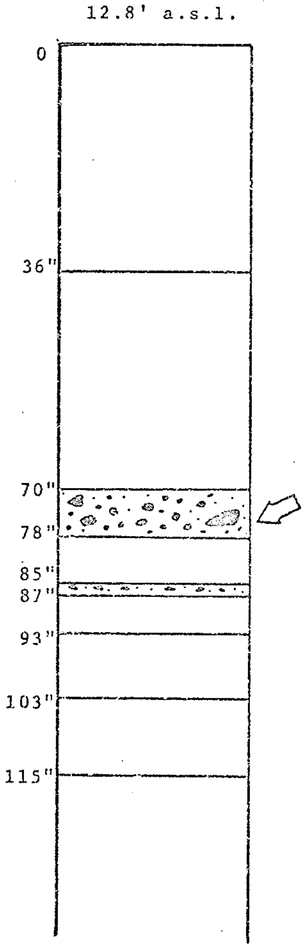


UNIT	THICKNESS	DESCRIPTION
6	36"	Peat, fibrous: undecomposed roots and stumps: entrapped alluvial materials
5	36"	Overbank deposits, dominantly silt with clay and organic layers
4	36"	Sandy clay/clayey sand Fine sand, X-bedded at base of unit
3	12"	Coarse sand, gravels: irregular thickness, tongues into
2	12"	Transition zone of blocky sandy clay
1		Marine fossiliferous clay

⇦ RADIOCARBON DATED DRIFTWOOD 1250±105 YEARS B.P. (GX-2063)

FIGURE C-12

STRATIGRAPHIC SUCCESSION AT PALSA CREEK (SITE 12)



UNIT	THICKNESS	DESCRIPTION
9	36"	Vegetation and root systems, silty and sandy materials entrapped: organic layers: sandy towards base of unit
8	34"	Overbank deposits, dominantly silt, organic layers, distinctly more sandy towards base of unit
7	8"	Gravels/coarse sand
6	7"	Very fine sand
5	2"	Medium/coarse gravel
4	7"	Very fine sand
3	10"	Transition zone, partially oxidised sandy clay
2	13"	Unoxidised sandy clay
1		Marine fossiliferous clay

⇨ RADIOCARBON DATED DRIFTWOOD
660±190 YEARS B.P. (GSC-1468)

FIGURE C-13

STRATIGRAPHIC SUCCESSION AT LONE TREE SITE
(SITE 13)

APPENDIX D

THE ORIGIN OF BEACON POINT

The evolution of the Nelson River has been investigated by Newbury (1968). The present channel represents the outlet to Hudson Bay of the final remnant of glacial Lake Agassiz. The Hayes valley on the other hand is older than the Nelson. Several lines of evidence indicate that it may have existed before the last glaciation.

(a) The broad depression along the line of the present Hayes valley in an otherwise evenly till covered landscape (Tyrrell 1916, p. 18).

(b) The misfit character of the present Hayes channel:

> ....Like in its upper portions it [the Hayes] does not anywhere fill the bottom of its valley, but swings from bank to bank, first washing the foot of a steep naked cliff on one side and then the foot of a similar cliff on the other side, with alluvial flats opposite these cliffs.[1]

(c) The greater thickness of stratified sediments in the area of the present Hayes estuary. Till is not exposed in the valley sides of the Hayes until a point approximately thirty-two miles upstream of Marsh Point.

> ....On the lower portion of the Hayes river, however, the stratified clays and sands are very much thicker than usual, for there would appear to have been a deep embayment in the Post-glacial shore line at this point, into which a mud-laden stream probably emptied and deposited its load of mud and sand as it reached quiet water.[2]

The width of the embayment was not extensive, since in the Nelson estuary to the northwest, and in the Machichi River to the east, till is omnipresent in the banks and stratified sediments are conspicuously absent.

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[1] Tyrrell (1916, p. 23).

[2] Tyrrell (1913, p. 208).

(d) Stream gravels in the Hayes valley of interglacial age (McDonald 1969) suggest that the broad depression corresponding to the present Hayes channel was probably occupied by an interglacial stream. Tyrrell (1916, p. 15) also observed interglacial deposits of coarse sand and gravel upstream of the confluence of the Shamattawa River (God's River) and the Hayes.

Observation of air photographs, and a vegetation reconnaissance by Ritchie (1960, Figure 2) indicates that a former channel connected the Hayes and Nelson rivers at the narrowest section of Beacon Point (Figure D-1). The alluvial materials in the vicinity of the confluence are associated with a distinct band of white spruce vegetation. The distribution of the latter species is confined almost invariably to the banks of streams, river islands, abandoned channels and raised beaches in the York Factory area. The channel is likely to have been a major distributary of the main Hayes channel.[3] Ten Shilling Creek also represents a former distributary of the present Hayes channel.[4] In view

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[3] Robson's Map (1745) of the York Factory ares (Figure 1.5) depicts Beacon Point as an island, separated from the "mainland" by the Penny-cut-away. This channel was used by the Indians to travel by canoe between the Nelson and Hayes. The Penny-cut-away represents probably a former distributary of the Hayes, which has since silted up.

[4] Bell (1878, p. 8CC) records that "about a mile above penneycutaway, the river goes off in a channel on the right, which is of considerable size during floods, but is nearly dry at low water. It emerges again about three miles above York Factory, and is here called Ten Shilling Creek."

of the wedge shaped distribution of stratified sediments, restricted to the lower Hayes, and the evidence of former distributaries, the initial stages in the formation of Beacon Point are illustrated in Figure D-2 . At this stage the Hayes probably functioned as a major outlet of glacial Lake Agassiz, as evidenced by the distribution of esker remnants and spillway systems in northern Manitoba (Figure A-18), and had a substantially greater discharge than at present. The latter flow was also considerably greater than the discharge in the "ancestral" lower Nelson. Tyrrell (1916, p. 24) postulated that the latter channel originated as the result of the combined discharge of the Grass and Burntwood rivers which flow into Split Lake. Terrace remnants, at 30 feet above sea level and 10 feet above sea level, preserved from subsequent destruction by the present Nelson River, were observed by Tyrrell in the lower reaches of the Nelson. These remnants were regarded by Tyrrell as manifestation of the flows that existed when the combined Burntwood and Grass rivers discharged by way of the present Nelson channel (Split Lake to Hudson Bay). Their destruction followed the increase in discharge which resulted from the junction of the stream flowing from Lake Winnipeg (i.e. the present upper Nelson) with the Burntwood-Grass rivers. Following the establishment of the Nelson as the outlet of the remnants of Lake Agassiz, the situation at the former confluence of the Hayes and Nelson was reversed. With the drainage of Lake Agassiz to the Lake Winnipeg stage, the Hayes valley no longer functioned as a spillway system, and gradually developed its present misfit condition. Consequently the major distributaries of the Hayes silted up. The main Hayes channel was diverted northeastwards by the Nelson. As both rivers continued to downcut through the stratified sediments deposited by the Hayes when functioning as a major outlet of glacial Lake Agassiz, a spit-like development of Beacon Point resulted, reflecting the dominance of the Nelson in terms of flow and sediment discharge, and the general anti-clockwise direction of offshore currents in Hudson Bay. (Figure D-2).

In the Hayes estuary a sequence of bars and islands evolved as a consequence of (a) the highly seasonal nature of the discharge, the Hayes being characterised by short periods of increased competence during the spring run-off period, (b) the erodibility of the stratified sediments of which the banks of the Hayes are composed, and (c) the effect of continued postglacial rebound. In the Nelson estuary the absence of bars and islands attests to the continued competency of the latter river to remove bed materials bayward, and to downcut at a rate commensurate with the rate of postglacial uplift. The Nelson is also characterised by a more uniform distribution of annual run-off, reflecting the storage potential of Lake Winnipeg.

By 2,500 years B.P., the initial stage in the present framework of analysis, the peninsular shape of Beacon Point and the estuarine boundary conditions within which sedimentation has since occurred, were already established (Figure 5.1a).

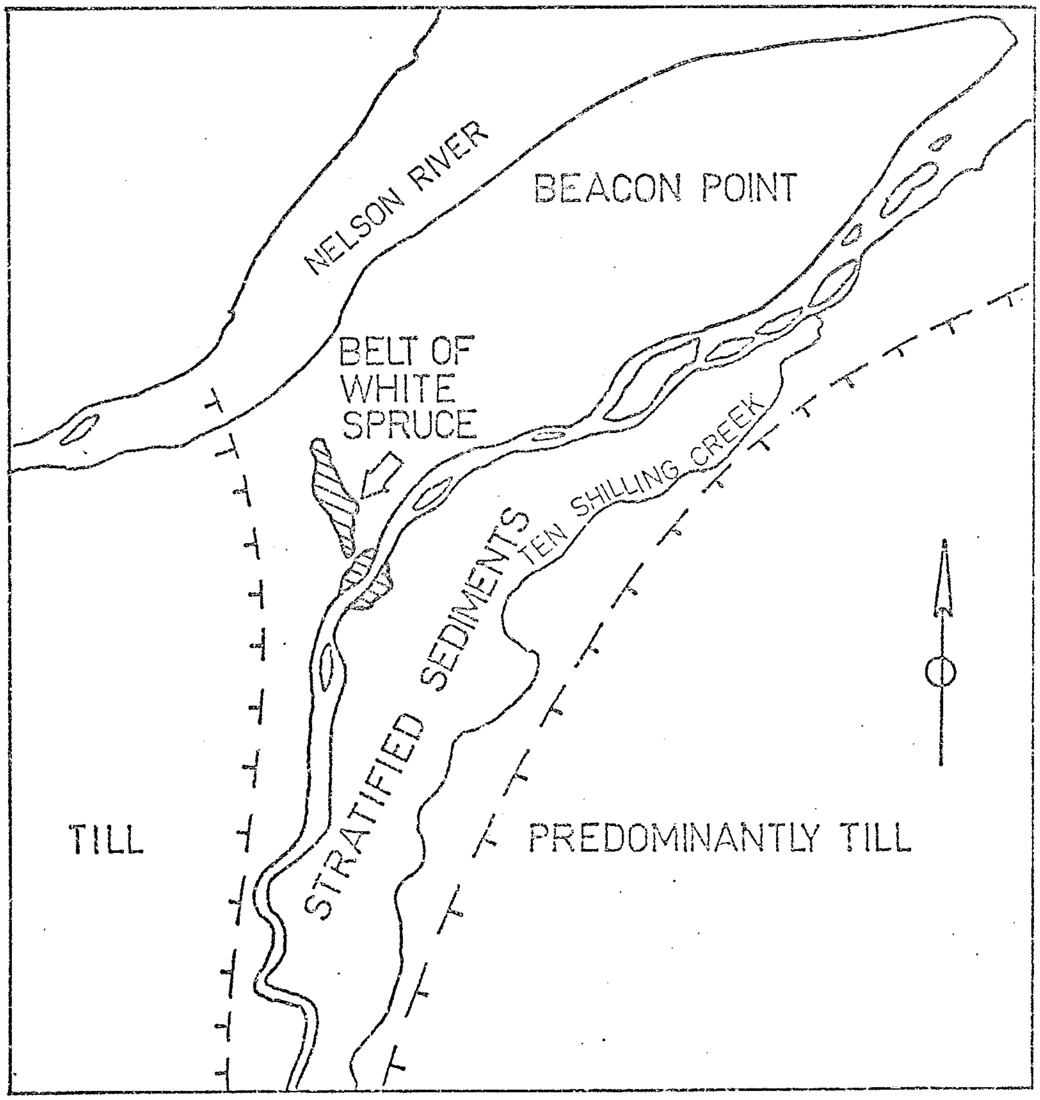

FIGURE D-1

SKETCH MAP OF BEACON POINT

ILLUSTRATING (a) THE PRESENCE OF WHITE SPRUCE VEGETATION IN THE VICINITY OF A FORMER DISTRIBUTARY OF THE HAYES

(b) THE APPROXIMATE DISTRIBUTION OF STRATIFIED SEDIMENTS

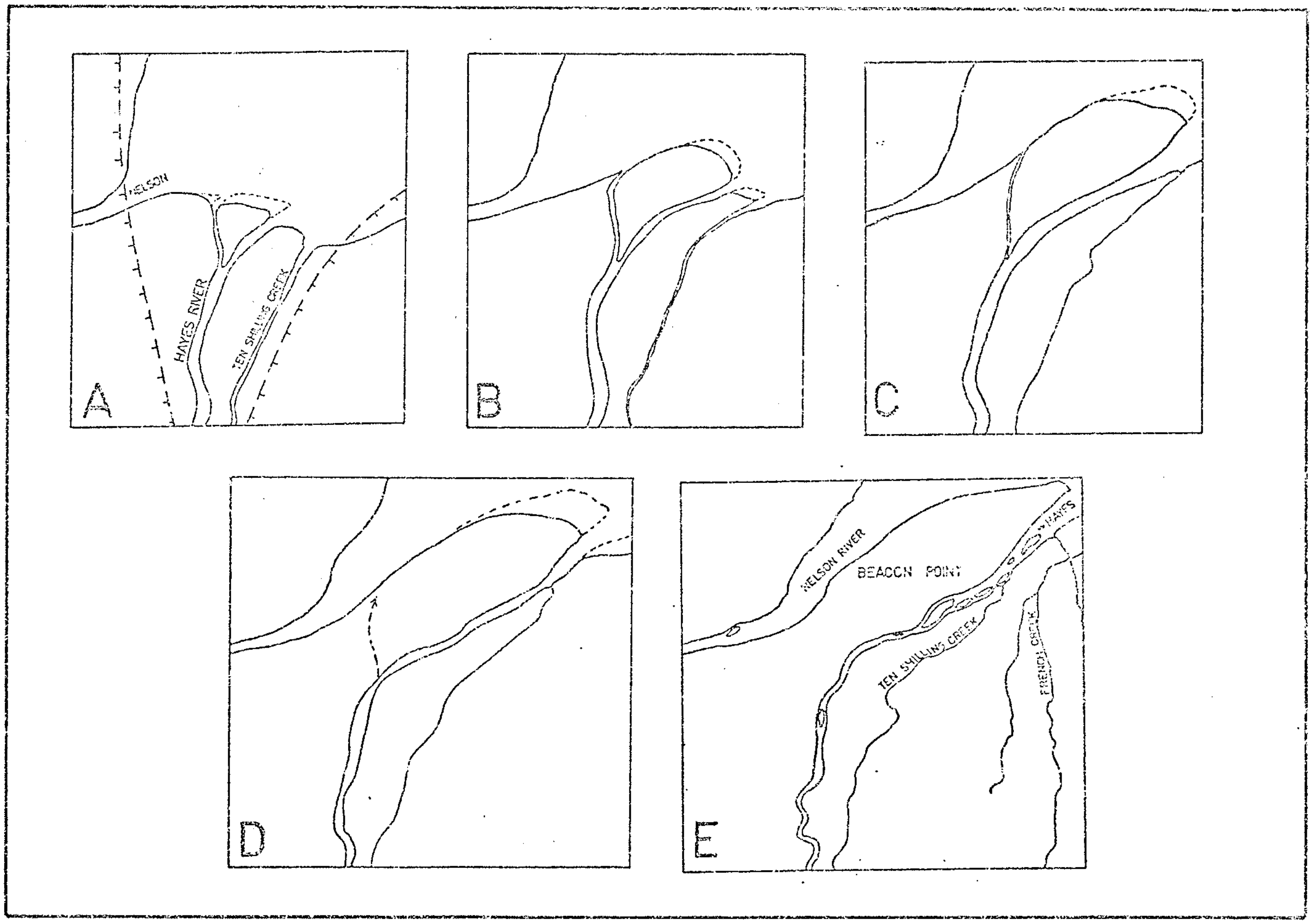

FIGURE D-2

TENTATIVE SEQUENCE OF EVENTS
DURING THE EVOLUTION OF BEACON POINT