Chapter 2:

Physical Geography of Ontario

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Introduction

Ontario, the second largest province of Canada, covers approximately 1 million km^2 and extends approximately from 42°N to 57°N latitude and from 75°W to 95°W longitude. The major patterns of geoclimatic features across the province are strongly interrelated and form the foundation for the biotic and natural disturbance processes of Ontario's many different landscapes. In this chapter, we describe the spatial distribution of the abiotic factors, including bedrock, surficial geology, climate, soils and hydrology, that influence and interact with the biotic systems. The relationships among these elements, and the various biotic and natural disturbance processes at work across the province, are the subject of subsequent chapters in Sections I and II of this book.

In keeping with the focus of this book on Ontario's northern managed forest landscape, we do not describe the southern, settled portion of the province, but refer the reader to well-known summaries of that region, such as Chapman and Putnam (1984).

Geology and Terrain

The geology and terrain of Ontario are best understood by first examining the foundation of bedrock geology underlying the surficial deposits and landforms. Table 2.1 provides a summary of the geologic time scale relevant to Ontario's bedrock and surficial geology.

The bedrock geology of Ontario is variable in lithology, structure and age, although approximately 61 per-

Table 2.1

English as a Second Language (ESL) enrolment by School District, 1993-94.

School District	*ESL Enrolment*	*ESL as Percent of Total District Enrolment*
Vancouver	25,960	48%
Richmond	8,686	39%
Surrey	5,775	12%
Burnaby	3,599	17%
Coquitlam	2,571	9%
North Vancouver	1,892	11%
Abbotsford	1,073	6%
Victoria	1,043	4%

Source: BCTF (1994).

cent of the province is underlain by Precambrian rock of the Canadian Shield (Thurston 1991). In the Phanerozoic age, sedimentary rocks developed in marine basins along the northern border of the Shield, forming the Hudson Bay lowlands, and in the Great Lakes Basins in the south (Figure 2.1). The Shield can be divided into three major geological and physiographic regions, from the oldest in the northwest to the youngest in the southeast. The northwestern region, known as the Superior Province, is more than 2.5 billion years old. This region, which can be described as lying north and west of the present city of Sudbury, is composed

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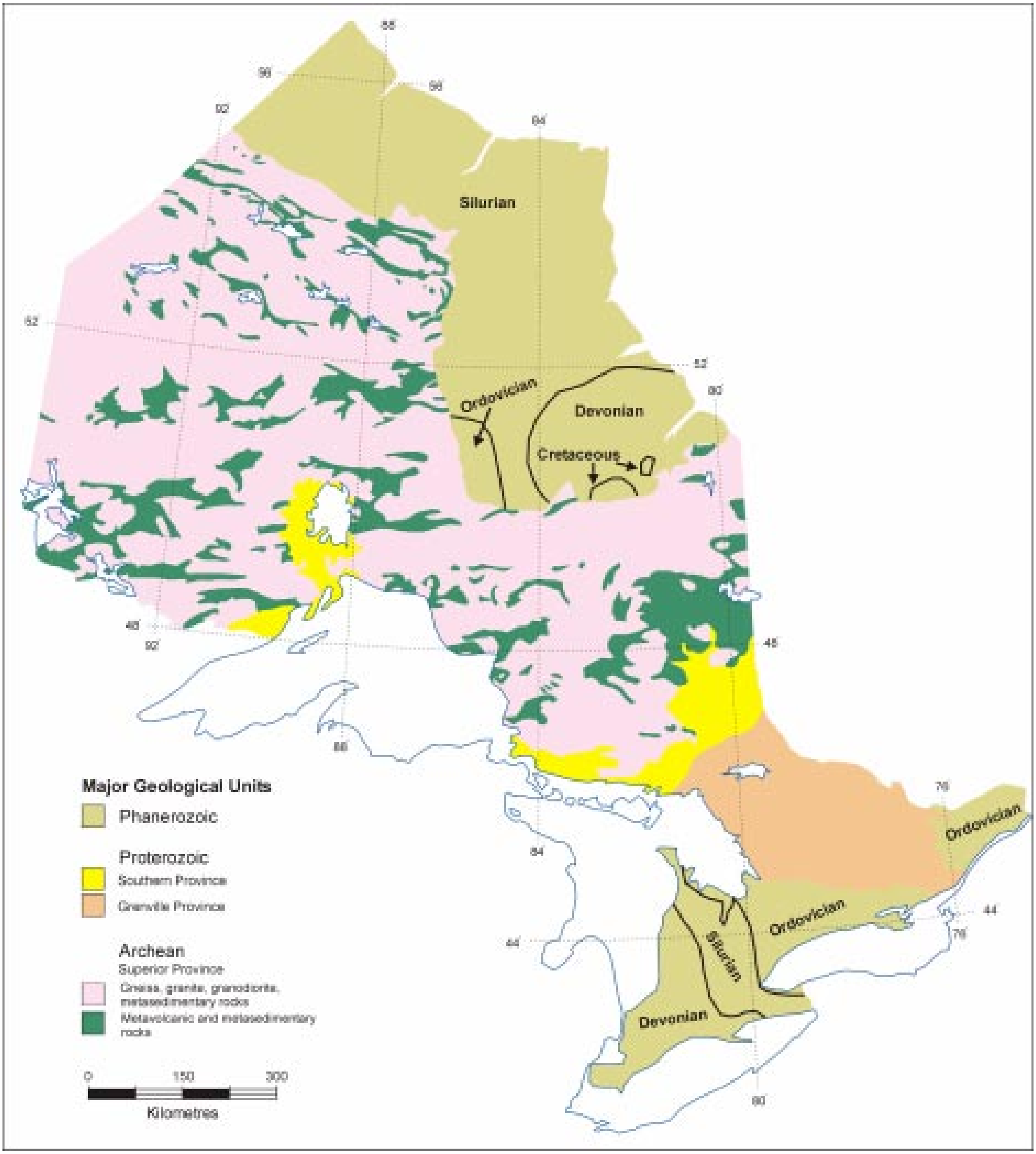

Table 2.1 Geologic periods relevant to Ontario's bedrock and surficial geology. (Adapted from Trenhaile 1998 and Webber and Hoffman 1970)

mainly of felsic intrusive rocks forming the rocky Severn and Abitibi uplands (Bostock 1970). The central region, known as the Grenville Province, is 1.0 to 1.6 billion years old. This region lies to the south of Sudbury, and is dominated by metasedimentary rocks that form the Laurentian highlands. The Penokean hills, a fold belt, and the Cobalt plain, an embayment, constitute the Southern Province, which is a narrow region approximately 1.8 to 2.4 billion years old extending from Sault Ste. Marie in the west approximately to Kirkland Lake in the east.

To the north of the Shield, in the area generally referred to as the Hudson Bay lowlands, the bedrock is composed of carbonate sedimentary formations. These formations date primarily from the Silurian period, but there are significant areas from the Ordovician and Devonian periods as well. Other sedimentary rocks occur near the city of Ottawa, in an area referred to as the Ottawa embayment, as well as throughout areas north of Lakes Erie and Ontario (Dyke et al. 1989). The clastic and marine carbonate bedrock of southern Ontario is interrupted by the Frontenac Axis, a southern extension of the Shield, which intersects the St. Lawrence Seaway east of Kingston. The Frontenac Axis has different forest cover and land use patterns than areas to either the west or east, owing to its uneven terrain and shallow, acidic soils, both characteristic of the Canadian Shield.

The topography of Ontario varies from flat plains to low, rolling uplands having 60 m to 90 m of relative relief, to dissected uplands with ridges, escarpments and cuestas as high as 200 m above the adjacent terrain. This variation in topography originates from the bedrock structure; from extensive pre-Quaternary erosion, which is estimated at more than 6000 m since the last mountain-building episode (Card et al. 1972); and from Quaternary glaciations that both eroded and filled the pre-Quaternary surface. The significant relief that is present elsewhere in eastern North America is absent from Ontario. The highest point in the province, Maple Mountain near Temagami, is 693 m. The most rugged and fragmented surfaces occur in a band extending from the north shore of Lake Superior, across the Algoma highlands, through the Sudbury region and north of Manitoulin Island, and across the Madawaska highlands. This height of land forms a continental divide between the Great Lakes and Arctic drainage of Hudson Bay; north of this line, the elevation falls off monotonically (Figure 2.2). The large river basins that flow to the north across most of Ontario have low total relief and deranged drainage patterns from glaciation, both of which result in poor drainage.

All of Ontario underwent a set of major glacial advances and retreats during the last major glacial stade, up to 12,000 years BP. Northern parts of the province were still covered with ice 8000 years BP (Hardy 1977, Ritchie 1989). The Hudson Ice, a distinct domain within the Laurentide Ice Sheet, had a number of separate lobes, one extending northeastward up the St. Lawrence River, a second westward into Lake Huron, and a third east-to-northeastward out of Lake Superior (Dyke et al. 1989). The retreat of the ice was neither uniform nor continuous. Isolated re-advances, such as the Cochrane surge, occurred during the period of final deglaciation. Figure 2.3 provides an overview of the major features and surficial materials across the province. During the retreat, streams formed along the margins of the ice sheets and created oblique, linear patterns of deposition. Glaciofluvial complexes that occur in various parts of the province (for example, the Oak Ridges complex in southern Ontario, and the Burntwood-Knife and Harricana-Lake McConnell complexes in central Ontario, each extending hundreds of kilometres, provide evidence of the massive scale of the convergent ice lobes and catastrophic meltwater discharges (Brennand and Shaw 1994) beneath the ice sheets and at their forward margins.

The retreating ice sheet fed a series of large meltwater lakes. Glacial Lake Algonquin covered much of the area from Sudbury to Huntsville. The Champlain Sea flooded well above the current levels of the Ottawa River Valley and of Lake Ontario. Lake Barlow-Ojibway covered a large area south of James Bay over what is now referred to as the Claybelt. The Tyrrell Sea lay over the Hudson Bay lowlands. In the northwest, Lake Agassiz covered virtually one-third of the province, joining with the Tyrrell Sea to the east for a short period (Teller 1985). Neither the postglacial lakes nor the Tyrrell Sea had fully receded until about 6000 BP. The general northward retreat of the Laurentide Ice Sheet left a predominately sandy to silty till cover over the southern part of the Shield and over southern Ontario, in contrast to the silty and clayey till and clay-rich lake and marine deposits that dominate the northern half of the province (Dredge and Cowan 1989). Low-lying and poorly-drained glacial deposits have become covered with peat and other organic deposits (Figure 2.3).

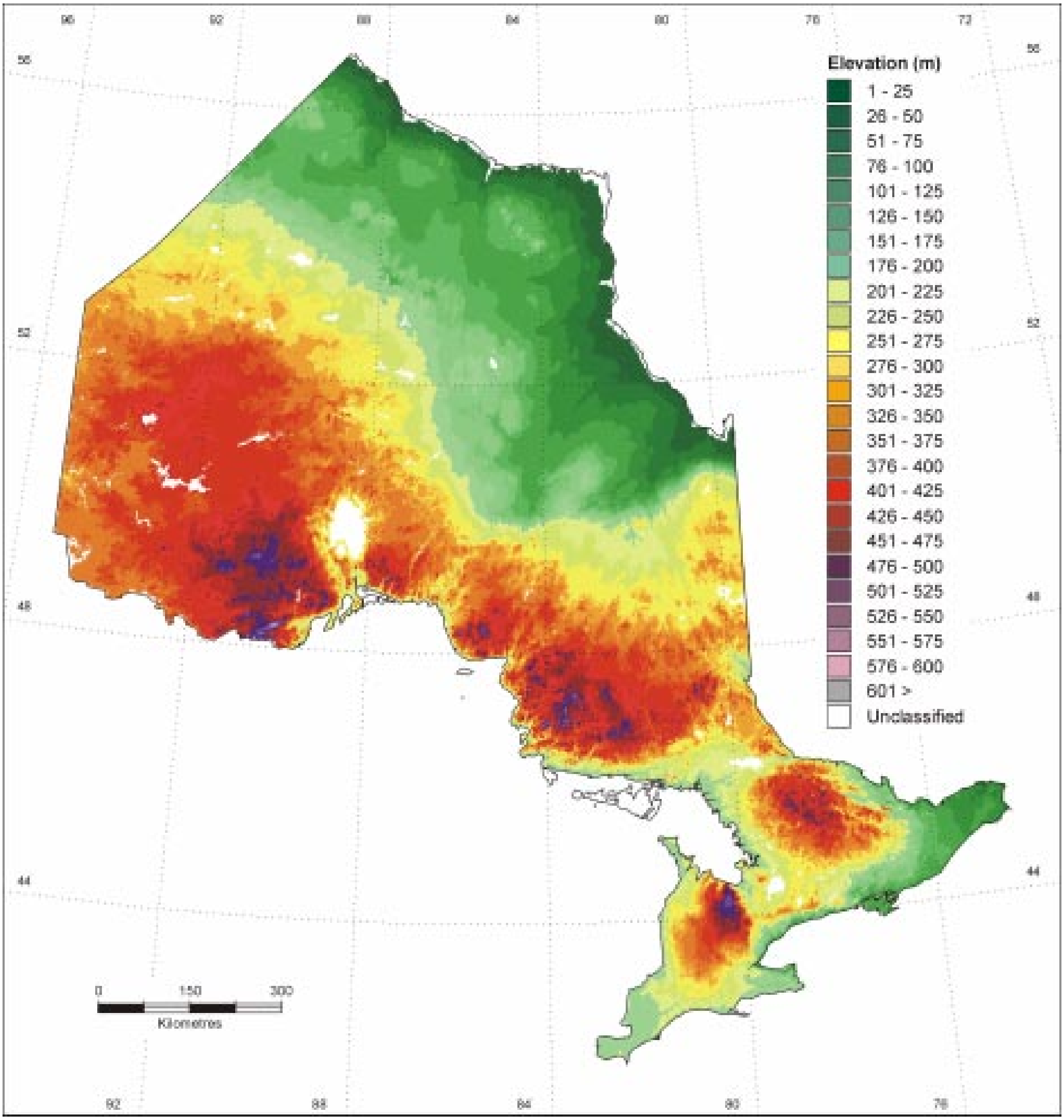

Figure 2.2 Topography of Ontario, generated from a 1-km digital elevation model. (Data from Mackey et al. 1994)

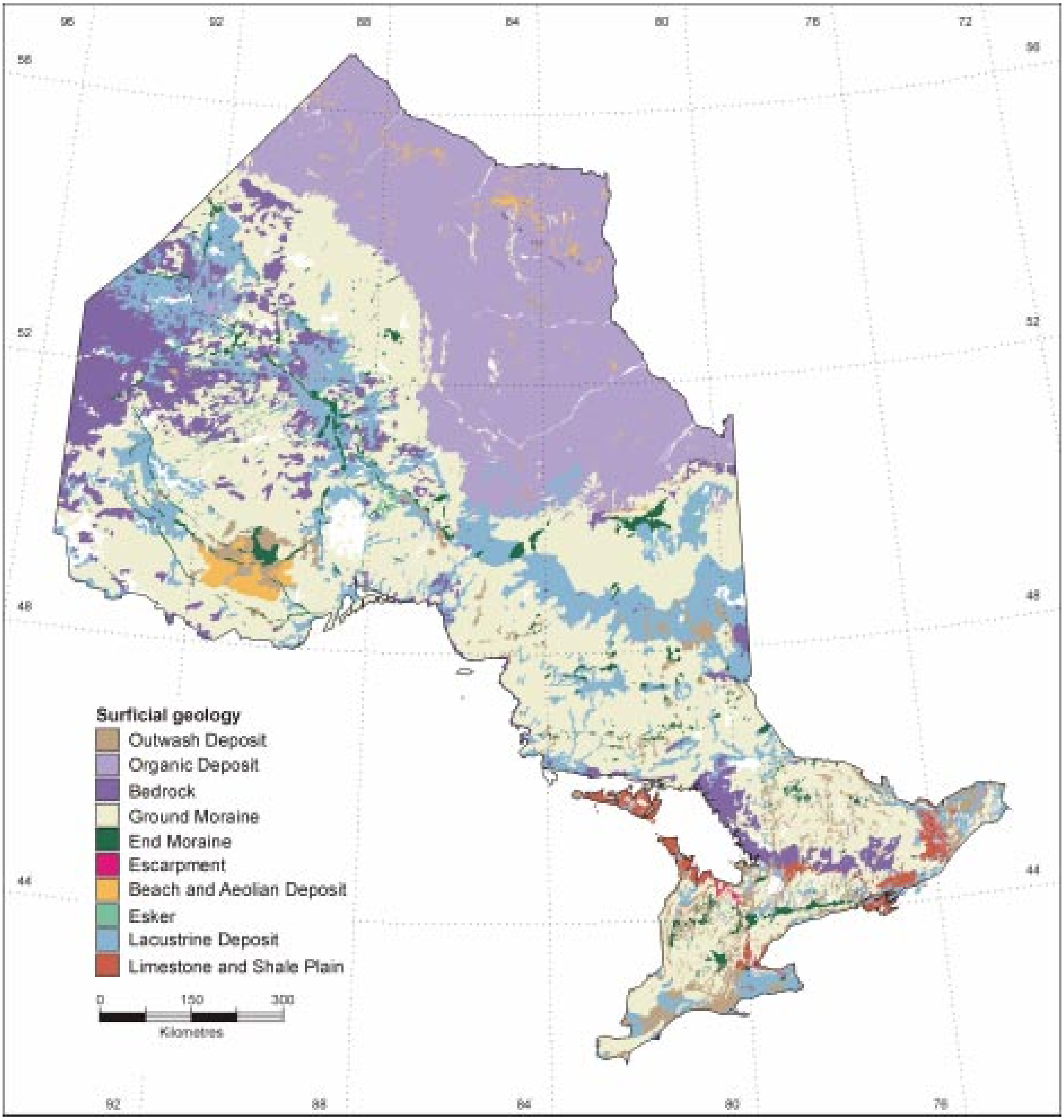

Figure 2.3 Surficial geology of Ontario. (Adapted from Forest Landscape Ecology Program 1996)

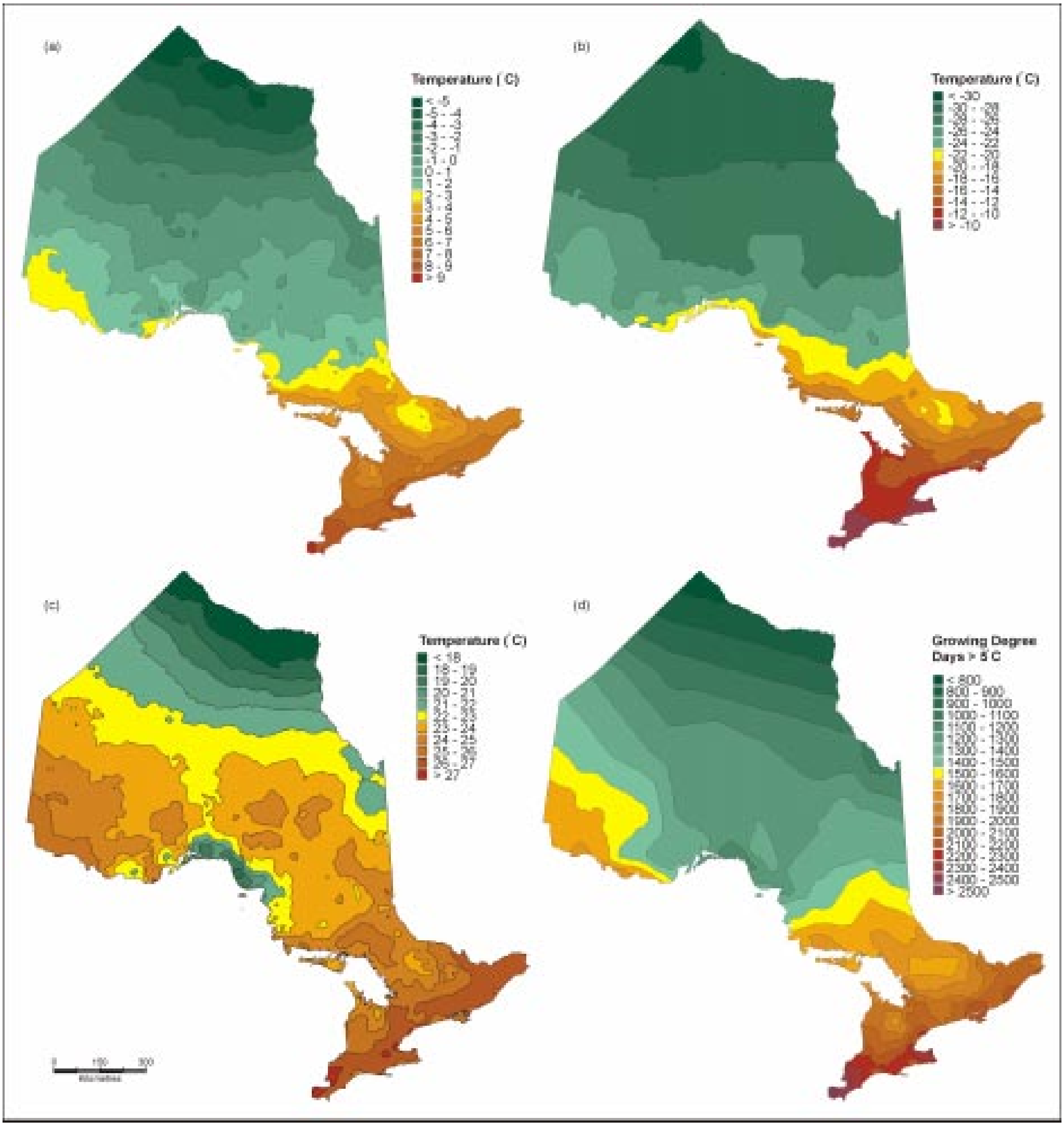

Figure 2.4 Temperature characteristics of Ontario: (a) annual mean daily temperature; (b) mean daily minimum temperature for January; (c) mean daily maximum temperature for July; and (d) growing-degree-days over 5°C. Temperatures interpolated from 30 years of data from more than 400 AES stations. (Adapted from Watson and MacIver 1995)

Together, glaciation and postglacial deposition largely account for the present landscape of the province. The ice sheets sculpted or rounded the land and generally reduced its elevation, removed the original topsoils, and exposed the bedrock. Deposits laid down by glacial streams and lakes have strongly influenced soil development and, consequently, the composition of present-day forests (Thompson 2000, this volume).

Till materials deposited range from compact lodgement tills to surface ablation tills, and form both plains and high relief forms such as moraines and drumlins. Kame deposits, interlobate moraines, and eskers, all composed of sand and gravel, are concentrated mainly in the southern half of the province, but also occur over large sections of the northern half (Dredge and Cowan 1989). The better-drained glacial and glaciofluvial landforms often stand above the more poorly drained substrate and thus provide locally distinct environments for drier ecosystems. Well-sorted sands occurring in long eskers and kame terraces, and other water-transported deposits, are often characterized by the development of distinct soils and forest cover complexes. Over most of the boreal and Great Lakes biomes, till deposits give rise to coarse soils, often with a considerable cobble component. Bedrock outcrops are common in the Shield, where parent materials were washed away or removed by glaciers.

Climate

Most of Ontario's climate can be described as humid continental, with the notable exception of areas under the influence of Hudson Bay, which have a more maritime character. In general, Ontario's climate is affected by three major air sources: cold dry polar air from the north, the dominant factor during the winter months; Pacific polar air passing over the western prairies; and warm, moist, sub-tropical air from the Atlantic Ocean and the Gulf of Mexico (Webber and Hoffman 1970). The effect of these major air flows on temperature and precipitation depends on latitude, on proximity to major waterbodies, and, to a limited extent, on terrain relief.

Temperature

The most evident climate trend in Ontario is a well-defined gradient of temperature increase from north to south (Figure 2.4a). This pattern is modified by the influence of Hudson Bay and the Great Lakes and, to a lesser degree, by major topographic features. The cold, maritime climate of Hudson Bay and James Bay influences the northeast portion of the province, affecting areas as far south as Kirkland Lake. The result is a substantial reduction in growing-degree-days, relative to other locations in Canada at similar latitudes. For example, Winnipeg, Manitoba lies at approximately the same latitude as Cochrane, Ontario, but has about 1000 more growing-degree-days. Lake Superior and the Lake Huron moderate the winter temperature, "bending" the isolines around their shores (Figure 2.4b). Lake Superior also has a cooling effect on the northerly flow of warm summer air (Figure 2.4c). The impact of this cooling influence is felt in a sharp drop in growing-degree-days in areas north of Lake Superior, from the town of Marathon north to the settlement of Nakina (Figure 2.4d).

Local relief modifies the general temperature gradient at significant areas of increased elevation in the highlands near Caledon in southern Ontario, in the area of Algonquin Park, in the Algoma highlands northeast of Sault Ste. Marie, and in the highland area northwest of Thunder Bay (Figure 2.2). Pockets of lower temperature are evident at each of these heights of land (Figure 2.4a), and each has fewer growing-degree-days than the areas surrounding it (Figure 2.4d). The western portion of the province is influenced by the vast continental area of the Canadian prairies and the great plains of the US mid-west. In summer, warm air flowing from the southwest pushes up around the western shore of Lake Superior (Figure 2.4c), generating warm dry conditions and increasing the number of growing degree days in this area, relative to eastern portions of the province at the same latitude.

Precipitation

The dominant precipitation trend in the province is an increase from northwest to southeast. This trend is modified significantly by strong lake and topographic effects in the central and southern portions of the province, particularly in areas to the lee of Lake Superior, Georgian Bay, and Lake Huron (Figure 2.5a).

Winter precipitation and snow accumulation are highly variable across the province (Figure 2.5b). The northern and western areas are influenced by the dry air of continental high-pressure zones. The southern and eastern areas are influenced by moister air from low-pressure areas. Winds accompanying the low-pressure conditions gather moisture while sweeping west to east across the Great Lakes and drop precipitation on the colder land mass. Several areas at the eastern ends of Lake Superior, Georgian Bay, and Lake Huron are called "snowbelts," as a result. The rise in elevation

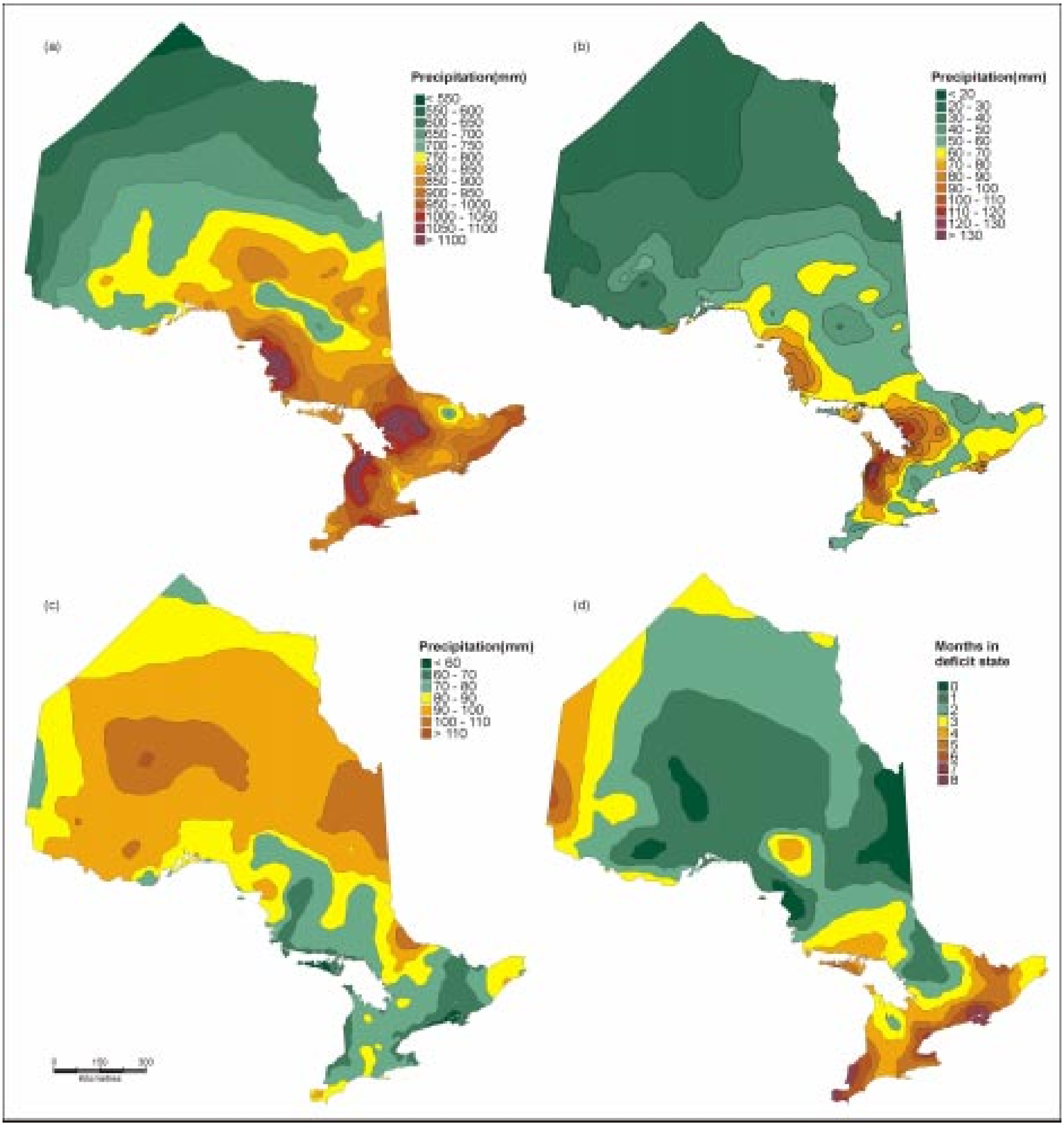

Figure 2.5 Precipitation characteristics of Ontario: (a) annual total precipitation: (b) monthly total precipitation for January; (c) monthly total precipitation for July; and (d) annual water deficit. Precipitation interpolated from 30 years of data from more than 400 AES stations. (Adapted from Watson and MacIver 1995)

over the Algonquin highlands causes considerably greater snowfall in the area of Huntsville and Dorset than along the upper Ottawa River valley, 100 km to the east.

Summer precipitation patterns are more related to continentality than to lake effects. The climate of western areas of the province is dominated by continental high pressure, which reduces precipitation in early to mid-summer (Figure 2.5c). Precipitation is greatest away from the lakes, where air masses and storm cells build over land. The highest summer precipitation occurs in the central portions of the province and in the upper Ottawa Valley, northeast of North Bay. The annual water deficit (Figure 2.4d), derived from the Thornthwaite water balance equation, measures water storage as a function of the following: mean monthly temperature, total precipitation, latitude, and soil texture as a measure of water-holding capacity (Watson and MacIver 1995). Deficit values are particularly high in areas of southern Ontario just outside the lake-effect precipitation zones. These areas have relatively low precipitation, high summer temperatures, and well-drained soils. The water deficit is also high in the far west of the province, near Kenora, where a more continental regime of low precipitation prevails and where temperatures are relatively warm. Areas with low water deficits include the area immediately to the north of Sault Ste. Marie, which receives a combination of heavy winter precipitation and cool summer temperatures from the northward flow off Lake Superior. Low deficit values are also found in a cool area extending from Lake Superior toward Lake Nipigon. Here, the cool temperatures outweigh the limited precipitation values to keep moisture loss low.

Temporal Patterns in Precipitation and Temperature

Figure 2.6 contains climographs for key stations across the province. In the west (for example at the town of Dryden) and in the north (for example, at Moosonee), the climate is more continental, winters are comparatively dry, and the annual range in temperature is wider. In the eastern and southern parts of the province (for example, around the cities of Toronto and Ottawa), precipitation is more evenly distributed throughout the year, and the annual temperature range is narrower.

Temporal trends in temperature and precipitation are not always clear, mainly for lack of consistent, long-term meteorological databases representing local climatic differences in various parts of the province.

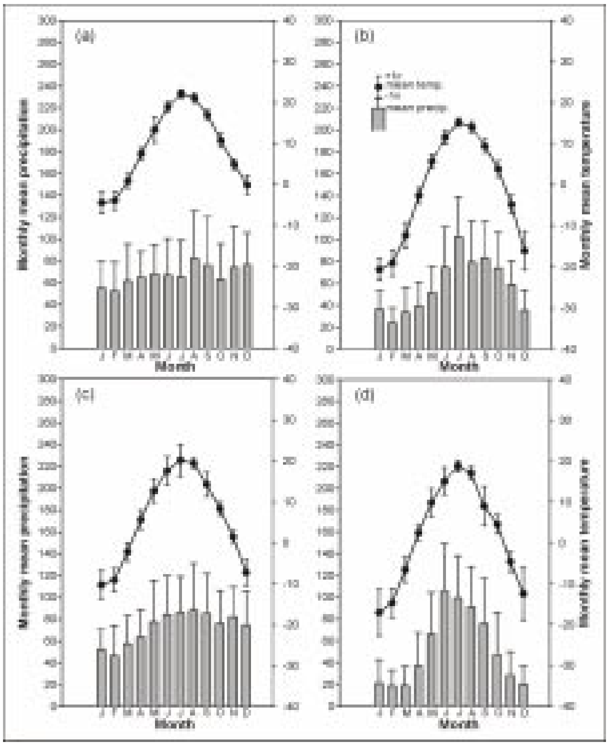

Figure 2.6 Climagraphs for key stations in Ontario: (a) Toronto; (b) Moosonee; (c) Ottawa; and (d) Dryden, derived from climate normals, 1961 to 1990. (Data from Atmospheric Environment Service 1990)

Several long-term records available from Environment Canada show a general warming trend from the late 1800s to about the mid-1900s. This trend reflects recovery from Little Ice Age conditions. Although there is no evidence of a similar trend in summer temperatures (Figure 2.7), winter temperatures at some stations have increased over the last couple of decades (Figure 2.8). No such trend is apparent in either annual or seasonal precipitation (Figure 2.9). It is not clear to what extent the apparent winter increases are caused by either short-term or long-term climate change, or to increasing urbanization in regions around the stations. The increases are apparently reflected in observations of satellite data made over the past two decades, which indicate a progressively earlier thaw and green flush and a longer active growing season in the subarctic regions of North America (Myneni et al. 1997). These observations may indicate a small increase in the length of the forest growing season in Ontario in recent years. It is unknown how this change may already be affecting the

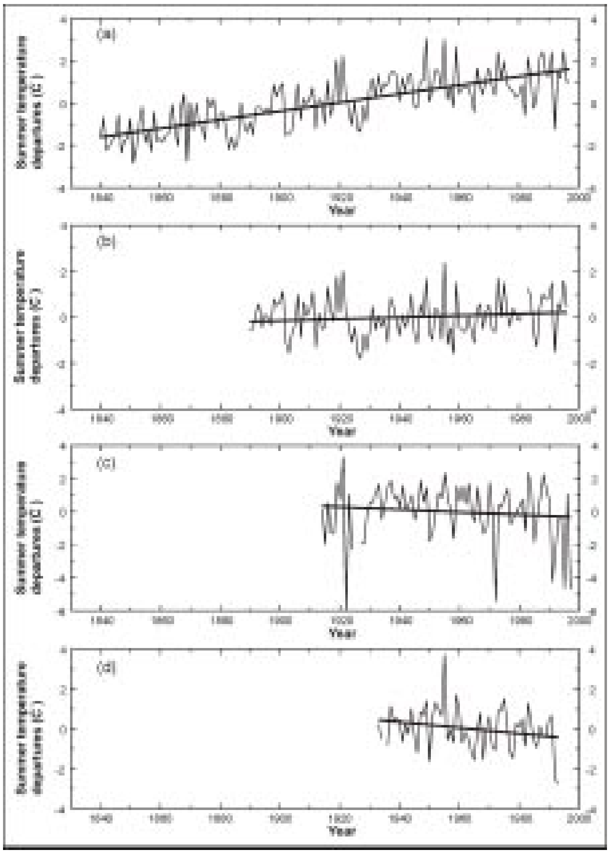

Figure 2.7 Time series of departures in summer temperature (June, July, and August) from period-of-record means for selected Ontario climate stations: (a) Toronto (downtown); (b) Ottawa; (c) Dryden; and (d) Moosonee. (Data from Atmospheric Environment Service 1998)

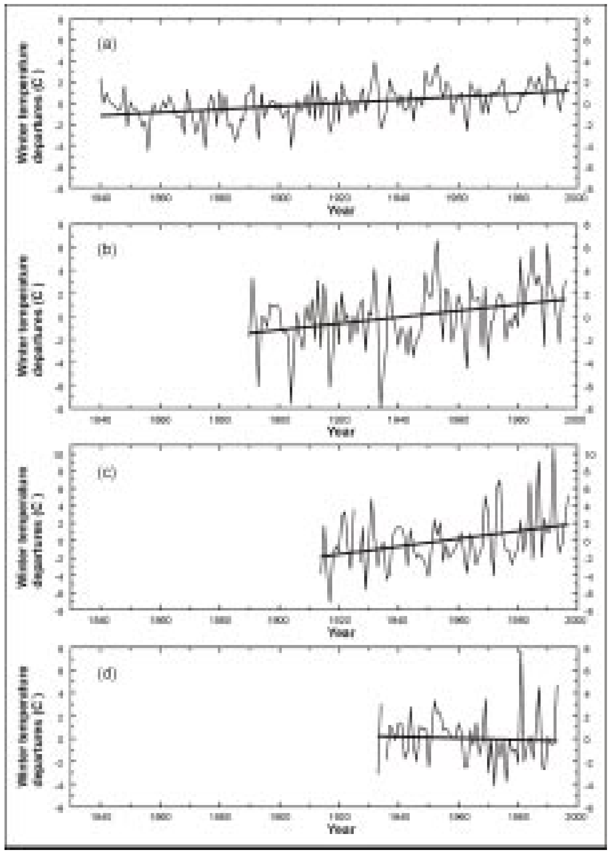

Figure 2.8 Time series of departures in winter temperature (January, February, and March) from the period-of-record means for selected Ontario climate stations: (a) Toronto (downtown); (b) Ottawa; (c) Dryden; and (d) Moosonee. (Data from Atmospheric Environment Service 1998)

productivity of forests or may influence forest community dynamics in years to come. Climate change and its effects are discussed by Flannigan et al. (2000, this volume).

Soil Development Patterns

The nature of soil development in Ontario depends on local combinations of climate, parent material, terrain, vegetation and other organisms over time. Soils are formed by the physical and chemical weathering of bedrock and glacial parent material, and are continually modified and shifted by water, wind and gravity. Where glacial action has scoured away overlying deposits, the soils of Ontario closely reflect the underlying bedrock. Other soils reflect the tills and other morainic and lacustrine materials deposited by advancing and retreating ice sheets and their meltwater.

The Canadian System of Soil Classification (Agriculture Canada 1987) is a standard series of orders and component great groups by which soils can be identified and described. Six of the soil orders in this classification are predominant in Ontario. These are the organic and related organic cryosolic soils in northern parts of the province, brunisols in the northwest part of the Shield and south of the Shield, podzols over much of the central and southern Shield, luvisols in the Claybelt and over much of southern Ontario, and gleysols in poorly drained areas and in the Claybelt lacustrine deposits. Regosolic soils are dominant only in a thin band along the southwest shore of Hudson's

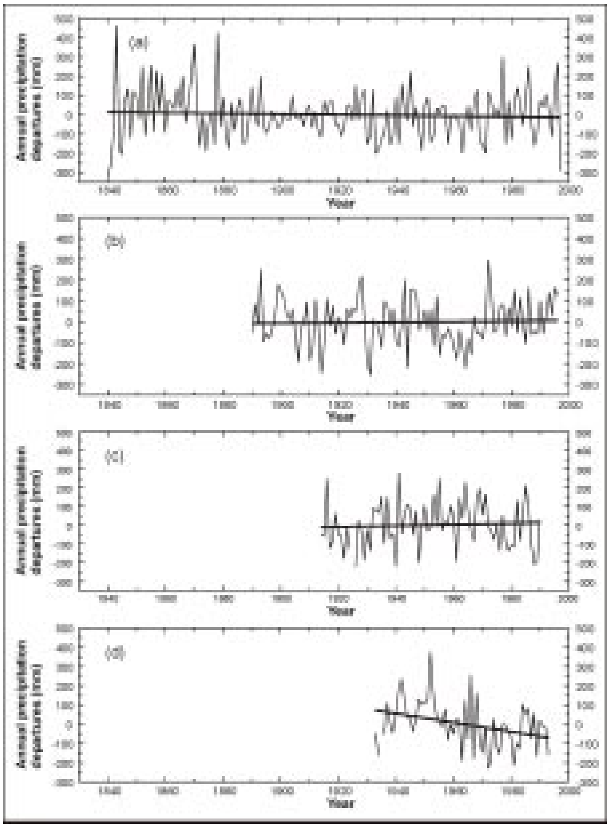

Figure 2.9 Time series of departures in annual precipitation from the period-of-record means for selected Ontario climate stations: (a) Toronto (downtown); (b) Ottawa; (c) Dryden; and (d) Moosonee. (Data from Atmospheric Environment Service 1998)

Bay. Figure 2.10 illustrates the soil orders and great groups that occur most extensively in Ontario, based on composition within the Soil Landscapes of Canada mapping units (Agriculture and Agri-Food Canada 1996). In the following section, we will examine these patterns of soil development in Ontario and the underlying factors of climate, geology, and terrain. The spatial relationship between soils and forest vegetation is examined by Thompson (2000, this volume).

Organic Soils

Organic soils dominate the Hudson Bay lowlands, the area of lacustrine deposits lying between Pickle Lake and Sandy Lake, and a band stretching from Espanola to Temagami, through Sudbury. They also occur as sub-dominant soils in poorly drained areas of otherwise sub-humid and arid landscapes (Clayton et al. 1977). As their name suggests, organic soils develop from organic deposits, and are defined as having more than a 30-percent component of organic material in specific portions or tiers of their profile (Agriculture Canada 1987).

Organic great groups are distinguished by the degree of decomposition of the organic material in the various tiers. The great group identified as fibrisols have a large percentage of well-preserved fibres in the upper and middle tiers of the soil profile. These soils are dominant in the vast bog and muskeg complexes of the Hudson Bay lowlands. Fibrisols have a particularly high water-holding capacity, and remain saturated for much of the year. Mesisols, the second great group, contain more material at a later stage of decomposition in the upper and middle tiers. These soils occur in a band around the wetter fibrisols along the south and west margins of the Hudson and James Bay lowlands, where the elevation declines into the lowland (Figure 2.2). They are also the dominant soils in the area of shallow tills and lacustrine deposits between Espanola and Temagami. They are intermixed with brunisols on the lacustrine deposits northeast of Pickle Lake, and with luvisols and gleysols in the Claybelt. Humisols contain highly decomposed organic material and are commonly referred to as muck soils. They dominate only in local patches, and are mapped as dominant only in a small area east of Lake St. Clair (Figure 2.10).

The water-holding capacity of organic soils, particularly fibrisols, moderates their soil temperature regimes, in comparison to surrounding or intermixed mineral soils. The latent heat involved in freezing and thawing the trapped water allows these soils to freeze and thaw later than other soils and thus to provide moderated growing conditions (Clayton et al. 1977).

Cryosols

One great group of cryosolic soils, the organic cryosols, dominate a substantial area at the extreme northwest of Ontario (Figure 2.10). Cryosolic soils are characterized by the presence of permafrost within 1 m of the surface and by a significant degree of cryoturbation, or permafrost-related disturbance of the soil column, which causes various distinctive surface patterns and formations (Agriculture Canada 1987). The organic great group, in particular, develops on organic deposits

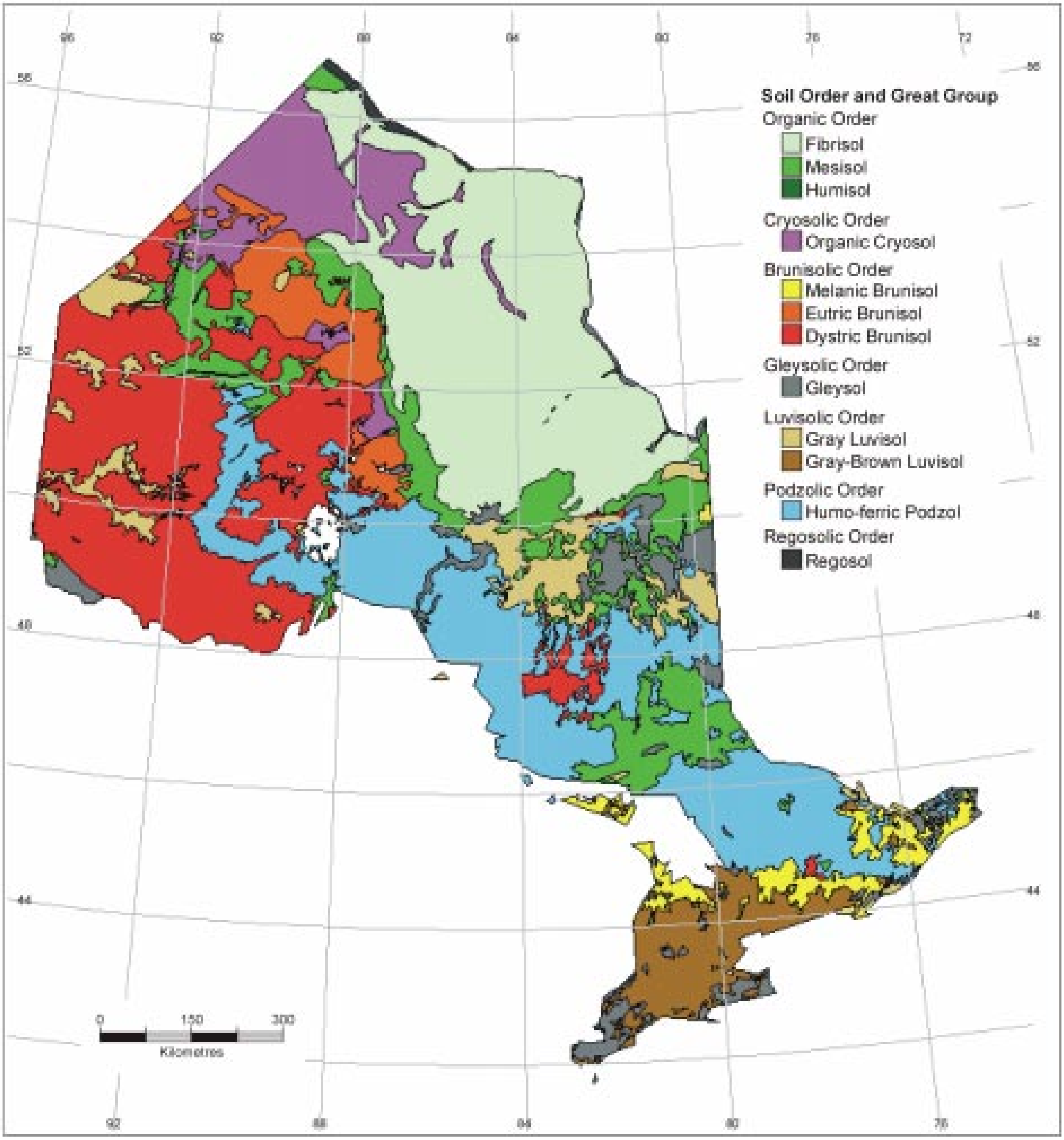

Figure 2.10 Dominant soil orders and great groups in Ontario, based on Soil Landscapes of Canada units. (Data from Agriculture and Agri-Food Canada 1996)

in permafrost environments, such as the far northwest reaches of the province (Figure 2.3).

Brunisols

Brunisols dominate much of the Shield west of Lake Nipigon, from the border between Canada and the United States to latitude 53°N, and are interspersed with luvisols and podzols. They also dominate a large patch in the area of Chapleau and Gogama, on Manitoulin Island, in the Bruce Peninsula, and in a band surrounding the southern and eastern margins of the Shield. These soils are typically found in forested areas over coarse to medium glacial till or outwash, and on aeolian deposits (Figure 2.3). They occur on both imperfectly drained and well-drained sites, and are typically associated with rolling terrain. The layer development in these soils is distinct enough to differentiate them from regosols, but leaching and weathering do not occur to the extent of forming a podzolic B layer (Clayton et al. 1977).

The brunisol great groups represented in Ontario include the melanic, eutric, and dystric types. Melanic brunisols develop on calcareous, rolling till and lacustrine deposits in eastern Ontario. Their distribution is closely associated with the limestone and shale plains surrounding the Shield, particularly on Manitoulin Island and in the Bruce Peninsula (Figure 2.3). Eutric brunisols also develop on calcareous till; in Ontario, their major distribution is associated with organic soils on a band of till between the organic deposits of the Hudson Bay lowlands and the lacustrine deposits of glacial Lake Agassiz. Dystric brunisols are more closely associated with acidic bedrock, with loamy to sandy acidic glacial till, and with outwash and lacustrine material. The Ontario brunisols are typically intermixed with luvisols and podzols in the western Shield area of the province.

Luvisols

Luvisolic soils are dominant in the lacustrine deposits of the Claybelt, intermixed with gleysolic and organic soils. They are also abundant in the lacustrine deposits near Kenora and Dryden and north of Opasquia Park. Southern Ontario soils are also dominantly luvisolic, intergrading with the band of melanic brunisols below the Shield in the north of the province and the gleysols of the Windsor and Niagara areas in the south.

Like brunisols, luvisols typically develop on relatively calcareous, forested glacial till and on glaciofluvial and glaciolacustrine deposits (Figure 2.3). The downward movement of forest litter and clay plays an important role in luvisol horizon development, but not to the extent of forming a podzolic B layer. Luvisols are typically intermixed with other forest soils, particularly the brunisols and podzols, but where transitions to grassland occur, gleysols are common co-dominants (Clayton et al. 1977).

Two great groups of luvisols are prominent in Ontario, the gray luvisols that develop in cool boreal and subarctic conditions, and the gray-brown luvisols found extensively in the south. The subarctic luvisols are typically unproductive; however, in boreal conditions, they are well suited to forest production (Thompson 2000, this volume). Large areas of luvisols support agriculture in southern Ontario and in the Claybelt.

Gleysols

Gleysolic soils are a dominant feature of the Claybelt, and also occur in poorly drained areas north of Lake Erie and in the vicinity of Rainy River (Figure 2.11). These soils also form a thin band along the shore of James Bay, and are found in depressions, interspersed with other soils, in many other landscape complexes.

Gleysols typically develop on nearly level, calcareous tills, on lacustrine deposits, and on slowly permeable clay plains (Figures 2.2 and 2.3). These areas are typically poorly drained (Figure 2.11) or saturated with static water. It is this water which causes the gleyed and mottled layers, associated with reduction processes, that define these soils. Gleysols are often interspersed with gleyed versions of luvisols and organics at local sites of poor drainage occurring in otherwise semiarid surroundings (Clayton et al. 1977). Gleysols successfully support agriculture in southern Ontario and the Claybelt. In conditions where these soils usually develop, however, the lack of aeration and the proximity of groundwater to the surface often make them unproductive forest soils.

Podzols

Podzols are the dominant soils of the central and southern Shield in Ontario. They extend from north and east of Lake Superior, to the Ontario-Quebec border, and from the Claybelt to the southern limit of the Shield.

Podzols develop under forest stands on coarse-textured, stony, glacial tills and outwash, and on glaciofluvial sand lying on acidic parent material. The close association between these soils and acidic Shield

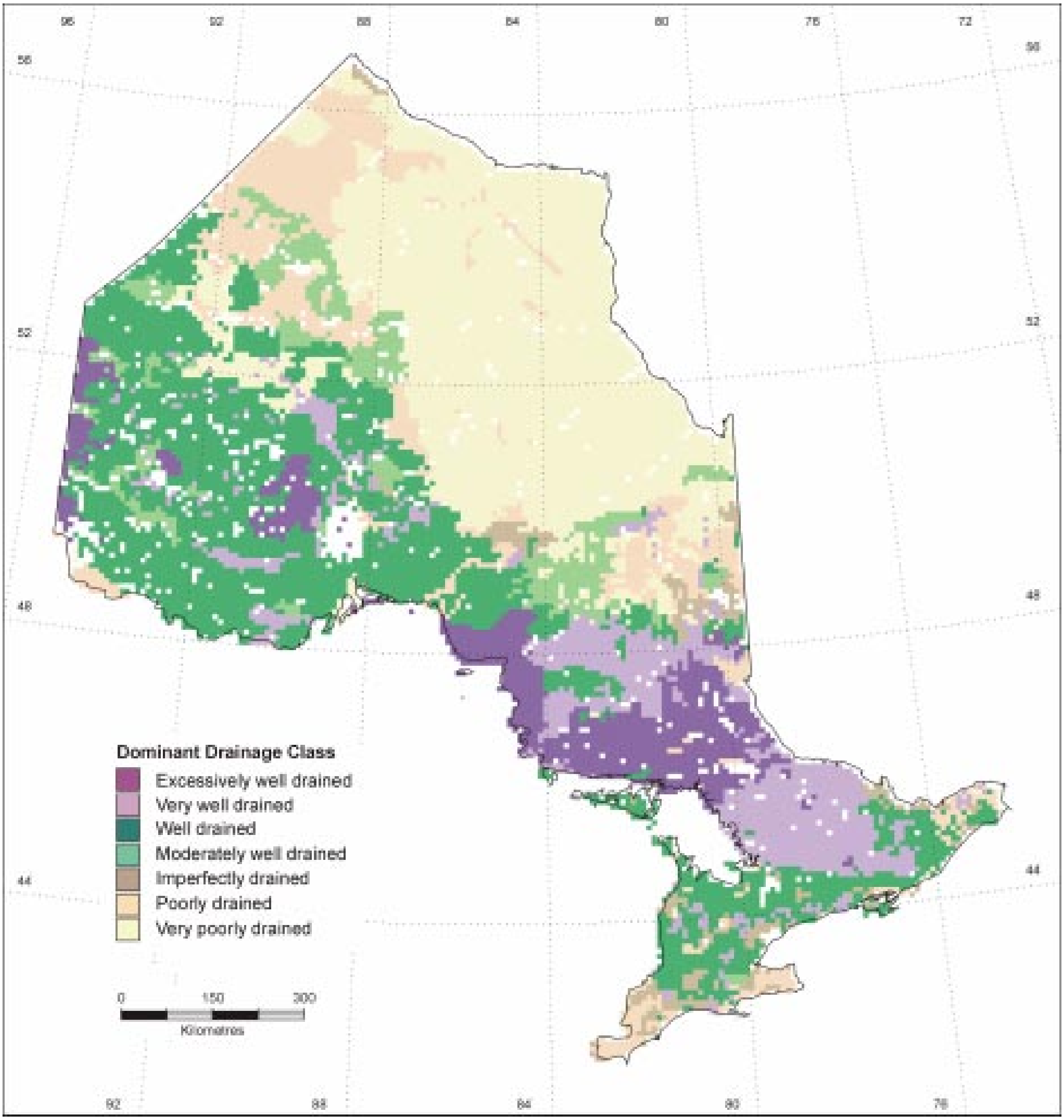

Figure 2.11 Dominant soil drainage classes based on Soil Landscapes of Canada units. (Data from Agriculture and Agri-Food Canada 1996)

Figure 2.12 Major drainage divides and watersheds of Ontario.
(Data from Environment Canada 1990)

conditions is evident in their correlation with the Frontenac Axis, which bisects plains of limestone and shale near Kingston (Figures 2.3 and 2.10). Forest litter is critical to the development of these soils. Strong weathering and leaching of organic matter and the presence of soluble aluminum and iron form the distinctive grayish podzolic B layer. Podzols develop in shallow layers in the Shield environment, and are more closely associated with the underlying bedrock parent material than many of the forest soils that develop on thicker glacial deposits (Clayton et al. 1977).

The dominant great group in Ontario, the humo-ferric podzols, typically develops on well-drained boreal sites, over coarse, iron-rich, acidic Shield areas (Figure 2.11). These soils are most commonly associated with exposed bedrock. Luvisols and brunisols, as well as organics and gleysols, also develop in depressions scattered across the Shield. Humid conditions, responsible for the substantial leaching of these soils, are also a determinant of their distribution (Figure 2.5a).

Regosols

Regosolic soils are the least prevalent of the major orders in Ontario; they dominate only a thin band along the Hudson Bay shoreline in the far northwest corner of the province. These are young soils, characterized by a lack of horizon development sufficient to meet the criteria of other soil types (Clayton et al. 1977). These soils directly reflect the parent material and may show cryoturbation, but not to the extent of the cryosolic order. Regosols are typically associated with tundra vegetation growing on materials of various grain sizes; however, the band of regosols in Ontario is developed on fine marine sediments.

The soils of Ontario are literally a product of their environment, in that they reflect either underlying bedrock units or patterns of surficial geology. The distribution of soil types and topography combine to determine drainage characteristics across the province.

Hydrology

The drainage divide between the Great Lakes system and Hudson Bay is located close to the Great Lakes, so that most of the province drains towards the north (Figure 2.11). The area of individual drainage basins north of the divide can exceed 100,000 km^2 (Figure 2.12). Precipitation, evaporation, and runoff determine the annual water balance of a watershed. Strong variation in annual water balance occurs across the province, following gradients in precipitation, temperature, surface cover, and soils. The general trend from south to north of lower temperatures, a shorter growing season, sparser canopy cover, and more predominantly clay-rich soils, is reflected in a corresponding increase in the ratio between annual runoff and annual precipitation. The extent of permafrost areas increases across the Hudson Bay lowlands and follows trends in soil drainage and temperature. Similarly, the combination of more poorly drained soils and lower temperatures is associated with a transition from forest to tundra and an increase in runoff ratio, despite lower overall amounts of precipitation.

Our comparison of the 30-year mean flow from 25 watersheds in Ontario with 30-year mean annual precipitation shows runoff ratios ranging from 30 to 40 percent in the watersheds of southern Ontario draining into Lake Ontario and Lake Erie. The watersheds draining to the north show runoff ratios well above 60 percent. Local variations in runoff ratio follow local variations in climate and soils as well as in the extent of forest and other land cover types.

Recent measurements of water balance recorded at sites in the boreal forest of northern Manitoba and central Saskatchewan show that mean daily evaporation during the growing season is roughly 1 mm per day, a rate which reflects energy limitations, stomatal limitations imposed by low root and soil temperatures, high vapour-pressure deficits, and sparse canopy cover (Sellers et al. 1995). These conditions are probably characteristic of the northern and western boreal biomes in Ontario as well, where they raise the potential for groundwater and soil-water runoff.

Summary

The province of Ontario contains a range of natural landscapes that reflect variations in bedrock geology and climate, and particularly variations in surficial geology derived mainly from late-Quaternary glaciation. The landscapes are relatively young, in terms of toposequences and substrate, and are characterized primarily by the deranged drainage pattern characteristic of recent glacial activity. In addition to lakes and wetlands, the terrain is blanketed by interwoven patterns of well-drained sands, poorly drained clays, and extensive peat deposits, each with its characteristic forest associations. Across most of the province, surface water runoff is abundant, although there is a trend toward water deficit in the extreme western and southern regions.

Patterns of climate, topography and hydrology are all strongly related at the provincial level. These broad patterns dictate the finer-scale patterns of soil development that result from both mesoscale and microscale climatic variation and from glacial, glaciolacustrine, and glaciofluvial deposition. The broad patterns outlined in this chapter control many of the processes occurring at the broadest landscape levels and provide the context for finer-scale landscape processes at work within landscape units. The nature of the relationships between landscape patterns and processes is examined in several of the chapters that follow.

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