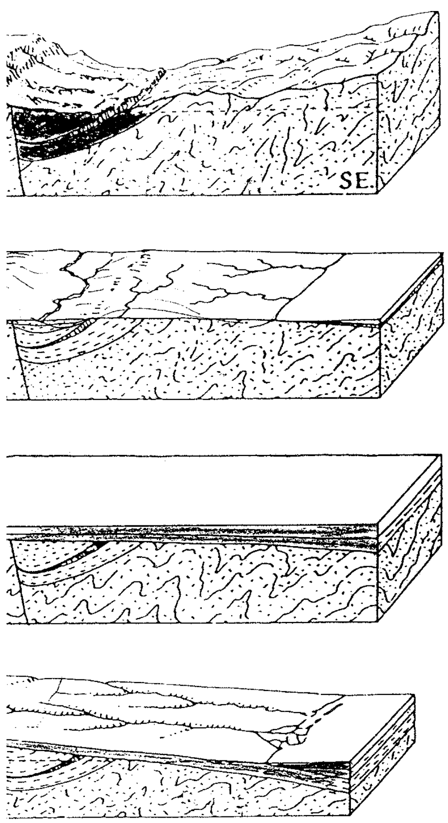
T3.1 DEVELOPMENT OF THE ANCIENT LANDSCAPE

The following summary of landscape development in Nova Scotia is based on Stea *et al.*[1] The evolution of Nova Scotia after the Triassic rifting episode has been debated over the last century. The arguments centre on two basic theories of landform development: the time-dependent, evolutionary concepts of the geomorphic cycle[2] and steady-state landscape hypotheses.[3] Goldthwait[4] and Roland[5] interpreted the geomorphic evolution of Nova Scotia in the light of Davisian concepts. They suggest that the entire region had been infilled after the Triassic and then planed off.

Welsted, on the other hand, argued that the trough of the Bay of Fundy had been in existence since the Triassic.[6] He maintained that there is little evidence for an extensive post-Triassic cover of rocks and superposition of streams. Welsted explained the flat uplands as exhumed surfaces of great antiquity. The Nova Scotia landscape, in this equilibrium model, has not changed substantially since the Triassic rifting episode.

Other studies have supported or diffused these two basic theories.[7–14] It is currently supposed that upland planation may have occurred during several cycles of uplift and erosion from pre-Carboniferous times to the present (see Figure T3.1.1). During the Cretaceous it seems likely that the area was part of a low-relief plain analogous to the Mississippi delta region. Uplift and erosion after the Lower Cretaceous is indicated by valleys cut into Cretaceous rocks and infilled with Tertiary sediments offshore, and by faulting and folding of Lower Cretaceous sediments on land. After the Tertiary, glacial erosion modified the landscape onshore and offshore but did not erode substantial quantities of rock.



1 Post-Triassic: rejuvenation, uplift and folding due to rifting.

2 Jurassic to Early Cretaceous: formation of the Atlantic Uplands peneplain.

3 Lower Cretaceous: marine-basin sediments onlap and cover.

4 Tertiary upwarping of the Atlantic Uplands and covering sediments, drainage pattern superimposed on the older surface.

Figure T3.1.1: Evolution of Nova Scotia since the Triassic. according to the cyclic mode.

The physical landscape is the product of the geology and structure of the terrain, the erosive processes acting upon it, and the length of time over which they act. The memory of past events recorded in the landscape of Nova Scotia is brief, in geological time scales. The last prominent event recorded was the split-up of Pangea and the opening of the present-day Atlantic Ocean in the Triassic Period. The Bay of Fundy (Unit 912), a rift valley, is the remnant of that split-up.

In Nova Scotia there is a variety of igneous, metamorphic and sedimentary formations which have been exposed to desert, temperate and glacial conditions over 140 million years. This long erosive history can be divided into three parts: the development of a planation surface (essentially complete by the Cretaceous Period); uplift, tilting and redissection of this plain during the Tertiary; and glaciation during the Pleistocene. Glacial activity in the province is described in T3.3; elements of the physiography attributable to the other two periods are described below.

THE CRETACEOUS PENEPLAIN

The first phase in the formation of the landscape was the development of a lowland plain during the period prior to the Early Tertiary, about 60 million years ago. At that time, Nova Scotia may have looked like a relatively uniform, flat plain almost at sea level. To the north, the plain extended well into New Brunswick; to the south, it stretched beyond the present coastline and out over at least part of today's continental shelf. The climate at that time was predominantly hot, and the formation of kaolinites in the Nova Scotia Cretaceous sediments implies that it was also moist.[15] Erosion was generally subaerial, with wind abrasion, flash flooding and diurnal expansion and contraction of exposed surfaces being the principal weathering agents.

The surface of the plain cut across some very resistant rocks: the granite and quartzite of the Atlantic Interior (Region 400) and the old metamorphic rocks of the Cobequid Hills, Pictou–Antigonish Highlands (District 310) and the Cape Breton Highlands (Region 200). Although the surface was broadly even, part of the northern plateau of Cape Breton (Region 100), the granite knolls south of Kentville, and Mount Aspotogan in Lunenburg County all stood above the erosion surface.

The planation surface was uplifted during Tertiary times and has since been dissected, so that little remains of its original uniformity. Nonetheless, it still contributes a great deal to the character of the Nova Scotian landscape. The even horizon line and relatively modest maximum elevations can both be attributed to this early levelling.

THE TERTIARY UPLIFT

During the Cretaceous period, the continental shelf subsided and thick sedimentary deposits began to accumulate offshore. At that time, erosion on land was very slow, and only very fine sediments were removed from the flat surface.

During the Late Tertiary, the crustal block of which Nova Scotia was a part was uplifted and tilted; sea level dropped to at least 200 m below the present level, and much of the continental shelf was exposed once again. Vigorous erosion commenced. The soft, unmetamorphosed post-Devonian sediments were stripped off, exposing an ancient landscape of resistant ridges (for example, the Rawdon Hills and Wittenburg Mountain, in District 420); old, hard blocks such as the Creignish Mountains of Cape Breton (Region 300); and old, buried river valleys (for example, parts of the Musquodoboit Valley and the East River Valley). Drainage systems which had formed on the tilted surface were further excavated and entrenched. The Bras d'Or Lake was deepened, and the Gulf of St. Lawrence shelf area became dissected by river valleys. Old coastal features which originally formed during the Carboniferous Period were re-exposed: for example, the coastal embayments of Mahone Bay and St. Margarets Bay (District 460). The river system which had formed west of Cape Split in the Bay of Fundy became further enlarged at this time, and the Minas Basin and Chignecto embayments began to develop. On the Scotian Shelf, a relatively level plain was dissected into hills and valleys, which became banks and channels during the subsequent rise of sea level.

The rate at which this erosion took place was closely controlled by the geology. The hard igneous and metamorphic rocks of northern mainland Nova Scotia, Cape Breton and the Southern Uplands were not worn down appreciably and became more prominent in the landscape as the surrounding soft sediments were removed around them. Lowlands formed from the Carboniferous strata of limestone, gypsum, shales and coal measures. The soluble deposits of the Windsor Sea were eroded, forming karst topography in the Carboniferous Lowlands (Unit

511). The coarse, gritty Horton sands were left as resistant shoulders against older, hard blocks such as the Pictou–Antigonish Highlands (Unit 312). The soft, Early Triassic deposits south of North Mountain were easily washed out by rivers flowing through the Annapolis Valley (District 610) and St. Marys Bay (Districts 810, 820, 910).

Where hard and soft rocks came into contact through faulting, differential erosion left steep escarpments, such as those on the west face of Aspy Bay and Cape North and on the north side of the Minas Basin.

MARINE INCURSION

Sometime in the late Tertiary, the sea level rose relative to the land, and the old coastline was drowned. Distinctive coastal features, such as the Bay of Fundy, Bras d'Or Lake, Canso Strait and St. Marys Bay, were inundated, together with other, smaller river estuaries and coastal embayments. The essential character of the landscape and coastline of Nova Scotia, reflecting its geological and erosional history, was established at this point and was modified only by the glaciation that came later.

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Associated Topics

T2.1 Introduction to the Geological History of Nova Scotia, T2.3 Granite in Nova Scotia, T2.4 The Carboniferous Basin, T2.6 The Triassic Basalts and Continental Rifting, T2.7 Offshore Geology, T3.2 Ancient Drainage Patterns, T3.3 Glaciation, Deglaciation and Sea-level Changes, T3.4 Terrestrial Glacial Deposits and Landscape Features, T3.5 Offshore Bottom Characteristics

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T3.2 ANCIENT DRAINAGE PATTERNS

The drainage patterns across Nova Scotia have developed almost entirely since the Tertiary and are closely tied to the geology. They are the response of water flowing down an inclined plain to the structure and composition of the underlying rocks. Water follows lines of weakness, such as soft strata, joints or faults, and establishes a characteristic drainage pattern. This is modified until the river develops a profile which is in equilibrium with the regional slope, precipitation and the geology of its drainage basin.

In Nova Scotia, drainage patterns diverge from their ideal form because of three influences: the Pleistocene glaciation, which scoured the surface of the province and then dumped unsorted rock debris upon it; fluctuations in sea level; and ancient river channels, which developed before the Tertiary and are now superimposed upon the terrain. All these factors are reviewed in more detail below.

ROCK TYPE

Potential for erosion, permeability and jointing of the bedrock determine both the proportion of water that is retained on the surface and how runoff is channelled. Impermeable, poorly jointed rocks ,such as granite, greywacke and slate, retain most of the water on the surface in a disorganized series of streams, lakes and bogs. This is called deranged drainage and can be seen on the South Mountain and across most of southern Nova Scotia (mainly in Region 400) (see Figure T3.2.1).

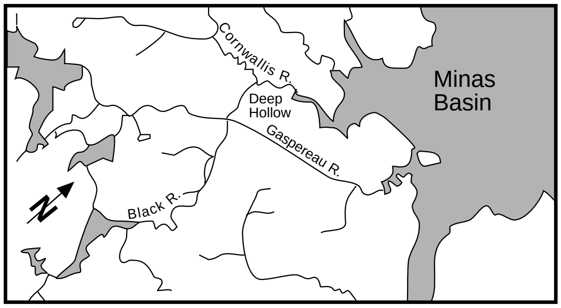


Figure T3.2.1: Deranged drainage. The Black River formerly drained through Deep Hollow into the Cornwallis River and is an example of river capture (see Figure T3.2.6). The more vigorous Gaspereau River has diverted the Black River at White Rock. Black River, in Region 400, is a deranged drainage pattern, now extensively dammed for hydro-electric power.

Permeable, well-jointed rocks, such as limestone, sandstone and gypsum, allow substantial infiltration, have few lakes, and channel surface runoff along joint lines and the bedding trend. The product is rectangular or trellised drainage (see Figure T3.2.2). This is well developed in the Carboniferous sandstones and salts of central and northern mainland Nova Scotia and Cape Breton (mainly in Region 500).

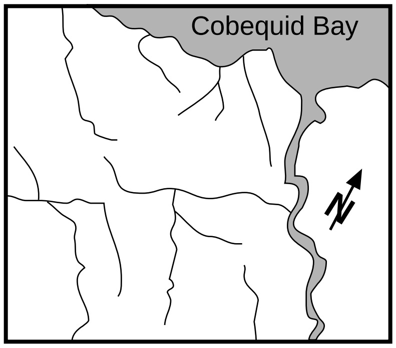


Figure T3.2.2: Trellis drainage, East Hants Co., District 510.

Dendritic drainage patterns develop on unconsolidated sediments with an even slope and on evenly resistant rocks with moderate to high relief. This is exhibited by the soft Triassic sediments in the Annapolis Valley (District 610), around the Minas Basin (Unit 913b), in Regions 600 and 700, and in the highland areas of the Cobequids, Pictou–Antigonish and Cape Breton in Region 300 (see Figure T3.2.3).

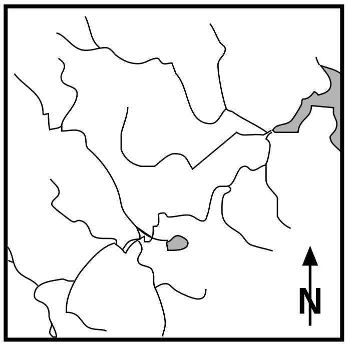


Figure T3.2.3: Dendritic drainage, West River, Antigonish Co. (Units 312 and 583a).

T3.2
Ancient
Drainage
Patterns

STRUCTURE AND SLOPE

In tilted or folded strata, where hard and soft rocks are interbedded, fluvial erosion tends to produce a ridge-and-valley topography. The valleys, and therefore the streams that flow in them, are parallel to one another. If the regional slope of the land surface is parallel to the axes of the folds, a parallel drainage pattern may develop, becoming rectangular in places where the ridges are crosscut. If the fold and slope directions are opposed, the pattern is generally strongly rectangular, or even trellised. While there are no good examples of this type of parallel drainage in Nova Scotia, structurally controlled rectangular patterns are well developed on the Northumberland Plain (Unit 521a), north and east of the Cobequid Hills.

Faults also add a linearity to drainage patterns, since the rubbly material along their zone of movement is easily removed by flowing water. This fault control is a feature of the West River St. Marys (Unit 572) and several nearby river valleys; for example, Tangier River (Units 453/834) and West Sheet Harbour River (Unit 413b) in Halifax County.

Parallel drainage is also characteristic of areas where streams cascade down a steep slope and do not branch appreciably before entering the sea; for example, the streams rising on North Mountain (District 720) and flowing down to the Bay of Fundy (see Figure T3.2.4).

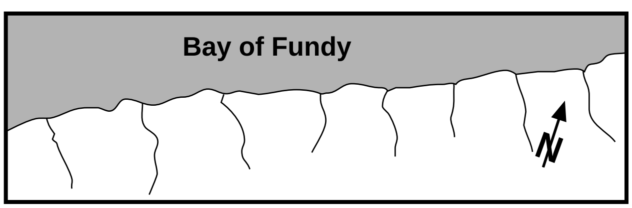


Figure T3.2.4: Parallel drainage, North Mountain, District 720.

When the highland area is rounded, the streams drain down the slopes in a radial pattern. The Cape Breton Highlands (Region 200) and Mabou Highlands (Region 300) both exhibit a modified radial-drainage pattern (see Figure T3.2.5).

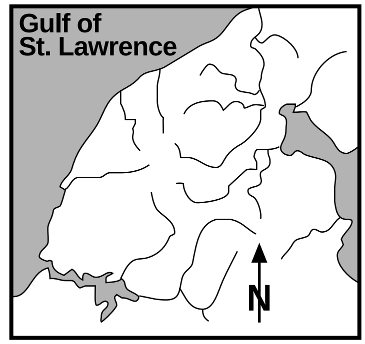


Figure T3.2.5: Radial drainage, Mabou Highlands, Unit 314.

ICE SCOURING

The scouring action of ice overprints a lineation on the bedrock, which is parallel to the direction of ice flow. This linearity may change the drainage pattern locally and override the control normally imposed by the bedrock. In Nova Scotia, this influence is locally manifest in the alteration of a dendritic pattern to one approaching parallel or rectangular; for example, along the western shore and eastern shore of the Atlantic coast (Region 800), and in southern Cape Breton.

DEPOSITION

In contrast to the linearity imposed by scouring, glacial deposits tend to block established channels and disorganize the drainage patterns. If the deposits had an even thickness and distribution, a dendritic pattern might be established. However, in Nova Scotia, glacial deposits tend to be very uneven and the drainage is deranged. The influence of glacial deposits is well displayed in southern Cape Breton, where thick glacial deposits on the flat bedrock have established a new regional slope. The Mira River, which once flowed southwards, now flows eastwards (Unit 870).

SEA-LEVEL CHANGE

In a stable environment, rivers and streams establish a concave profile from source to mouth, which is in equilibrium with the relief, geology and distance from the headwaters to the estuary. The profile is

Plate T3.2.1: Folly Gap, looking south; an ancient river valley modified by glacial actions (Units 311 and 521a). Photo: R.Lloyd

established above a "base level," which is ultimately sea level. When sea level changes, the profile is no longer in equilibrium. If sea level falls, stream energy increases and starts to cut down actively and erode incised valleys; if it rises, the streams become more sluggish and deposit material in their lower reaches. On the Atlantic coast, since sea level is currently rising at a rate of about 25 cm a century,[1] streams and rivers are more liable to deposit than erode near the estuary. They are consequently less able to cut through and redistribute glacial material than they would if the base level were constant. Rising sea level thus reinforces the disorganizing effect on drainage patterns imposed by glacial deposition.

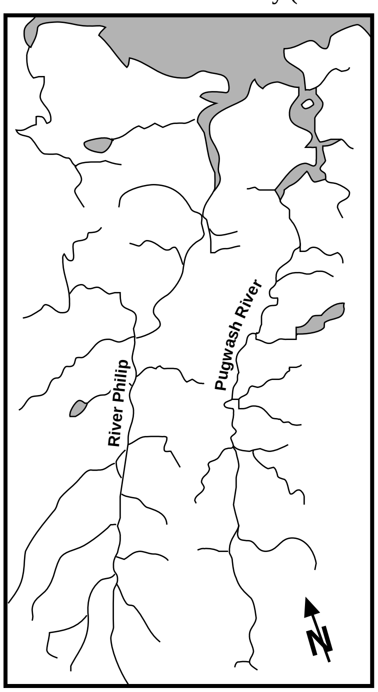
RELICS OF AN ANCIENT DRAINAGE SYSTEM

Some features in the fluvial landscape of Nova Scotia do not appear to be the product either of erosion since the Cretaceous or of glaciation. For example, the Musquodoboit River flows through a valley cut directly across the Granite Ridge (District 450). The Cobequid Hills are also crosscut by two valleys, the Folly Gap and the Parrsboro Gap, which were cut by rivers much larger than those that occupy them today (see Plate T3.2.1).

Several lines of evidence indicate that these are relics of a pre-Tertiary drainage system which developed at a higher level above the present erosion surface on a plain which was tilted towards New Brunswick. As the rivers cut down through the overlying strata, they became superimposed upon the rocks at the present level of erosion. The original direction of drainage (to the north) shifted 180°, and these rivers established a southerly flow, abandoning part of their old channels. Subsequent erosion and the disruption of glaciation has removed all but a few ghosts of these systems. This remaining evidence can be used to attempt a broad, speculative reconstruction of the ancient drainage network. For a fuller discussion, see Roland.[2]

WATERSHED BOUNDARIES

Watershed boundaries are continuously changing as rivers which drain areas of weaker rocks erode backwards and establish progressively larger drainage areas at the expense of neighbouring streams. For instance, in the interior of eastern mainland Nova Scotia many rivers which flow southwards to the Atlantic across the Atlantic Interior have lost part of their drainage areas to the West River St. Marys. Similarly, the watershed of Country Harbour River has been reduced by the westerly extension of the South River and Salmon River systems, which flow into St. Georges Bay and Chedabucto Bay respectively (District 570).



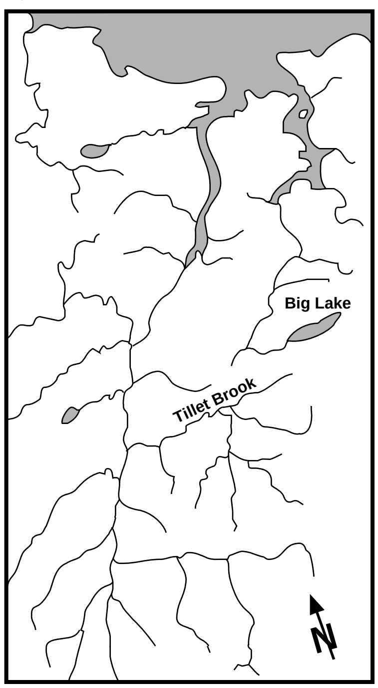


Figure T3.2.6: Example of river capture. River capture of former headwaters of the Pugwash River by River Philip. Both rivers exhibit a classic trellised pattern reflecting the east-west folds in the sandstone bedrock, District 520.

RIVER CAPTURE

There are numerous examples of river capture across the province, where streams or major rivers have been directed into the upper reaches of an adjacent watershed. A wind gap or dry valley is then left along the original course of the stream, and the remaining stream is undersized for the valley in which it flows.

An excellent example of river capture can be seen in the headwaters of River Philip, Cumberland County (see Figure T3.2.6). Several streams which once flowed down a fault into the Pugwash River have been diverted to the west and now flow into River Philip, parallel to their original course. Similarly, the Gaspereau River has intercepted the Black River at White Rock, Kings County, leaving an underfit stream to occupy the lower portion of the valley known as Deep Hollow.

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Associated Topics

T2.1–T2.7 Geology, T3.1 Development of the Ancient Landscape, T3.3 Glaciation, Deglaciation and Sea-level Changes, T3.4 Terrestrial Glacial Deposits and Landscape Features, T8.1 Freshwater Hydrology, T8.2 Freshwater Environments

Associated Habitats

H3.1–H3.6 Freshwater

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T3.3 GLACIATION, DEGLACIATION AND SEA-LEVEL CHANGES

As early as the late 1800s, when the glacial theory was born, the nature of glaciation in Nova Scotia was being debated. Was glacial ice from local areas, originating in uplands and confined to the province, or was the ice part of a great continental mass that crossed the Bay of Fundy? The Reverend D. Honeyman, curator of the provincial museum at that time, discovered amygdaloidal basalt boulders along the Atlantic coast near Halifax. They had been transported a distance of 130 km. He used the observation to support the concept of a continental-based ice movement that crossed the Bay of Fundy.

Robert Chalmers of the Geological Survey of Canada mapped surficial deposits and glacial features in eastern Canada.[1] He carefully mapped glacial grooves and striations in Nova Scotia and interpreted a sequence of local ice movements. He proposed that northern Nova Scotia had been glaciated largely by local glaciers, with floating ice a secondary agent in low-lying areas. In contrast to Honeyman, he did not believe that a glacier had crossed the Bay of Fundy.

L.W. Bailey[2] and W.H. Prest[3], working in mainland Nova Scotia, observed erratics that supported both previous views.

Over the next 80 years, as new evidence arose, the two models were debated, with either one or the other and sometimes both, being at the forefront of scientific acceptance. During this period, the radiocarbon-dating method became established, and processes of glacier mechanics were being more fully examined.

Pleistocene mapping in the Annapolis Valley was initiated at Acadia University, Wolfville.[4,5]

Since 1977, the Nova Scotia Department of Natural Resources has conducted regional glacial mapping and till-geochemistry programs. These programs have also involved the systematic stratigraphic and lithological analyses of till sections. The mapping and till-provenance data from over 3000 samples have enabled us to construct a picture of the ice-flow events that is different from either of the two models that have been favoured since the 1800s.

Today, in most continent-wide interpretations of the late Wisconsin, a relatively simple, monolithic glaciation model is advocated (maximum model).[6] In this model, a vast ice sheet centred in Hudson Bay or Quebec (Laurentide) overrode much of Maritime Canada and extended to the shelf edge. This single-glaciation model—one major advance and generally linear retreat—contrasts with the terrestrial record of successive glacial advances from shifting ice centres in the Maritimes themselves.[7,8]

The major features of the landscape of Nova Scotia—the overall relief, the distribution of highland, upland and lowland areas—are all the product of its long geological history. The minor features—the final rounding of surface features, the alignment of surface lineations, surficial deposits and sea-level changes—are the product of glacial activity during the Quaternary Period.

The last phase of glaciation ended about 10,000 years ago and left behind an unconsolidated mantle of sediment (see T3.4). On this substrate, drainage patterns were re-established and soils developed.

THE GLACIAL HISTORY OF NOVA SCOTIA

Deep-ocean-sediment core samples provide evidence that there were more than sixteen glaciations during the Quaternary. These glaciations generally each lasted about 100,000 years and progressed slowly and hesitantly from a warm interval (interglacial) to colder and colder conditions, until huge ice sheets covered most of Canada. The transition from glaciers to renewed warmth was rapid. The present relatively warm, ice-free period may mark the end of the ice age, but it could also be an interglacial or even an interstadial interval—a pause before the next advance.

In Nova Scotia, only the last two glaciations (called the Illinoian and Wisconsin after type localities in the United States) have been identified. The Wisconsin glaciation started about 75,000 years ago and ended between 12,000 and 10,000 years ago.[8] Each major glacial advance, by its nature, tends to destroy evidence of previous glaciations. The glacial deposits and features in Nova Scotia are therefore almost all of Wisconsin age.

During the Wisconsin stage, glaciers crossed over Nova Scotia and also formed over Nova Scotia itself. This is not surprising, because Nova Scotia has the highest rainfall in eastern Canada. When it cools down sufficiently, this turns to snow and then to ice.

The last interglacial period, the Sangamon, is represented by marine and terrestrial deposits underlying tills of the Wisconsinan glacial period. Shelly marine sand in cliff sections in southwest and northern Nova Scotia has a warm-water fauna, indicating present-day conditions. During this time, sea level was four or six metres higher than at present. This higher sea level cut a shoreline of which the remnants are flat, wave-cut rock benches underneath glacial deposits. A wave-cut platform rings Cape Breton and is also exposed on the western shore of mainland Nova Scotia (District 820).

The main events of the Wisconsin glaciation have been interpreted from the deposits resting on top of this marine platform and from striation patterns which indicate ice-flow patterns. Figures T3.3.1 show the timing, location and extent of a glaciers in Nova Scotia during the last 75,000 years.[9]

ICE-FLOW PHASES

Ice-flow phases are determined by the mapping of striations and other ice-flow indicators, such as glacial deposits.[8, 9, 10] Each phase is associated with one or more distinct till sheets. Stacked till sheets and superimposed striae are interpreted as changes in ice flow and help determine the direction of movement.

Phase 1

Patterns of glacial striations (grooves formed by ice) and distinctive erratics (boulders transported from rock sources far away) show the earliest and most extensive ice flow following the Sangamon in Nova Scotia was eastward (see Figure T3.3.1a) then southeastward (see Figure T3.3.1b) across the Bay of Fundy. This is called the Fundy Stade.[11]

The vast majority of the drumlin fields in Nova Scotia were formed during this phase and modified during Phase 2.[12]

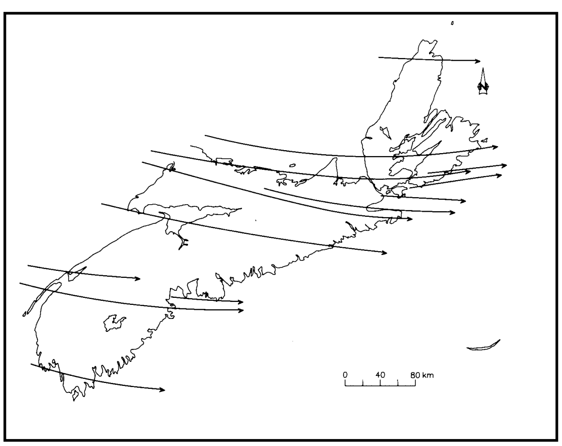

Figure T3.3.1a: Ice-flow Phase 1a. Ice moving eastward across Nova Scotia.

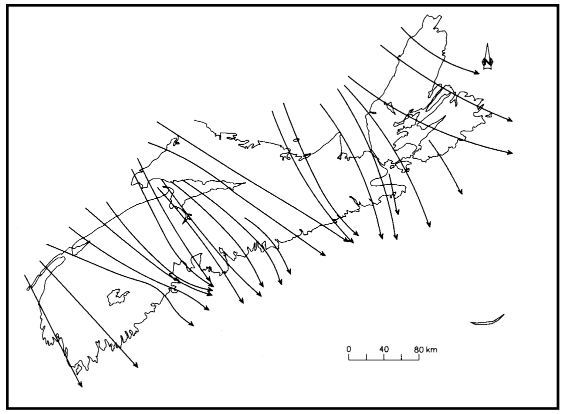

Figure T3.3.1b: Ice-flow Phase 1b. Ice moving southeastwards across Nova Scotia.

Phase 2

The second major ice flow was southward and southwestward from the Escuminac Ice Centre in the Prince Edward Island region (see Figure T3.3.2).[13] Loamy material from the vast area of redbeds in northern mainland Nova Scotia and Carboniferous basins associated with Prince Edward Island were transported southward onto the metamorphic and igneous bedrock terranes of mainland Nova Scotia. Southward dispersal of distinctive Cobequid erratics occurred with the dispersal of the red material.[14]

The major glacial advance from the north established much of the drumlin topography in southern and eastern Nova Scotia. It also produced the north–south and northwest–southeast alignment of geomorphological features on the mainland.

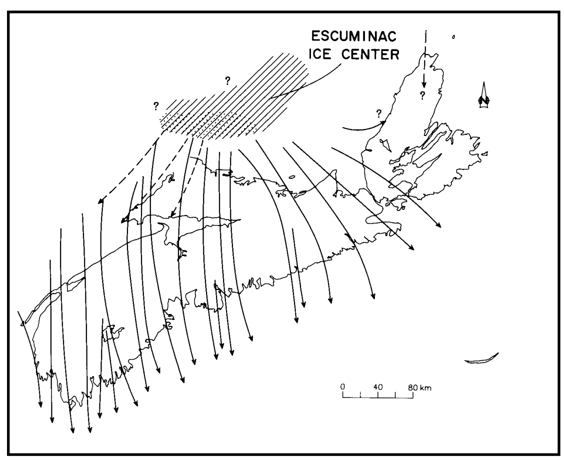

Figure T3.3.2: Ice-flow Phase 2.

Key to Figures T3.3.2, T3.3.3, T3.3.4

Ice center or divide. early

Ice center or divide. late

Flow paths early late

Phase 3

An ice divide in southern Nova Scotia (Scotian Ice Divide) precipitated a northward ice flow across the northern mainland of the province (see Figure T3.3.3). During this phase, granites from the South Mountain Batholith were transported northward onto the North Mountain basalt cuesta. Cobequid erratics can be found throughout the Carboniferous Lowlands to the north.[13] This phase correlates with Grant's interpretation of the ice dome located south of Cape Breton Island.[14, 15, 16, 17]

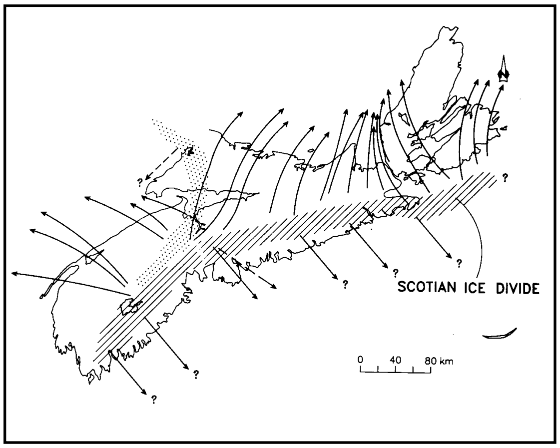

Figure T3.3.3: Ice-flow Phase 3.

Phase 4

Remnant ice caps developed from the Scotian Ice Divide and formed over the Chignecto Peninsula and southern Nova Scotia marked by moraines, ablation till and glaciofluvial sediments. The ice flow during this last phase was strongly funnelled into the Bay of Fundy (see Figure T3.3.4).

None of the advances in the late Wisconsin was as strong as those before, and they became progressively weaker, until the ice caps finally disappeared from Nova Scotia about 10,000–12,000 years ago.

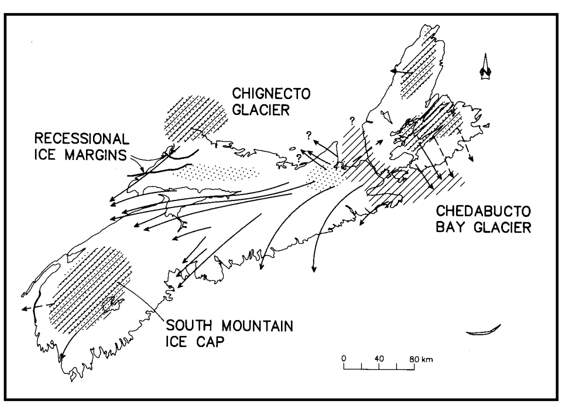

Figure T3.3.4: Ice-flow Phase 4.

OFFSHORE MARGINS OF FLOW PHASES

The offshore extent of the various flow phases is not generally known. A major moraine system known as the Scotian Shelf Moraine System was thought to represent the margin of late Wisconsin glaciers.[18] Other margins have since been proposed. Stea et al[9] have shown that the moraine material appears similar in texture and composition to stony, ground moraine of the Eastern Shore called the Beaver River Till[11], which was deposited by ice stemming from the Scotian Ice Divide (Phase 3) in Nova Scotia.[19]

If the correlation with the Beaver River Till is valid, then it would suggest that flow from the Scotian Ice Divide overrode or formed these moraines and was more extensive than generally believed.[20, 21] This interpretation is consistent with striation data that implies extensive flow from the Scotian Ice Divide across highland regions in northern Nova Scotia above an elevation of 200–300 metres.[15] The location of the Scotian Shelf end-moraine system is illustrated in Figure T3.5.1.

DEGLACIATION

The distribution of late-glacial features during ice-flow Phase 4 suggests that the last glaciers flowed radially from centres of remnant ice. Earliest deglaciation occurred in the Bay of Fundy. Ice flowed southwestward out of Chignecto Bay and westward out of Minas Basin, probably as a response to marine incursion into the isostatically depressed Bay of Fundy. The timing and extent of this ice-flow phase is uncertain; however, evidence suggests that the Bay of Fundy was ice free up to the Chignecto Peninsula by 16,000 years ago[22] or, at the latest, 14,000 years ago. Stea and Mott [23] estimated that the ice retreated to the present coastline by 13,000 years ago. Dates on glaciomarine deltas and minimum dates on lake sediments and buried organic horizons in northern Nova Scotia, however, imply residual ice until at least 12,000 years ago and, in some highland areas, probably much later.[23, 24]

The retreat of the ice in northern Nova Scotia after 15,000 years ago was slow or interrupted by several stillstands and possible readvances. A late-glacial readvance is documented in northern Nova Scotia, stemming from the Antigonish Highlands (Unit 312).[15] This ice sheet flowed southwestward and southward into the adjacent lowlands. Along the Eastern Shore, the margin of this ice mass was presumably offshore. Moraines off Sheet Harbour, in Unit 911, indicate two stillstands and possible readvances after the deposition of the Eastern Shore Moraine.

REBOUND AND SEA-LEVEL RISE

Since the last recession of glacial ice, global sea level has been rising, rapidly up to about 6000 years ago and at a much slower rate since then. Following the removal of the ice burden, the land surface rebounded in proportion to the former degree of loading. Since the ice had decreased in thickness from north to south over Nova Scotia, there was a parallel pattern of rebound. Almost simultaneously, sea level rose as water was released from the ice caps to the north.

The Bay of Fundy was greatly depressed by the weight of the glacial ice, so that as the ice melted, seawater flooded onto the present land surface. As the mass of glacial ice on land and coastal waters melted, the load was removed and the surface rebounded. This isostatic uplift extended the land surface of Nova Scotia into the Bay of Fundy. Uplift soon exceeded the rise in sea level and the coastline became raised, leaving strandlines several tens of metres above the present high-tide mark; good examples can be seen in the Advocate Harbour area (District 710).

The remainder of Nova Scotia was not depressed to the same extent. Around Yarmouth, the uplift and sea-level rise were about equal, leaving the coastal features in the same position relative to the sea. In the southern parts of the province, from Shelburne County to Guysborough County, there was less crustal rebound, and the coastline was drowned as the sea moved landwards across the continental shelf.

RELATIVE SEA-LEVEL CHANGE

During the Quaternary, the sea level cyclically rose and fell as much as 120 metres. The first comprehensive work on changing relative sea level (RSL) in the Maritimes was that of Grant, who documented many sites with C_{14} dating of former sea levels during the Holocene.[25] This work demonstrated that RSL during the Holocene was rising. Later work has provided rates of RSL rise for many locations around eastern Canada.[26–34]

The rates of RSL rise tend to be higher along the Atlantic coast of Nova Scotia and inside the Bay of Fundy, and show a trend of decreasing rates from east to west; i.e., the rate of RSL rise decreases towards the former ice centre.[25]

It is debatable exactly how low relative sea level was. Some place it at 120 m below present,[18] while others say it was 80–90 m lower than sea level today.[30]

The sea-level record based on field observations from emerged features and lake cores will be discussed in three segments: Sangamon sea levels, Late Wisconsin sea levels and Holocene records. Coastal and marine features related to sea-level rise are described in T3.5 and T7.3.

Sangamon Sea Levels

(ca. 120,000–100,000 Years before Present [yr. BP])

The earliest record of former sea levels in the Bay of Fundy predates Phase 1 in Nova Scotia's glacial history. Tills formed during Phase 1 lie above a rock bench 4–6 metres above sea level.

This bench suggests a wave-cut feature relating to higher sea levels during the Sangamon Interglacial.[35] There are no direct dates on this feature, but peat beds have been found above the bench that possibly date to the last interglacial. Grant pointed out that the feature records a former equilibrium state between sea level and crustal rebound after a major glaciation.[35] The present interglacial period will presumably reach this state in another 2000 years, assuming the current rate of submergence of about 30 cm per century.

Late Wisconsin Sea Levels

(16,000–10,000 yr. BP)

The Bay of Fundy is part of a zone of emergence followed by subsidence. Raised marine features dating from 16,000 to 12,500 years ago are found at various levels around the Bay of Fundy. Wave-cut terraces, raised beaches and deltas were the major landforms produced during the late-glacial high sea level. The general pattern is a north-to-south decrease in marine emergence from 80 to 40 metres in the western region and a west-to-east decrease from 40 to 0 metres at the head of the Bay.[29,36]

In the only continuous record offshore, from Sable Island (District 890), the oldest dates we have are 11,000 years ago, and extrapolation suggests sea levels were about –80 m at 15,000 years ago.[30] It is possible that a strip of unglaciated land or a series of islands on the outer continental shelf connected Nova Scotia to New England during the last glacial ice advance. Evidence for this comes from freshwater peat dredged from depths of 100 m in the Gulf of Maine and mastodon teeth found at similar depths.[37] This connection would have been flooded about 15,000 years ago during the initial rapid rise of sea level.

Holocene Sea Levels

(10,000 yr. BP to present)

There are a number of theories regarding the rates of RSL rise during the early Holocene. However, all studies indicate fluctuations, with an average decrease in rates towards the late Holocene. More recently, the rates have increased quite rapidly, as indicated by records during the last 250 years.[25]

RSL was somewhere below 40 m at 10,000 years ago. Some records suggest it then rose rapidly with high rates of submergence at 1.1 m/century occurring prior to 7000 years ago.[33] Sea-level inflection points dated at 7000 years ago have been reported.[31,38] Other records suggest that sea level was falling in that period.[26,29]

The latest theories show RSL to be a two-tiered process, with a very rapid rate between 12,000 and 11,000 years ago, a decrease between 11,000 and 8000 years ago, and a rapid rise between 8000 and 5000 years ago.[39]

In most areas where we have RSL data back to 4000 years ago, we can see a break in the rate of RSL rise at 2500 years ago.

Rates of RSL rise prior to 2500 years ago can be as high as 1 m/century. Rates of RSL after 2500 years ago are usually less than 20 cm/century, except at the edge of the continental shelf, where rates do not appear to have changed since 4500 years ago.[30]

Average RSL rise in Nova Scotia is between 25 and 30 cm/century, almost all of which is due to crustal subsidence resulting from isostatic adjustment at the Earth's surface following glaciation.[26] It has also been suggested the current rate of RSL is possibly part of a sea-level rise.

Analysis of tide-gauge records at Halifax, Saint John and Charlottetown indicates an average rise of 41 cm/century (see T8.1). Geodetic levelling has confirmed this,[40] indicating a depression of the crust southeast across the Maritimes from the St. Lawrence River. Maximum depression of the crust is in the Amherst-to-Truro area of the Bay of Fundy (see Figure T3.3.2).

Associated Topics

T3.1 Development of the Ancient Landscape, T3.4 Terrestrial Glacial Deposits and Landscape Features, T3.5 Offshore Bottom Characteristics, T7.3 Coastal Landforms

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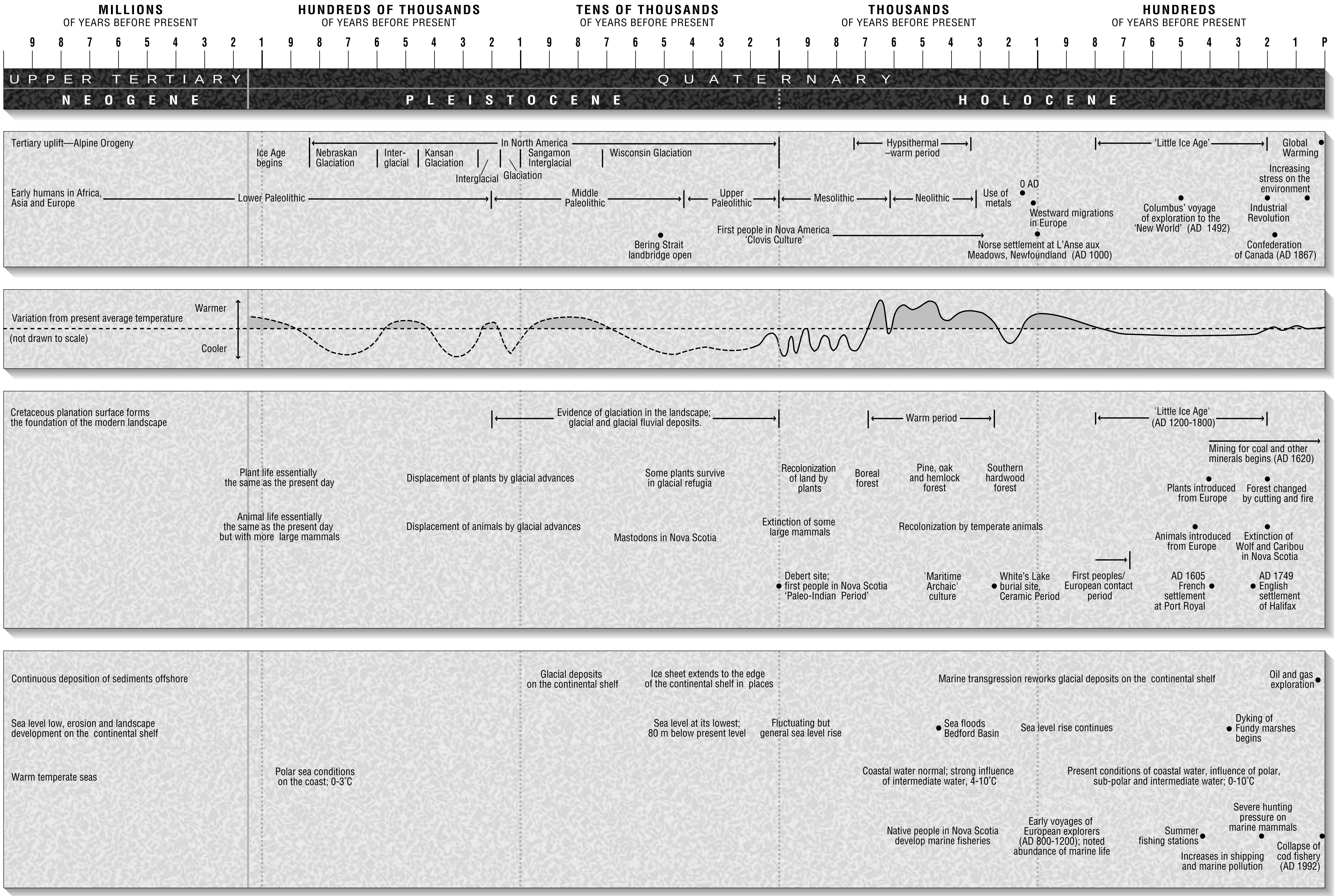

Figure T3.3.5: Major Events of the Quaternary Period.

T3.4 TERRESTRIAL GLACIAL DEPOSITS AND LANDSCAPE FEATURES

Glaciations during the Quaternary Period have had a profound effect upon the landscapes of Nova Scotia. Glaciers changed narrow V-shaped tributaries to broad U-shaped valleys, such as the St. Marys River, and blanketed the province with a veneer of glacial deposits of varying thickness and form, in some areas up to 300 metres thick. The deposits were generated by the action of the ice as it scoured, abraded and plucked at the bedrock during its advances across country. Glaciers do not always erode earlier deposits. They can modify them or leave them alone. Glaciers have been described as "fickle" erosional agents.

The texture of the glacial material (its clay, sand and stone content) reflects the physical properties of the parent bedrock, particularly hardness. Slate, for instance, is fairly easily reduced to clay, and sandstone is reduced to sand, but granite, quartzite and other hard crystalline rocks tend to remain as pebbles and angular stones.

The spatial relationship of the deposit to the parent rock and also its form are determined by several factors: the direction of ice movement, the position of the material underneath or within the ice, the flow characteristics of the ice mass, the agent of deposition (i.e., the ice itself), meltwater or wind.

In this Topic, the character and distribution of terrestrial glacial deposits are covered in some detail, in order to provide a basis for later topics and habitat descriptions. Offshore glacial deposits are discussed in T3.6.

STRIAE

Evidence of ice movement is provided by grooves and scratch marks (striae) made by hard rocks as they were dragged across the surface of softer strata. Each phase of ice movement produces its own set of markings, and occasionally striae pointing in different directions can be found on the same rock surface. Glacial striae are common on exposed rock ledges, but particularly good examples can be seen

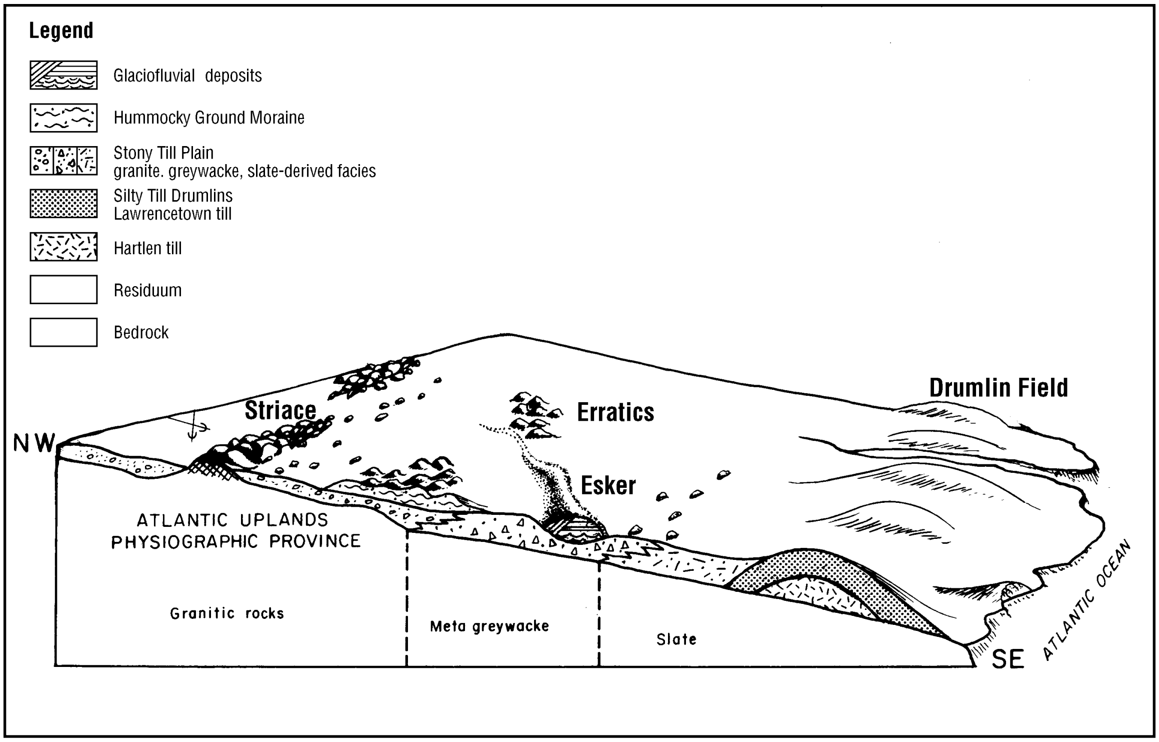

Figure T3.4.1: Cross section of the Quaternary deposits of the Atlantic coast of Nova Scotia.[1]

in Point Pleasant Park (Unit 851), at the Ovens Natural Park on the west side of Lunenburg Harbour (Unit 832), and on the south side of Lake Kejimkujik (Unit 412a).

ICE-FORMED DEPOSITS

Materials deposited directly by the glacier are known as till. They can be of many sediment sizes and are characteristically unsorted. Tills that relate to the four phases of ice flow not only overlie striated bedrock surface but at many locations they overlie older nonglacial and glacial deposits[1,2] (see Figure T3.4.1).

Ground Moraine or Till

Till is the general name given to the material scraped off or ground down from the bedrock. Glacial till is usually divided into a compact bottom or basal till, with a platy type of structure, and an upper, looser ablation till. Ground moraine is the till at the base of the ice that is left behind, more or less in place, like a mantle over the previously ice-covered landscape. It is often a structureless, unstratified deposit, but in some places consists of a lower compacted, smeared and relatively impervious layer of basal till. Basal tills derived from sedimentary or metamorphic rocks generally have a larger fraction of illite and smectite (swelling clays) than is found in granitic rocks. These clay minerals, which are derived from mica, will absorb more moisture than the clay minerals in granitic rocks, improving moisture and nutrient storage. Above the basal till, looser (sometimes sorted) ablation till is found.

Ground moraine usually reflects the character of the underlying rocks more directly than other glacial deposits. It is, for instance, likely to be fairly thin and with a high clay content over slates, very stony and often absent altogether over granite, and thick and loamy over soft lowland strata. The stone content is generally high, but variable.

The thickness of the ground moraine cover varies considerably across the province. In general, the thinnest deposits are found on high ground and over resistant rocks, whereas the thickest are in lowland areas and local depressions. The upper surfaces of the Cobequid Mountains (District 310) and Cape Breton Highlands (Region 100 and District 210) have very little glacial cover, while Cumberland County,

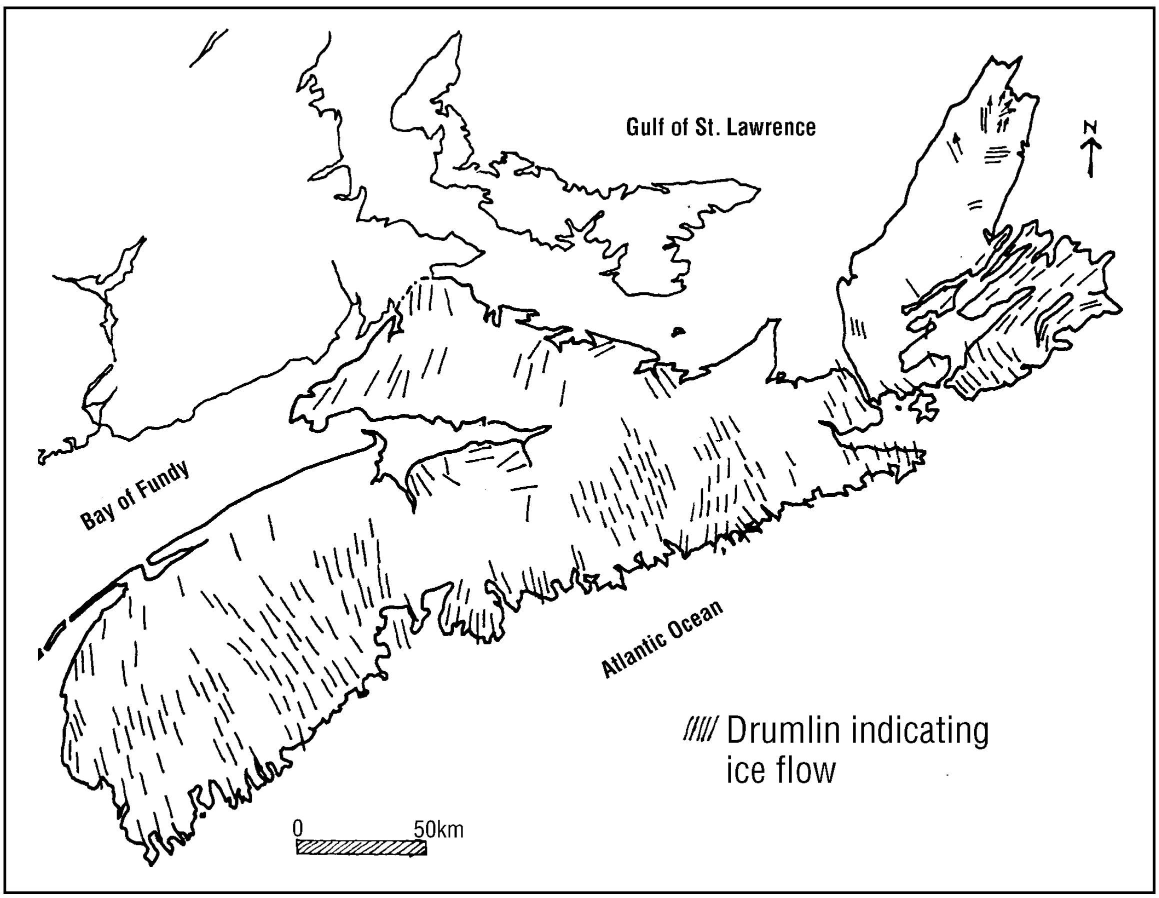

Figure T3.4.2: Orientation of drumlins in Nova Scotia.[3]

Hants County and the lowlands of Cape Breton have deposits tens of metres thick (Region 500). On the mainland, glacial deposits tend to thicken southwards, and coastal sections frequently show deposits which are 10 m or more in thickness.

At a smaller scale, the distribution of moraine reflects the way an ice mass responds to the underlying morphology. Local high areas may be swept clear, for example, Mount Uniacke and Halifax Airport, and the surrounding low spots filled in, for example, Miller Lake area (Districts 410, 430).

The drainage characteristics of ground moraine are determined by its thickness, its clay/sand/stone composition and the permeability of the underlying bedrock.

Drumlins

Drumlins were formed in Nova Scotia during the ice-flow Phases 1, 2 and 3 (see T3.3). The vast majority were formed during Phase 1, and later modified by Phase 2. Glacial till is often moulded into specially shaped hills called drumlins. These are frequently 15 to 30 m high, and may be more than a kilometre in length. Seen from above, they are generally egg-shaped and aligned parallel to the axis of ice movement, with the pointed end indicating the downstream direction of flow (see Figure T3.4.2).

Texturally, drumlin deposits range from sand to clay loam. They are not usually stratified in the strict sense, but may show a colour and textural variation from bottom to top as locally derived material is overlain by other material carried at a higher level in the ice. Drumlins typically contain scattered stones and boulders of various sizes; the deposits are generally uncompacted, well drained and easily eroded.

Drumlins seem to have a relatively high buffering capacity, which may result from the inclusion of sediment from the carbonate-rich rocks of the Carboniferous Lowlands (Region 500).

Drumlins are typically found in swarms in the Atlantic interior and coast (Districts 430, 830) and Cape Breton (District 870), where the heavily laden ice moved across level areas or down slopes. Most drumlins are associated with slate strata and are generally scarce once a granite or quartzite boundary has been crossed. In areas where slates and quartzites are interbanded, drumlin fields may cross the quartzite area but do not seem to incorporate much new material. The association of drumlins with slate areas is less clearly marked in the Halifax–Guysborough area than in southwestern Nova Scotia.

"Red" drumlins are found throughout the Atlantic interior and along the Atlantic coast. These distinctive landscape features are formed from materials carried from the Carboniferous Lowlands to the north. Red drumlins often occur together; the greatest concentration is in Lunenburg County, but they may also be seen north and east of Halifax Harbour and in isolated localities in Halifax and Guysborough Counties. On soil maps, these red drumlins are Wolfville soils. By contrast, drumlins formed from local slates are "grey" in appearance. A few isolated drumlins, composed of predominantly granite or quartzite rocks, are found in southwest Nova Scotia. Drumlins in Nova Scotia have been extensively farmed and settled.

Erratics

In a glacial landscape it is common to find large rocks or boulders resting in areas far distant from their source. The direction in which these lie relative to their parent rocks provides valuable evidence of the direction of movement of ice masses. Cobequid-type stones, for instance, are rarely found in the Carboniferous Lowlands but are common further south and form a large proportion of the rocks in the bed of the Salmon River at Truro, near Pictou and on Pictou Island. Similarly, igneous rocks from the Creignish Hills in Cape Breton are found to the east near Sydney. In western Nova Scotia granite and basalt are found in a wide area south of their respective outcrops on South Mountain and North Mountain.

WATER-LAIN DEPOSITS

As the ice melted, immense quantities of sands and gravel were released and sorted by the seasonal streams and rivers issuing from the front of the glacier or flowing across its surface. Eskers were formed by streams beneath or within the ice; kames formed in low areas on the ice surface; alluvial fans were built up where streams entered temporary lakes; and outwash plains developed in front of the glacier as the heavily burdened streams carried sand and gravel from the retreating ice front.

Eskers

Eskers are steep-sided ridges up to 30 m high, composed of poorly sorted sands, gravels and rounded cobble stones. They run across country for up to 10 km, sometimes at an angle to the existing water courses, but more often along rivers or natural drainage channels. Those eskers that seem to be superimposed on the topography probably formed within the ice and later slumped down; those that follow natural drainage channels formed at the base of the ice.

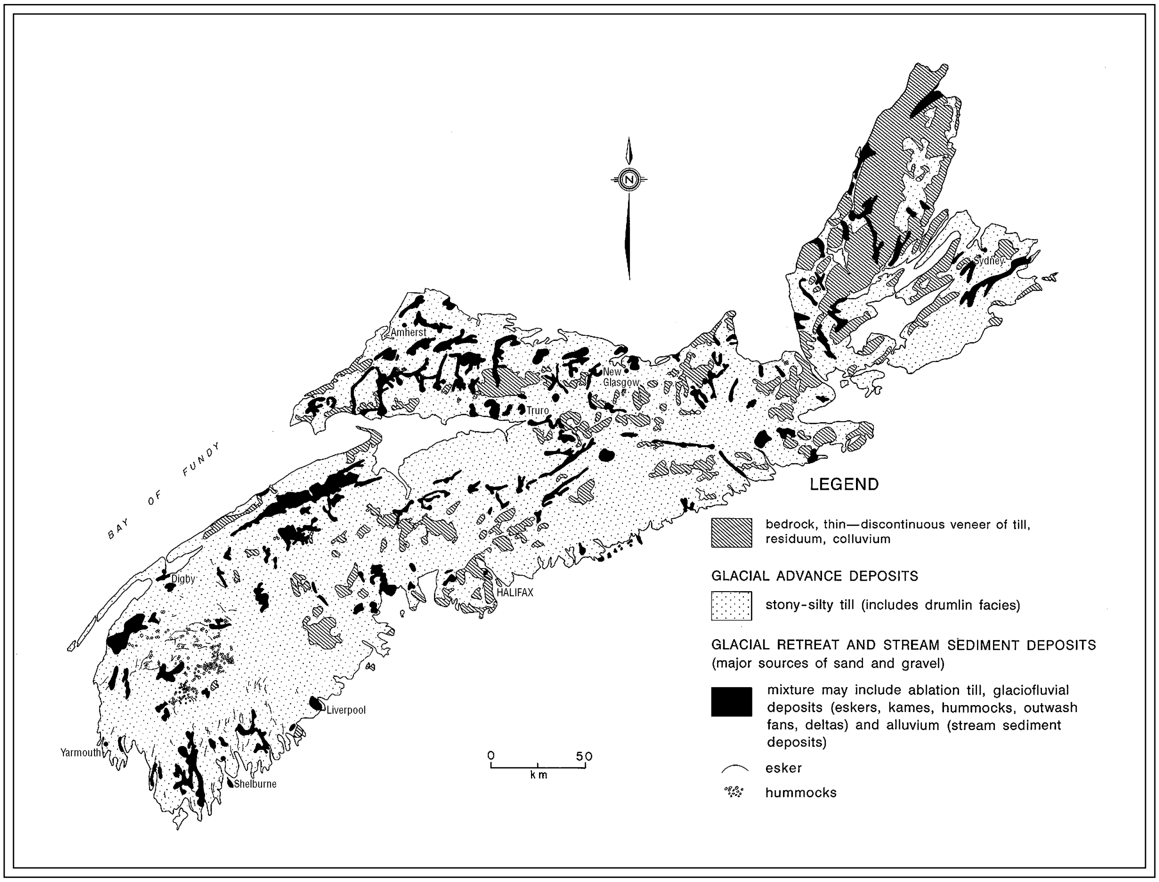

Figure T3.4.3: The simplified surficial geology map is divided into three groups or units. Pre-glacial material includes exposed or nearly exposed bedrock, residuum (weathered bedrock) and minor amounts of colluvium (a mixture of soil and rock derived from slope failure and creep). Glacial advance deposits consist of stony-silty till and includes the various drumlin-related facies.[4] Compiled by Nova Scotia Department of Natural Resources.

Eskers are rare in northern Nova Scotia but are common in the southwestern counties. One of the best known is the "Boar's Back," which runs for nearly 20 km from Halfway River along the west side of River Hebert in Cumberland County (Units 581, 532). The Sable, Jordan and Clyde rivers (Unit 412) in southwestern Nova Scotia each have eskers along some part of their courses. Eskers are also found inland, particularly near the edges of lakes. The maps listed in the references should be consulted for localities.

Kames and Kame Terraces

Kames are mounds of stratified sand, gravel and water-worn cobble stones which were deposited in pools and holes within the ice and along its margin. If the material is dropped from melting water flowing along the surface of the ice at the side of a valley, a kame terrace may be formed.

Kames and kame terraces are very common throughout the province; the terraces are particularly conspicuous along valleys and in water gaps. In northern Nova Scotia, good examples of kame deposits can be found in the Parrsboro Gap, the Folly Gap, Wentworth Valley, and along the divide between the Parrsboro River and River Hebert (Unit 311). Kame terraces are also found along the Gaspereau River in Kings County (Unit 422a) and south of Berwick and Aylesford (District 610). In Cape Breton, they occur along the Sydney River (Unit 585b). Most valleys in southern Nova Scotia have examples of kame deposits and many can be seen from the highways.

Outwash Deposits

The material carried away from the front of the glacier by streams is sorted and deposited over a wide area as fans, deltas and plains. The texture depends upon the ratio of sand to cobble stone, and the material is generally well drained. Thickness may vary within a fairly small area.

Outwash deposits are particularly thick where glacial meltwater was channelled through passes and down river valleys. Good examples are found south of the Parrsboro and Folly gaps and at the mouths of all the rivers between Truro and Parrsboro. They were also formed in the Stewiacke River valley and near the James River south of Antigonish. In Guysborough County, the river valleys were almost filled with sand and gravel. Indian Harbour River has deposits along most of its length, and Indian Harbour Lake has been cut off by a wide alluvial bar. Country Harbour and Isaac's Harbour have extensive deposits on their margins, while at New Harbour the inlet is divided into sandy bars by outwash material. In Cape Breton, outwash deposits can be seen in many valleys but are particularly well developed in the northern part of the Mira Valley and in most of the Margaree Valley.

Water-lain and Wind-sorted Sand

In the northwestern part of the province, the Annapolis–Cornwallis valley (District 610) is covered with fine sands. Some were deposited by streams, some in glacial lakes, and some were carried by the wind and deposited as dunes; the latter can be found in the area around Kingston. Loess, a fine wind-blown silt, is also found on the slopes of the South Mountain between Middleton and Nicholsville and in the vicinity of Debert. Farther west, deltas were formed near Bear River and at Sandy Cove on Digby Neck.

Water-sorted glacial deposits provide potential reserves of sand and gravel and have been mapped as such by the Nova Scotia Department of Natural Resources, though not always with their morphological name attached (an example of sand and gravel extraction is shown in Plate T12.4.1).

KARST TOPOGRAPHY

Karst topography is a landscape feature characteristic of highly soluble bedrocks (such as limestone) and evaporite deposits (such as gypsum and anhydrite). In the Carboniferous Lowlands, gypsum underwent erosion during the Tertiary and planation during glaciation. Glacial tills covered much of the eroded gypsum, but sinkholes and disappearing streams reveal the presence of ancient karst topography. Karst features are very visible wherever gypsum is mined, and where streams and rivers have removed surficial sediments to expose gypsum, for example, at St. Croix, where erosion on the bluff has revealed the gypsum.

Karst surface conditions are characterized by conspicuously pitted topography. This uneven surface impedes forestry and has contributed to the fact that some very old coniferous forests still grow at places like Dutch Settlement and Hayes Cave. The ground

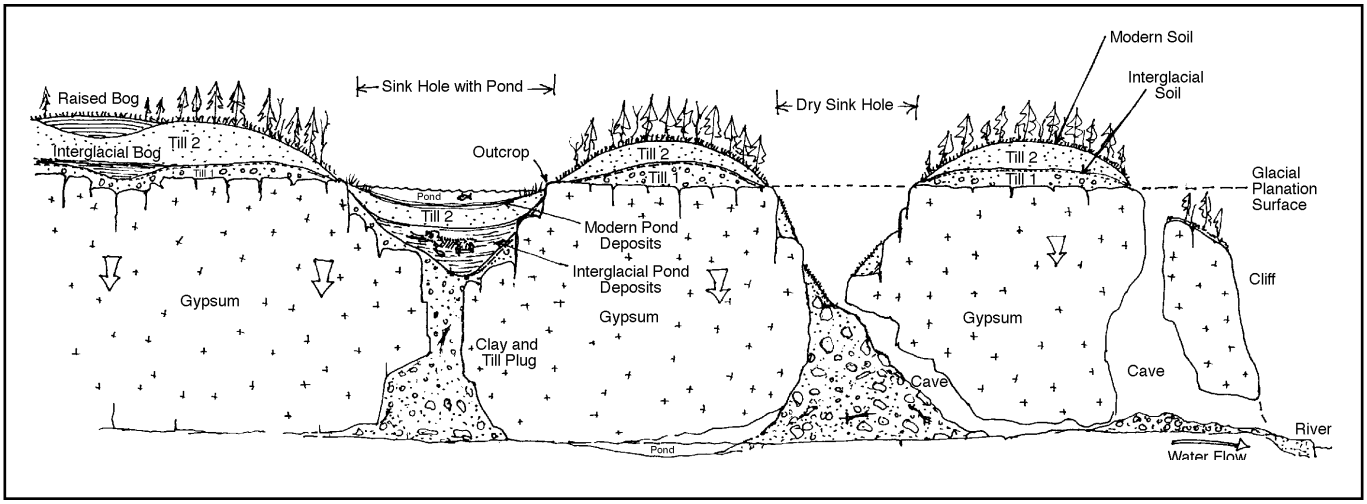

Figure T3.4.4: Diagrammatic cross section of karst features on gypsum in Nova Scotia, based upon examples at South Maitland, Hants Co., and Dutch Settlement, Halifax Co. (Unit 511a).

flora and fauna associated with karst is characterized by calcium-loving plants and various species of land snail.

The Hayes Cave site at South Maitland (Unit 511a) has several typical karst features, such as the cave itself, sinkholes and a collapsed cave system. Groundwater solution contributed to the erosion of the gypsum, creating sinkholes. The ancient stream channels and sinkholes were subsequently infilled and have been preserved as solution-collapse and cavity-fill structures.[5] Caves are important hibernacula for bats and other mammals (see Figure T3.4.3).

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Associated Topics

T3.3 Glaciation, Deglaciation and Sea-level Change, T3.5 Offshore Bottom Characteristics, T9.1–T9.3 Soils, T10.12 Rare and Endangered Plants, T11.16 Land and Freshwater Invertebrates, T12.4 Glacial Deposits and Resources

Associated Habitats

H5.3 Cliff and Bank, H5.5 Cave

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2 Mott, R.J., and D.R. Grant (1985) “Pre-Late Wisconsinan paleoenvironments in Atlantic Canada.” *Geographie Physique et Quarternaire* 39: 239–54.

3 Cameron H.L. (1966) *Glacial Landforms in Nova Scotia*. Nova Scotia Research Foundation. (Map).

4 Stea, R.R., H. Conley and Y. Brown (compilers) (1992) *Surficial Geology of the Province of Nova Scotia*. Nova Scotia Department of Natural Resources. (*Map* 92–3), Scale 1:500 000.

5 Morris, L., ed. (1985) The Hayes Cave Site, South Maitland, Nova Scotia. Nova Scotia Museum. (*Curatorial Report* No. 50).

Additional Reading

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• References in T3.3 Glaciation.