Postglacial Vegetation of Canada

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Contents

1 Introduction

The vast and varied landscapes of Canada are mantled by a tapestry of vegetation whose diversity and richness stimulate our senses, tantalize our intellects, and underpin our national economy. This green cover ranges from the soaring rain forests of the Pacific coasts, through the transcontinental monotony of the taiga, to the transient seasonal brilliance of the northern tundra and the plains grasslands. Few countries have such a range of vegetation diversity set out on such a massive scale.

Furthermore, in both its present landscape and its immediate past, Canada has been dominated by glaciations on a vast scale. On the one hand, the periodic inundation of Canada by Quaternary continental and montane ice sheets resulted in the almost complete removal and destruction of soft, fossil-bearing sediments deposited during past interglacial periods. On the other hand, there is the remarkable opportunity to trace the details of the process of revegetation of buried and denuded landscapes across the full width of the continent. Indeed, the central theme of this book will be that there were several different patterns of revegetating the country as it emerged from the waning ice sheets of the latest glacial period.

The plan of the book is to provide a concise account of whatever background information is essential to an understanding of vegetational history – the physical setting, consisting of climate, geology, and soils; the modern flora and vegetation as expressed in the pattern of landform–vegetation regions; and a summary of the autecology of the main species of the past and present vegetation and of their representation in modern pollen spectra. It is important to stress that in the chapter on the physical setting, I am presenting only those aspects that I consider to have direct relevance to the later chapters. The reader will find nothing on tectonics and pre-Quaternary geological history; synoptic climatology is kept to a bare minimum, and I have combined the description of regional climates with concise accounts of the modern vegetation. Aspects of the physical environment are emphasized that appear to have a direct role in influencing the ecological relations of a regional vegetation complex – physiography, surface roughness and materials, and climatic factors – that determine the thermal and moisture characteristics of sites and regions. Then follows the core of the book, an account of the record of vegetational history since the latest glaciation for each of the major regions, based chiefly on data from pollen analysis. Finally, attempts are made to collate these data in the form of regional accounts of vegetational history and to relate these trends and events to climatic and other environmental changes. In the presentation of the fossil data, I have exercised selection, attempting to use results from sites that I consider to be both representative of large areas and of optimum quality in terms of the details of pollen identification, control of the chronology by isotope and other dating methods, and interpretive rigour. No attempt is made to provide a catalogue of every site in Canada from which some palaeobotanical data have been recorded – such listings can be found elsewhere (Harington and Rice 1984; Bryant and Holloway 1985).

In its broad, philosophical outlines, the book follows roughly an ecological schema that is certainly not novel or original, but whose roots go back in both the development of ecological ideas and in the molding of my own complexion of biases, predilections, and insights. It is based on the notion that the most useful unit of study is the landscape region defined loosely as an area with similar topography or landforms, macroclimate, and zonal vegetation. This theme has its origins in the landshaft–vegetationen groupings of Ludi and other European plant ecologists (Sukachev 1960), and is expressed in such modern approaches as the IGCP Project 158b investigation of mires and lakes (Berglund and Digerfeldt 1976), and various biophysical and ecosystem classifications in North America (Hills 1960; Thie and Ironside 1976). I used the approach in a regional summary of part of the Western Interior of Canada (Ritchie 1976), and interested readers can find a lucid statement of the concept in an essay by Rowe (1984).

A critical question in the use of such an approach is that of scale. In regions with a dense network of sites, each with detailed palaeobotanical records, the ecological regions can be small, perhaps approaching the recommended size of a few thousand square kilometres (Berglund 1986). However, in Canada, which combines vast land area with relatively few investigated sites, an appropriate size of an ecological region would be 50,000 to 150,000 km^2 in the plains region and smaller in the western montane belt.

It is pertinent here to clarify the general question of the spatial scale of the pollen record used to reconstruct the past vegetation of Canada, so that the limitations of the method can be appreciated fully. The problem of spatial scale has been recognized for many years and discussed fully, and somewhat repetitively, in the recent literature. It is that "paleoecologists are frequently frustrated by the difficulty of defining precisely the geographic area represented by pollen data derived from the sediments of a given lake" (Jacobson and Bradshaw 1981, p. 83). These authors provide a useful summary of the literature and show that in forested regions, closed-drainage lakes less than 1 ha receive 75 to 100 percent of their pollen from sources within 20 m of the site. That is, changes in forest stands can be expected to be registered in such very small sites. On the other hand, lakes larger than 5 ha receive pollen chiefly from a regional source area, defined loosely as an area with a radius of several kilometres surrounding the site. A recent analysis by Bradshaw and Webb (1985) of the areal representation of pollen spectra from lakes of different sizes in Wisconsin and Michigan provides an excellent illustration of the value of detailed, dense networks of pollen sites and reliable quantitative estimates of forest cover. This signal contribution addresses the central problem of the relationship between the proportions of a taxon in the pollen sum and in the surrounding landscape, as it is influenced by both the size of the sedimentary repository and the area of the contributing vegetation. I will return to their findings in Chapter 3, where the pollen productivity and representation of individual taxa are examined. Similarly, a detailed investigation by Janssen (1984) of the pollen spectra in surface samples from a large mire complex in Minnesota demonstrates convincingly that the different scales of vegetation pattern are represented by pollen types of different source areas. The interested reader can find excellent reviews of these matters in Birks and Birks (1980, Chapter II); Birks and Gordon (1985, Chapter 6), and Prentice (1983, 1985), and an exemplary practical demonstration by Heide (1984) of the different spatial resolution of pollen records from a lake, and from a small hollow in the adjacent forest.

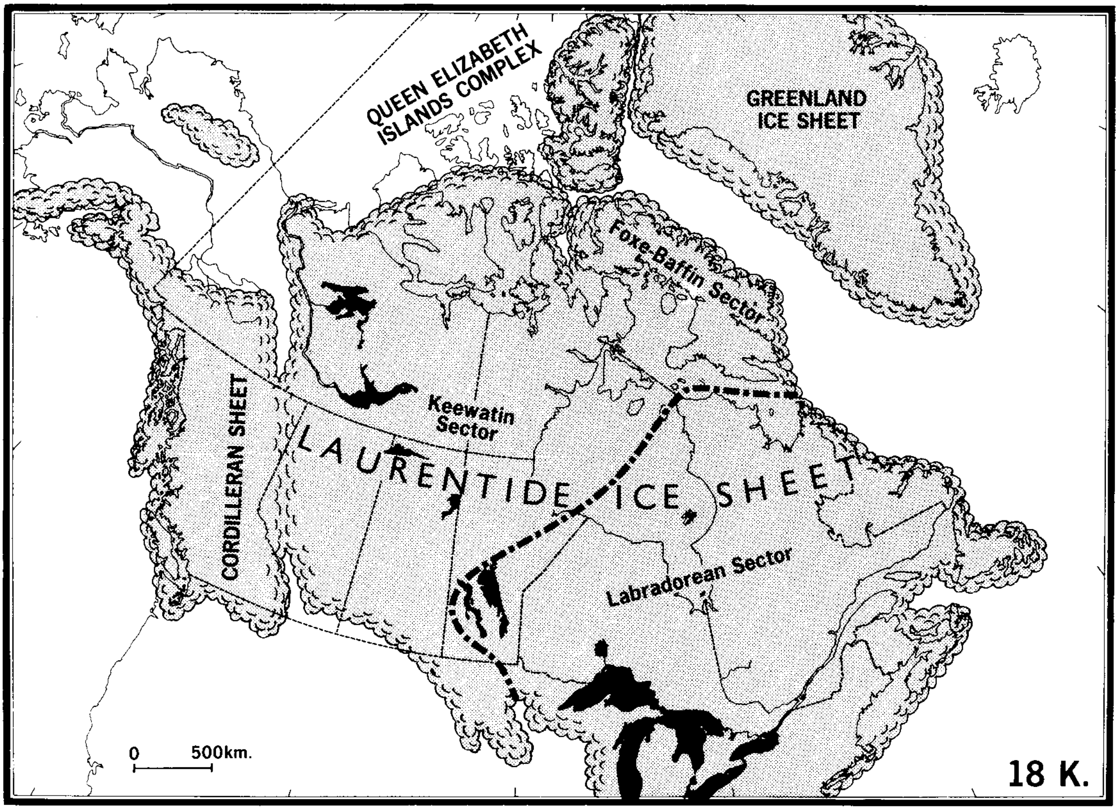
The general conclusion of these and other studies in the forested regions of the temperate zone, excluding montane areas, is that pollen spectra in lakes of 5 to 75 ha are derived primarily from regional sources. Forest regions are defined loosely as areas "in which the same vegetation succession will occur on the same physiographic site, providing the type and degree of disturbance is the same" (Hills 1960, p. 410). In practical terms, only minor attention need be paid to the problem of spatial scale – the reality is that even in the area of Canada and the adjacent United States with the most dense network of sites, the pollen record is predominantly regional because lake size is almost invariably greater than 5 ha and the level of detailed pollen identification and enumeration is rarely adequate to decipher local vegetation changes at the stand level.

Generalizations about spatial scale should be accepted cautiously. Most that have appeared recently (Davis 1969; Webb, Yeracaris, and Richard 1978; Delcourt and Delcourt 1979; Delcourt, Delcourt, and Webb 1983) have relevance only to forested plains regions, as Berglund (1986) stresses. Montane and arctic areas, which make up roughly one-half of the land surface of Canada, present quite different problems of pollen representation. Spear (1981), for example, has documented the difficulty of pollen analysis in mountainous regions – first, montane vegetation types are relatively unproductive of pollen so that "only a small percentage of the total pollen assemblage is definitely produced by high-elevation species" (p. 52); and second, as earlier investigators have concluded, "Surface-sample data show that a large amount of pollen from low-elevation trees is carried upward far beyond elevations where these trees occur" (p. 71). These difficulties are confronted but not resolved in Chapter 7 on Pacific and Cordilleran vegetational history.

Arctic regions are equally intractable in the interpretation of the pollen record, and several investigations from different sites in the circumpolar tundra zone have shown that the regional, treeless vegetation, particularly in the higher latitudes, produces a small proportion (20 to 50%) of the pollen recorded in lake sediments (summarized by Birks 1973).

The reader may quickly comprehend the central thrust of the book by examining Figures 1.1 to 1.3. They set out the rudiments of our undertaking.

Figure 1.1. The approximate extent of glaciers in North America at 18,000 yr BP, after Prest (1984), to illustrate that all of Canada, except for areas in the far northwest, was covered by ice. The broken line marks the approximate boundary between the Keewatin and Labradorean Sectors.



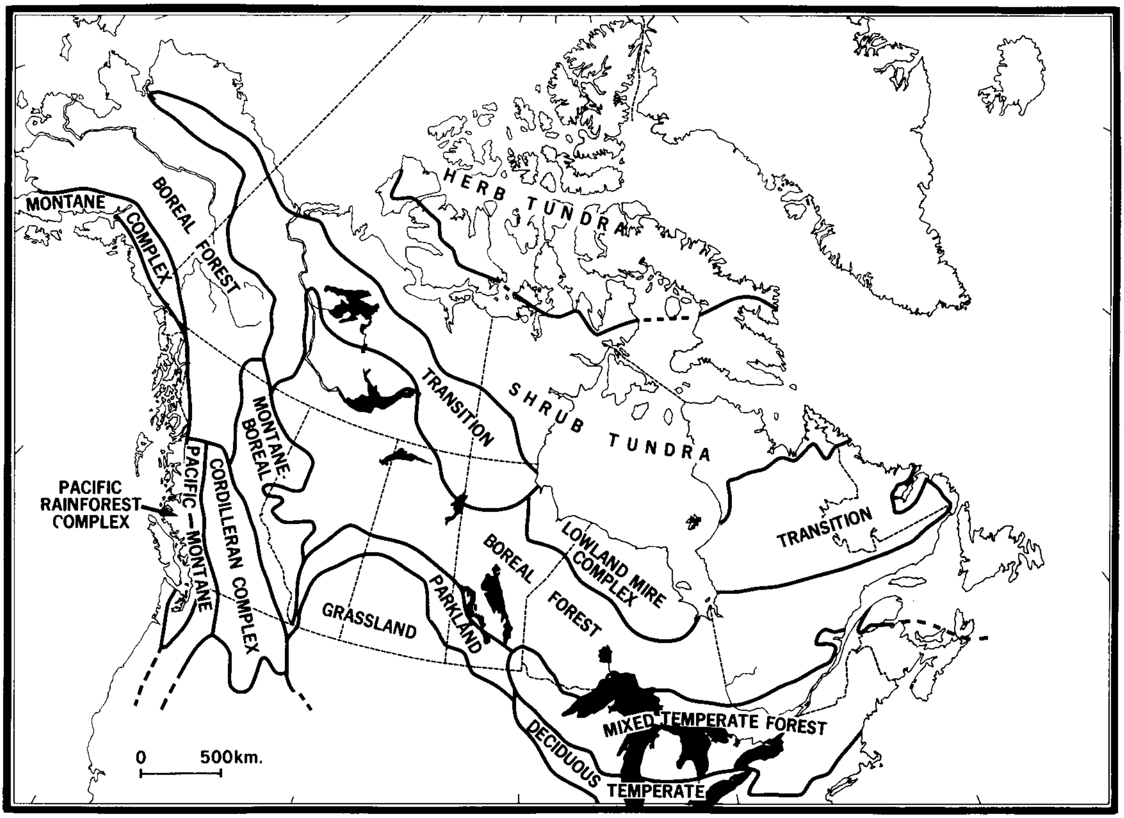
For several millennia centred on 18,000 yr BP, Canada, except for a few areas in the far northwest and a few high mountain peaks, was covered by ice, as shown in Figure 1.1. This massive aggregation of continental and montane glaciers extended into the United States for variable distances between 100 and 600 km beyond the southern border of Canada. In fact, there was not a single glacier mass but several complexes that were extensively confluent at about 18,000 yr BP (Prest 1984). The Laurentide Ice Sheet was made up of three main segments – the Foxe-Baffin Sector, centred on west Baffin Island; the Labradorean sector, centred on the Quebec–Labrador uplands and extending west to fuse with the Keewatin Sector and south over the Great Lakes–St. Lawrence basin; and the Keewatin Sector, centred in Keewatin and extending west to the mountains, north to the arctic, and southwest to the plains. The Cordilleran Ice Sheet consisted of a complex of many intermontane, piedmont, and valley glaciers that formed a "2000-m thick mass in the central and southern interior of British Columbia and its surface probably stood higher than the confining Mountain ranges" (Prest 1984, p. 20).

It is important to note that there is considerable disagreement in the geological literature about various limits and extents of Wisconsin ice sheets, such that the recent map by Prest (1984) depicts both a "maximum portrayal limit" and a "minimum portrayal limit." The differences are rarely important from our viewpoint, and, in any case, the scale of the maps used here is such that precise locations of ice front positions cannot be depicted.

In response to climatic warming, the ice began to recede, not uniformly, but with local asynchronous advances and recessions by the ice front position. This complex process, accompanied by the formation of large proglacial lakes and a global scale rise in sea level, began about 16,000 yr BP and ended when the two main residual continental ice caps disappeared from Keewatin and northern Quebec–Labrador about 6,000 years ago. Between the time of maximum ice cover and the present day, when a broadly zonal pattern of vegetation covers Canada (Fig. 1.2), a complex, still incompletely known process of revegetation occurred. This book aims to gather together into a coherent synthesis what is known of this roughly 15,000 years of history.

The total array of Canada's vegetated landscapes comprises five ecological provinces – Tundra,

Figure 1.2. The approximate limits of the five main ecological provinces (Tundra, Boreal, Temperate, Grassland–Parkland, Montane Pacific–Cordilleran) with subdivisions and transitional zones shown where appropriate.



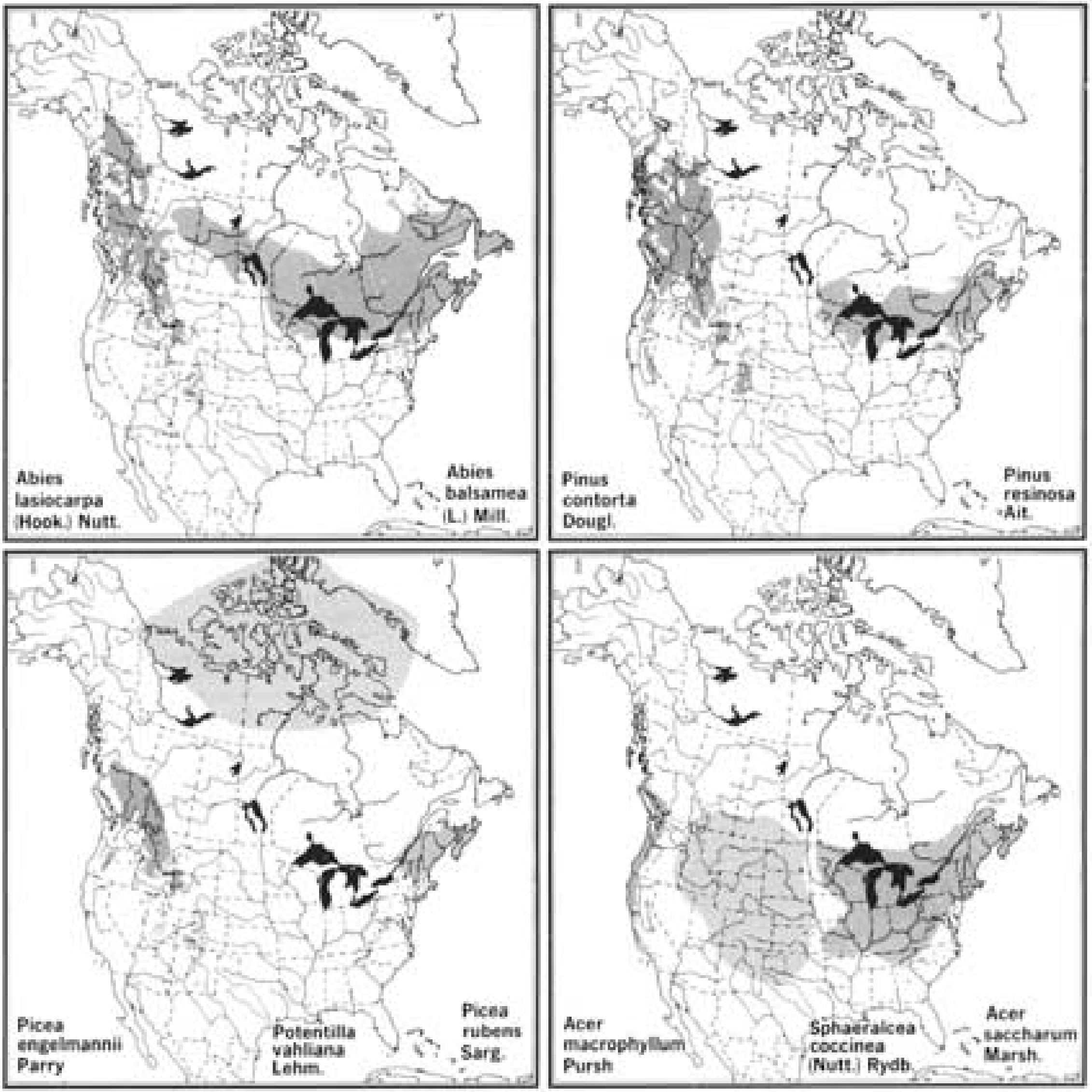
Boreal, Temperate, Montane Pacific–Cordilleran, and Grassland–Parkland. I use the term *ecological province* to conform both in concept and in application with a recent, very effective description of the climates, soils, and vegetation of Canada (Ecoregions Working Group in press). An ecological province is the highest unit of classification of terrestrial landscapes, and it describes an area that has a distinctive array of macroclimates and a distinctive type of plant cover both floristically and physiognomically. My usage of these terms will become obvious in Chapter 2, and it will be clear that they correspond closely with similar terms and groupings used elsewhere or in Canada by other treatments (e.g., the ecosystem regions of the United States of Bailey 1980; the land regions of the ecological (biophysical) classification in Canada by Thie and Ironside 1976). The five classes are subdivided hierarchically, where appropriate, in Chapter 2, under "Bioclimates." However, as was noted above in the comments on the question of scale, subdivision will take place only to the level for which fossil information is available. It would, of course, be desirable to subdivide Canada into small units of about 50,000 to 100,000 km^2 (the type regions of the IGCP Project 158 in Berglund 1986), but the irregular distribution of fossil sites and low density even in the most thoroughly investigated region (southern Quebec), preclude such an endeavour at present.

The five primary, essentially biogeographic groups provide both a framework for organizing the data to be examined and a logical basis for moderate subdivision into smaller units, for example, into various major physiognomic types, from tundra through conifer woodlands and forests, to mixed conifer–hardwood forests, to parklands and grasslands, all with enormous regional diversity of structure and composition along gradients of topography, humidity, thermal regime, and surface materials (Fig. 1.2).

It will be discovered that this classification into five ecological provinces, or bioclimates, meets the requirements of a "good classification" (Egler 1977, p. 451) both in its provision of a coherent hierarchy and, more interestingly, in that major classes appear to have "an equally shared past history."

The size limitation of this book, and the magnitude of the task, preclude a detailed treatment of the modern vegetation of Canada along the lines

Figure 1.3. Geographical range maps of ten taxa to illustrate the more important floristic elements in Canada – Arctic (*Potentilla vahliana*), eastern Boreal (*Abies balsamea*), eastern Temperate (*Pinus resinosa*, *Picea rubens*, *Acer saccharum*), Prairie (*Sphaeralcea coccinea*), Cordilleran (*Pinus contorta*, *Abies lasiocarpa*, *Picea engelmannii*), and Pacific (*Acer macrophyllum*). The data for these and the range maps in Chapter 3 have been abstracted from Fowells (1965), Little (1971), and Porsild and Cody (1980).



of a previous synthesis of one small segment of the country (Ritchie 1984a). I have chosen instead to integrate a very brief description of the modern vegetation with the account of climate, using a schema of bioclimates borrowed from others (Ecoregions Working Group in press), but I direct the reader to more detailed descriptions of regional vegetation at appropriate points in the text.

The task can be further elaborated by considering briefly the ranges of a few of the species that dominate some of the regional plant communities. Some (*Picea glauca*, *Populus balsamifera*) have achieved continent-wide distribution. Others (*Fagus*, *Tsuga*, *Pinus strobus*) are confined to the southeastern part of the country, extending for variable distances north or south of the Great Lakes–St. Lawrence axis. Some (*Abies lasiocarpa*, *Picea rubens*) have been restricted to western or eastern areas, whereas one interesting group of herbs and shrubs is restricted to the southern plains region and another more or less to the modern arctic–subarctic zone (Fig. 1.3). An attempt will be made to trace the histories of both individual taxa and the aggregations they make up at any particular time past in assembling the record of past vegetation.

Terms and abbreviations

The following terms are used throughout the text.

Brief reference is made in Chapter 2 to the soils that are characteristic of particular bioclimates; only the main categories are used, following the hierarchical classification of the Canada Soil Survey Committee, Subcommittee on Soil Classification (Canada Department of Agriculture 1970). They are the nine soil orders found in Canada, as follows:

Regosols: Soils weakly developed with absence of genetic horizons, usually due to youthfulness or instability

Solonetzic: Soils developed over saline parent materials, usually in semiarid climates, with a characteristic prismatic or columnar B horizon

Chernozemic: Soils of subarid regions with a thick organic A horizon, and lacking the properties of Solonetzic soils

Brunisolic: Soils with weakly developed eluvial and illuvial horizons, with a characteristic diffuse brown B horizon

Luvisolic: Soils developed on base-saturated, often calcareous parent materials, with eluvial and illuvial horizons, the Bt of the latter always within 50 cm of the surface

Podzolic: Soils with well developed eluvial (Ac) and illuvial (B) horizons, the clayey B horizon (Bt) occurring at depths greater than 50 cm

Cryosolic: Soils with permafrost within 1 m of the surface, usually affected by cryoturbation, occupying most of the arctic-subarctic

Gleysolic: Soils with saturated lower horizons that also have reducing conditions, resulting in ferrous mottling effects

Organic: Soils made up of deep peat, muck, or other organic material

The following conventions and abbreviations are used:

PAR, pollen accumulation rate, is expressed as the number of pollen grains per cm^2 per year, and NAP is sometimes used as the short form of nonarboreal pollen.

Système International units are used throughout.

I have tried to avoid using such recent items of ecological vocabulary as catastrophe, crises, disturbances, etc. (Raup 1981) to describe, for example, disease epidemics, because the imagery associated with these words connotes spurious notions, particularly that some factors are intrinsically different from such "natural" factors as climate. The norm is that several major environmental factors, varying greatly in frequency and intensity, cause change in vegetational structure and composition. It is probably more useful to describe that range of factors and to record and quantify their effects in as much temporal and spatial detail as possible, without designating some as catastrophes, disturbances, etc.

Radiocarbon dates are given as years Before Present (BP), using the 1955 Libby half-life value. When a radiocarbon age for an event, trend, or change is given with its standard deviation, a level of precision defined by the indicated probabilities is implied; on the other hand, if no standard deviation is shown, it should be understood to indicate an approximate age, roughly to the nearest millennium. Similarly, when I summarize pollen data in the text, approximate pollen percentages are given, rounded off in most cases to the nearest 5 or 10 percent.

I use the terms *full glacial*, *late glacial*, and *postglacial* in the conventional but informal way of most North American treatments, for example, the recent statement of Porter (1983), and in most cases the radiocarbon age is included to remove any doubts. *Full glacial* is used to describe events associated with the maximum extension of glacier ice and in the present book that means from about 20,000 to 14,000 years ago for many but not all regions. *Late glacial* describes transitional conditions when glaciers were still widespread and, while occasionally expanding, were in general receding. *Postglacial* usually refers to events or times subsequent to either the disappearance of glacial ice or the end of a glacial climate, but clearly the postglacial in northern Labrador, for example, began several millennia later than in New Brunswick. Similarly, the term *Holocene* is used imprecisely to refer to the latest 10,000 or 12,000 years of the Quaternary period, characterized generally as a time of nonglacial climate, or as the beginning of the present interglacial climatic mode. Two recently published companion volumes, one on the late Pleistocene (Porter 1983) and one on the Holocene of the United States (Wright 1983), illustrate the fact that, in the words of one of the editors, "The environmental changes of the latest Pleistocene and the Holocene can, therefore, be viewed as a continuum in part reflecting the ongoing recovery from the glacial age but also reflecting the secondary climatic variations superimposed on the general first-order trend" (Porter 1983, p. xiv). This continuum is reflected in considerable overlap and even duplication of material between the two volumes, in no way detrimental to their great value.

Final revision of the scientific aspects of the manuscript was made in June 1986, which was also the latest date for references cited in the text.