Glaciers of the Northeastern US:
a brief review

The Quaternary period began 1.8 million years ago and was marked by a series of advances and retreats of successive enormous ice sheets that originated in the Hudson Bay area of Canada. The Quaternary period is divided into two epochs: the Pleistocene and Holocene *(Figure 3.1)*. The Pleistocene is simply the equivalent of the Quaternary minus the most recent (and current) interglacial interval, the Holocene. Ice age conditions existed when the ice sheet advanced over the North American continent; interglacial or warming periods existed when the ice sheet retreated north. Advances of the ice sheet over the northern United States occurred several dozen times over the course of the Pleistocene epoch of the Quaternary.

The most recent glacial advance reached its maximum extent 25-20,000 years ago and had an enormous impact on the Northeast. The glaciers blanketed much of the region with glacial deposits, challenging agriculture with rocky fields; limestone ridges, however, were ground and spread, increasing soil quality south of limestone outcrops. The topography was sculpted and drainage patterns shifted by the scouring action and deposits of the glacier. Abundant and easily mined sand and gravel also resulted from glacial deposits. Marks left behind by the glaciers on the high peaks of the Adirondacks and New England mountains tell us that the ***glaciers*** reached a thickness of between 1 and 2 kilometers, covering the tallest peaks in the Northeast. By 10,000 years ago, the ice had fully retreated from the Northeast. This ice-free interval, which we are in currently, is called the Holocene or Recent. Although all glacial advances had impacts on the surface of the Northeast, the effects of only the last ice sheet are well documented, since each succeeding glacial advance erodes and smears the record of the previous advance.

The ice sheets are a form of glacial ice. As snow falls and is compacted, individual snowflakes become smaller, rounder and thicker, changing to granular snow. Upon further burial, compaction and cementation from recrystallized meltwater, the granular ice is changed to ***firn***. When the firn has been buried to a depth greater than 30 meters, ice flow occurs, causing subsequent deformation. The firn recrystalizes to glacial ice, forming interlocking ice crystals, just as

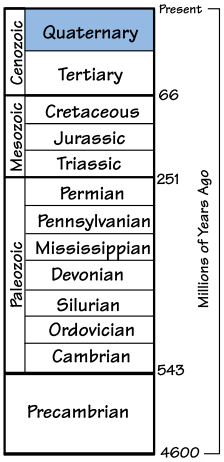
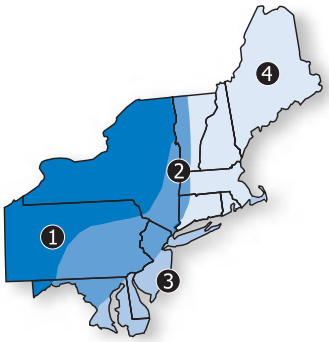


Figure 3.1: Geologic Time Scale (not to scale).

Glaciers *are a build-up of snow, firn and ice, partially or wholly on land, which move downhill under their own weight.*

Firn *is a transitional form between granular and glacial ice.*



Glaciers

see Rocks, p.29, for the **rock** *cycle.*

sedimentary rocks are recrystalized to form metamorphic ***rocks***. As snow accumulates, packs down, and is converted to glacial ice, the weight of the accumulating snow causes the underlying glacial ice to flow out in all directions from the center. Like water, ice flow is driven by gravity, and moves downhill.

There are two types of glaciers: smaller-scale valley glaciers and large-scale ice sheets. Found in mountainous regions at high altitudes, valley glaciers form by erosive action in bowl-shaped scours called cirques and flow down pre-existing valleys on high altitude mountains. Ice sheets occur on a much larger scale, spreading from a central point outward in all directions across a continent. ***Greenland*** and ***Antarctica*** currently have ice sheets similar to the one that stretched over North America 20,000 years ago.

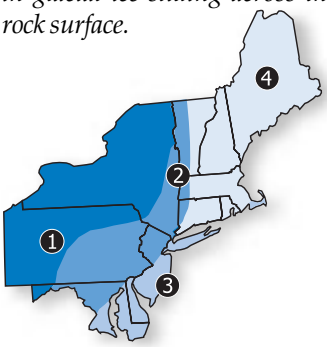
The **Greenland** *and* **Antarctica** *ice sheets make up 95% of all the current glacial ice on the planet.*

Glaciers will only form in specific environments. They require adequate snowfall so that each year more snow is accumulating than melting. This allows for the build-up and compaction of snow that will gradually become glacial ice. Thus, cold climate and sufficient moisture in the air for the precipitation of snow are both necessary for the formation of a glacier. Cold climate conditions exist at high altitudes and high latitudes. It is not surprising that the ice sheets of today are in the high latitude polar regions of Greenland and Antarctica, where temperatures are low. For continental ice sheets to occur, there must be landmasses over the high latitudes, since flowing ice will not form over open water.

Very fine sediments and clay resulting from the grinding action of glaciers is called **rock flour**.

Meltwater from the glacier enters cracks in bedrock beneath the ice sheet and freezes, expanding the cracks and breaking up the bedrock. The glacier then **plucks** *the sediments from the bedrock.*

Long, parallel **scratch** *marks that look like pinstripes on a rock are called striations. Striations result from the grinding sediments in glacial ice sliding across the rock surface.*



Glacial Scouring

The ice sheet left its mark in many ways on the Northeast, resulting in many noticeable topographic features. As the 1-2 kilometer thick glacier advanced forward, flowing under its own weight from the center of accumulation, it scraped and scoured the crust beneath. Boulder- to clay-sized sediments were ***plucked*** from the underlying bedrock and soil. The glaciers incorporated this sediment into the glacial ice or bulldozed it forward in front of the advancing ice. Sediments in the glacial ice acted like coarse sand paper, scouring and scraping the bedrock beneath. Sediments and less resistant sedimentary rocks over which the glacier moved were often eroded and ground-up into very fine sediment and clay (called **rock flour**). More resistant igneous and metamorphic rock was often polished and ***scratched*** by the grinding action of the sediments in the glacial ice. Knobs of resistant rocks, polished by the glaciers, are common in the

Northeast. Streams of meltwater from the glacier, frequently gushing and full of sediment, caused significant amounts of scour as well. The abrasive sediments in the flowing water created ***potholes*** in the bedrock and ***plunge pools*** at the base of waterfalls.

When sediment-laden water wears away bedrock in swirling eddies it forms **potholes** *and* **plunge pools** *at the base of waterfalls.*

Valley glaciers, flowing from the high mountains in the Adirondacks, Catskills and New England, originated near the peaks in bowl-shaped scours called ***cirques***. Though the mountains are now free of glacial ice, the distinctive scoop-like cirques are still visible in some peaks in the Northeast. (Tuckerman's ravine in New Hampshire is a cirque.) Scouring by the valley glaciers and the ice sheet that covered the mountains eroded a great deal of bedrock, rounding out and shortening the mountains, sometimes by hundreds of meters.

Valley shapes

A river cutting through bedrock tends to make a V-shaped valley, as it erodes deeper and deeper towards sea level. A glacier, on the other hand, makes a U-shaped valley as a tongue of ice cuts through bedrock. Often, glaciers flow down pre-existing river valleys, reshaping them to broader, deeper, U-shape valleys. Unlike a river that erodes to sea level, a glacier may form valleys that are deeper than sea level.

How do we know the mark of glaciers?

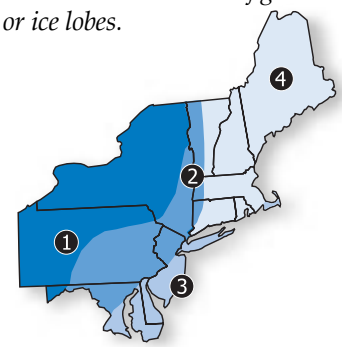
How do we know that striations, polish, scoured basins, U-shaped valleys and the variety of deposits attributed to glaciers are in fact a result of glacial action? Before the modern understanding of the ice ages, many believed that the features now attributed to glaciers were the result of a great flood similar to the story of Noah and the Ark in the Bible. By studying modern glaciers, however, geologists have come to understand the resulting features of glacial scour and deposition that are readily identified in much of the Northeast. Modern glaciers include the large-scale ice sheets in Greenland and Antarctica as well as the small-scale valley glaciers found in mountain ranges in places such as Alaska, Canada and the Alps.

Glacial Deposits

In an action similar to a bulldozer, the glacier plowed over the land. As it moved forward, the glaciers scraped up earth and pushed ahead piles of sand, gravel and broken rock to form characteristic glacial deposits *(Figure 3.2)*. The unsorted mixture of boulders, gravel, sand, silt and clay picked up and later deposited by glaciers is called ***till***. Where the bulldozing glacier stopped its advance for a time and then melted back, the ridge of till that had been pushed in front of the glacier was left behind, marking the end or terminus of the glacial advance. The ridge of till is called a ***moraine*** and ranges in length from hundreds to thousands of meters. Till that has been molded and reshaped by the underside of an advancing glacier into a streamlined, elongated hill is called a drumlin. This is till that has been trapped underneath the glacier, and has thus been deformed by the ice flowing above. The elongated shape of a drumlin is parallel to the direction of ice flow, and thus an excellent clue to determine the flow of the ice sheet

The term **till** *originated with farmers living in glaciated areas who were constantly removing rocks from their fields (and building the famous stone walls of New England.) The rocks are deposits of cobbles and gravel left by the glaciers that made it more difficult to farm parts of the Northeast.*

Many **moraines** *mark the terminus or edge of the glacier. Lateral moraines may also occur in between and at the sides of glaciers or ice lobes.*



Well-sorted *deposits have relatively uniform grain size.*

A **braided stream** *carries more sediment than a typical stream, causing the formation of sandbars and a network of crisscrossing streams.*

Eskers *are sinuous, elongated ridges of sand and gravel. They are found in many parts of the glaciated Northeast, and are often mined for their well-sorted sand and gravel.*

Erratics *are often distinctive because they are a different type of rock than the bedrock in the area to which they've been transported. For example, boulders and pebbles of igneous and metamorphic rocks are often found in areas where the bedrock is sedimentary; it is sometimes possible to locate the origin of an erratic if its composition and textures are highly distinctive.*

during its most recent advance.

Meltwater flowing off the glacier also left behind deposits. Unlike till deposits, meltwater deposits are ***well sorted***, just as other rivers and streams have well sorted layers of sediment. As the glacier melted, streams of sediment-laden meltwater poured off the ice, often creating networks of ***braided streams*** in front of the glacier. Streams of meltwater flowing under the glacier deposited sand and gravel. When the ice sheet retreated, these ridges of meltwater stream deposits, known as ***eskers***, were left standing.

Other glacial features include kettles, kames and erratics. Kettles are ponds or depressions left behind by the melting glacier. Blocks of ice broken off from the glacier often were buried or surrounded by meltwater sediments *(Figure 3.3)*. When the ice eventually melted, the overlying sediments had no support, collapsing to form a depression that often filled with water to become a lake. Many kettle lakes and ponds are found throughout the glaciated Northeast. Kames are mound-like deposits of sediment from the melting glacier. ***Erratics*** are rocks that the ice sheet picked up and transported further south as it moved over the continents.

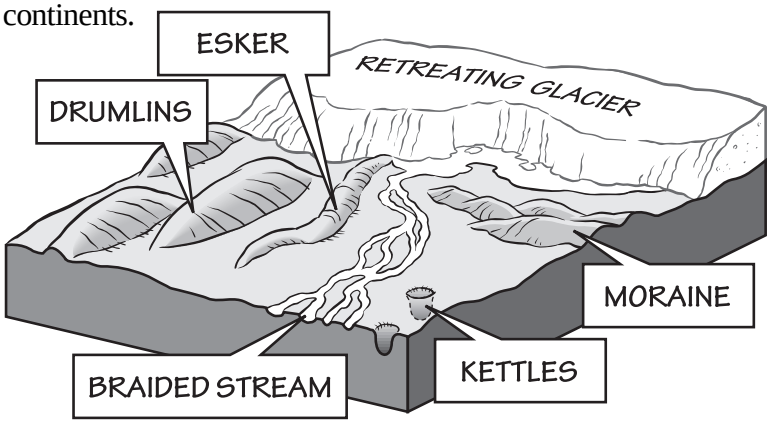
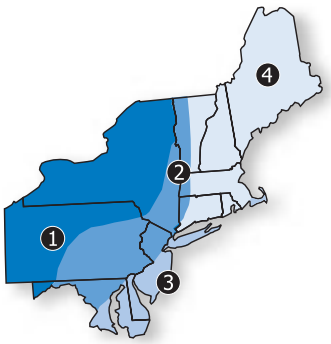


Figure 3.2: Glacial deposits. Figure by J. Houghton.



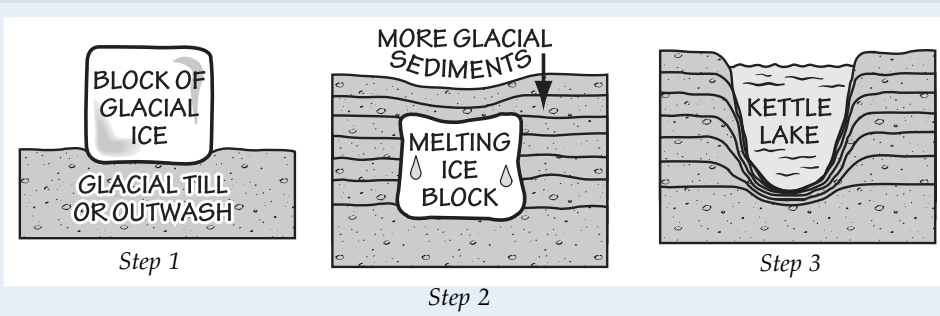


Figure 3.3: Formation of a kettle lake. Figures by J. Houghton.

Periglacial Environments

Though not all of the Northeast was covered by the ice sheet, the entire region felt its effects. The region covered by the ice sheet was scoured and covered with glacial deposits; the region south of the ice sheet has its own distinctive landscape and features because it was next to the ice margin. This unglaciated but still affected zone south of the ice sheet is called the ***periglacial*** zone.

There are a variety of features associated with a periglacial zone that also provide clues to the extent of the most recent ice sheet. In the tundra-like environment of a periglacial zone, ***eolian*** deposits are common. Sand dunes and wind-transported sediments are found in former periglacial areas and in glacial lake bottoms of the Northeast. The permafrost associated with the periglacial area, in which the ground is frozen much of the year, can cause mass movement of sediment. When the surface layer of the permafrost ground thaws, it is full of moisture. This water-heavy layer of soil may move rapidly down a hill in a process called ***solifluction***. ***Physical weathering*** of the bedrock is magnified in the periglacial environment because of the freeze-thaw cycles associated with permafrost. When water enters the cracks and fissures in the ground and subsequently freezes, the ice wedges the cracks further and further apart *(Figure 3.4)*. Because ice takes up more space than water, the pre-existing cracks and fractures are widened when the water freezes. Along ridges, rocks are eventually broken off as ice wedges continue to expand in joints and fractures. The boulders and blocks of bedrock roll downhill and are deposited along the slope or as fields of ***talus.*** Especially in the Appalachian/Piedmont region, talus blocks are carried far down slope and are found as fields of boulders. Frost action also brings cobbles and pebbles to the surface to form nets, circles, polygons and garlands of rocks. These unusual patterns of sorted rock are known as ***patterned ground.*** Solifluction and ice wedging are found exclusively where the ground remains perennially frozen, yet is not insulated by an ice sheet. Such conditions only occur in areas adjacent to ice sheets.

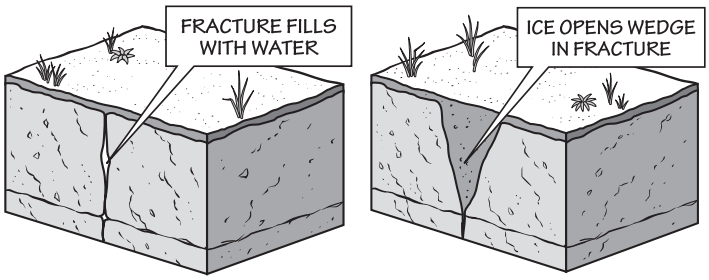


Figure 3.4: Physical weathering from freeze-thaw cycles. Figures by J. Houghton.

The average annual air temperature in a **periglacial** *area is between –12° and 3°C. Though the surface of the ground may melt in the summer, it refreezes in the winter. When the ground surface has remained frozen to a certain depth for most of the year, it is called permafrost.*

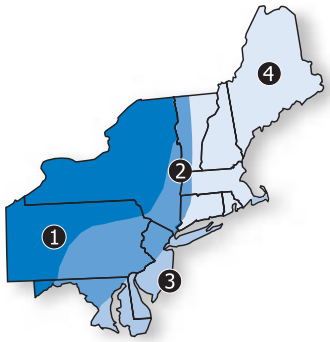
Eolian *means wind. Sediments that have been* wind transported *are often polished, giving them a 'frosty' appearance.*

Solifluction *is similar to a landslide or mudslide (which are triggered by things other than permafrost).*

Physical weathering *is the break-up of rock due to physical processes (such as erosion by wind, water and ice) rather than chemical processes.*

Talus, *or block-fields found on the sides of steep slopes, are common in periglacial environments.*

As the ground freezes and thaws, the rocks and pebbles in the soil are repeatedly heaved upwards and then settled. This movement of the material in the soil causes sorting and **patterns** *to occur.*

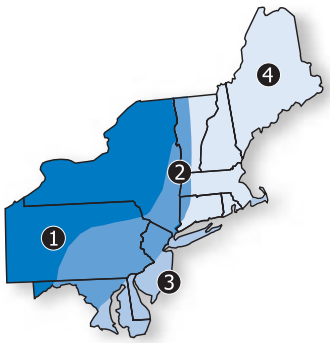


Why was there an ice age?

Scientists continue to debate the causes of the glacial advances and retreats in North America over the last 2 million years. Movement of the Earth's plates may have been a direct or indirect cause of the glaciation. As plates shifted, continents moved together and apart, changing the size and shape of the ocean basins. This altered the oceanic currents and subsequent wind currents. Mountain building, occurring when continents collided, put up obstacles to prevailing winds and changed moisture conditions.

An ice **dome** *is the spreading center for an ice sheet. Glacial ice flows outward from the ice dome, where snow continues to accumulate, like pouring pancake batter into a frying pan.*

Calving *refers to the breaking of chunks of ice from the ice sheet into the ocean.*



The Pleistocene

Whatever its cause, a cooling climate triggered the start of a series of ice ages shortly before the Pleistocene began. The most recent ice age before the present interglacial period began 65,000 years ago and affected the Northeast until 10,000 years before the present. Initially, the ice was spreading from a single ***dome*** located in northern Canada over the Hudson Bay. Twenty thousand years ago, this ice sheet reached its maximum extent, as far south as Long Island and northern Pennsylvania in the Northeast.

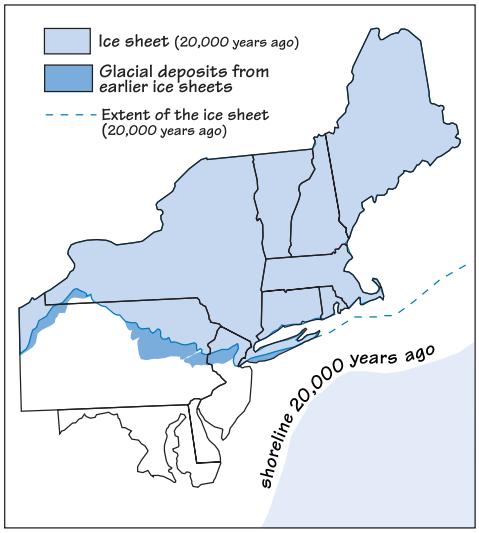


Figure 3.5: The approximate position of the ice sheet 20,000 years ago. After Hughes, T., et al, 1985.

The formation of glaciers comes from precipitation of water originating from evaporation of ocean water. Thus, significant glacial build-up ties up water in ice sheets, causing a sea level drop. During the Pleistocene glacial advances, sea level dropped an estimated 110 meters! The coastline of the east coast was an estimated 100 kilometers east of its present location 20,000 years ago *(Figure 3.5)*.

By 18,000 years ago, the ice sheet was in retreat because of a slight warming of the climate *(Figure 3.6)*. Melting ice caused the ice sheet to begin ***calving*** into the St. Lawrence River and the Gulf of Maine, raising sea level. Though the ice sheet alternately moved forward and melted backward, overall it was on the retreat. Even during full glacial times, the glacier was always melting at its fringes. During times of glacial retreat, the ice sheet was not flowing backwards. The glacier continued to flow forward, but it was melting faster than it was advancing.

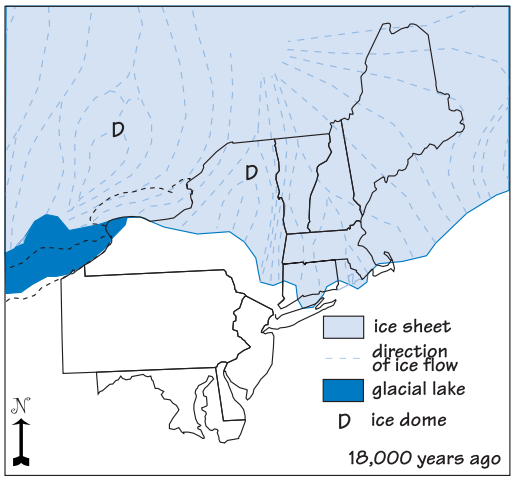


Figure 3.6: The approximate position of the ice sheet 18,000 years ago. After Hughes, T., et al, 1985.

By 14,000 years ago, sea level had risen so high that the ocean flooded the St. Lawrence River. The formation of the ***St. Lawrence Seaway*** cut off the glacial ice that covered much of Maine. Continued melting left the Northeast free from the ice sheet 10,000 years ago. Though the crust was ***rebounding*** now that the heavy glacial ice was gone, continued melting of the ice sheet caused sea level to rise faster than the crust.

Sea level rise and the slowly rebounding crust caused the Northeast coastline and inland lakes to be flooded. Lake Champlain, many times larger than it is now, was flooded by ocean water to become the Champlain Seaway. The basins scoured by the glaciers to form the ***Great Lakes*** were flooded by meltwater and formed lakes with boundaries much larger than today *(Figure 3.7)*.

Figure 3.7: The approximate position of the ice sheet 12,000 years ago. After Hughes, T., et al, 1985.

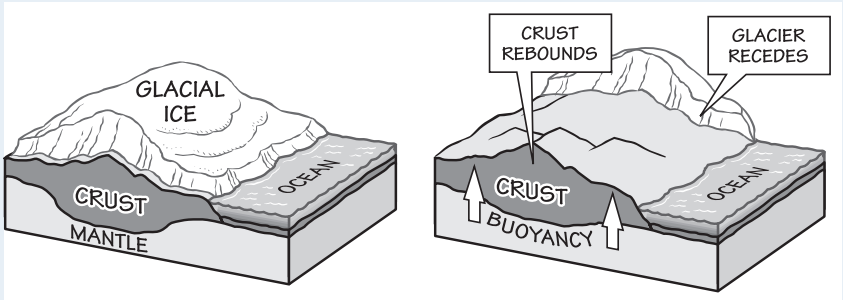
When the melting ice sheet uncovered the St. Lawrence River, the river valley was flooded with ocean water from rising sea level and became the **St. Lawrence Seaway.** *Maine was left with its own local icecap and spreading center from which ice flowed in all directions (even, strange as it may seem, north!). Though the ice sheet continued to radiate from the Hudson Bay ice dome, there were several other smaller ice domes throughout the ice sheet from which glacial ice flowed as well.*

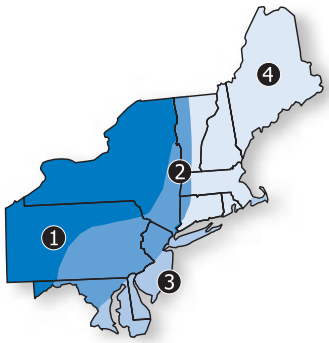
Prior to glaciation, the **Great Lakes** *were river valleys that had been scoured and deepened repeatedly by the many ice advances during the Quaternary period. Many sizable glacial lakes were formed at the edge of the melting glacier that no longer exist today or have significantly shrunk in size.*

Glacial Scouring

Rebounding of the crust

A 2 kilometer thick ice sheet can weigh quite a bit. The enormous weight of the ice sheet over the continent depressed the crust into the asthenosphere just as the weight of a person in a canoe causes the boat to ride lower in the water. When the person steps out of the canoe, the buoyancy of the canoe allows it to once again rise. When the ice sheet retreated from the Northeast during the most recent ice age, the crust rebounded and continues to do so today. However, the crust could not rebound as fast as sea level was rising from the melting glaciers. The result was flooding of the coast and glacial lakes. The rebound of the crust when it is freed from overlying ice is known as isostasy. Figures by J. Houghton.





Glacial Features of the Inland Basin

Region 1

Excellent examples of glacial scouring are found in the Inland Basin region of the Northeast. Lakes Ontario and Erie were formed by the scouring action of glaciers. The broad, deep basins of Lakes Ontario and Erie, former river valleys, were scooped out by tongues of ice as the glacier advanced over North America. When the glacier began its retreat, meltwater flooded lake basins. Lakes Ontario and Erie were both much larger than today. Glacial meltwater poured into these basins, and the ice blocked drainage that would eventually flow to the northeast via the St. Lawrence River. The Erie and Ontario Lowlands, as well as the once-flooded Mohawk River Valley south of the Adirondacks, are the remains of the much larger lakes. Flat, lowland topography and characteristic lake bottom sediments are found in the areas where the lakes once reached.

The Finger Lakes region of New York was also formed by glacial scouring *(Figure 3.8)*. The Finger Lakes were pre-existing river valleys before the tongues of ice covered the area and widened and deepened the valleys. The stream valleys were dammed at their southern end by glacial till and flooded to form the Finger Lakes when the ice sheet retreated. Whereas streams only erode as far down as sea level, glaciers are able to erode more deeply. The bottoms of two of the Finger Lakes (Lakes Seneca and Cayuga) are actually below sea level.

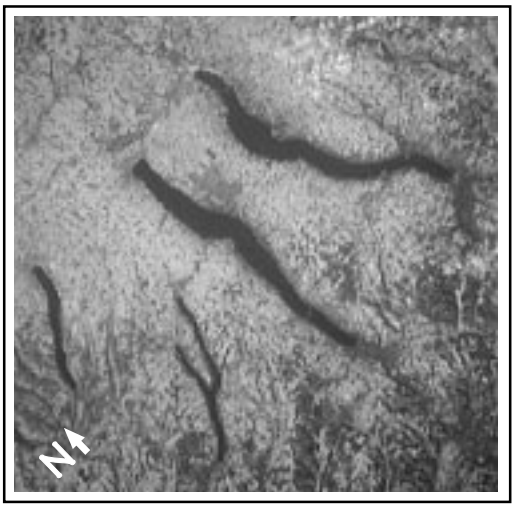
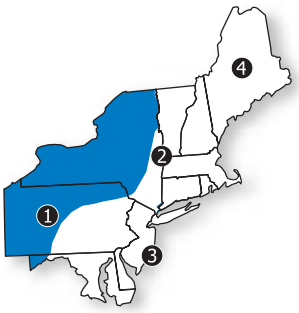


Figure 3.8: A view of the Finger Lakes region glacially carved lakes from the Space Shuttle.
Image courtesy of Alan Spraggins, NASA, JPL, Houston.

The bottoms of Seneca (193 meters deep) and Cayuga (132 meters deep) Lakes are deeper than sea level.



The Finger Lakes region is famous for its numerous gorges, which also resulted indirectly from the glaciers of the Laurentide ice sheet. After the glaciers retreated, or began retreating, tributary streams began running into the Finger Lake Valleys. The erosive force of the glaciers, however, considerably deep-

ened these valleys. Thus, tributary streams were left hanging far above the lake surface, forming a series of waterfalls and cascades all along the Finger Lake Valleys. These stream valleys are called ***hanging valleys*** *(Figure 3.9)*. In a matter of only several thousand years, deep erosion by the tributary streams has moved many of the waterfalls hundreds of meters back away from the edge of the Finger Lake Valleys and created beautiful long, narrow gorges *(Figure 3.10)*. It is possible, though not always easy, to document that some gorges were formed during one or more previous glacial advances and simply re-excavated and further eroded since the last glacial event; some gorges formed during previous glacial advances were buried by sediment (till) in the most recent glacial advance and have not been re-excavated.

The tributary streams rapidly eroded the valley trying to reach the new base level in the Finger Lake Valleys. Resistant rock units have temporarily slowed the stream erosion, and the waterfalls remain.

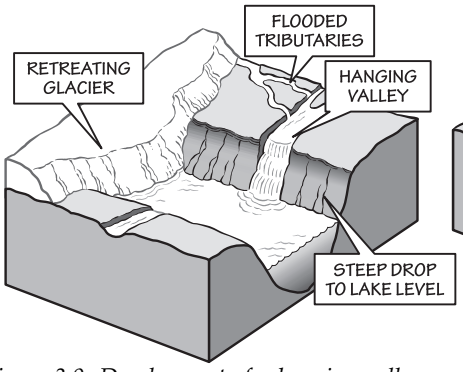


Figure 3.9: Development of a hanging valley following glacial retreat. Figure by J. Houghton.

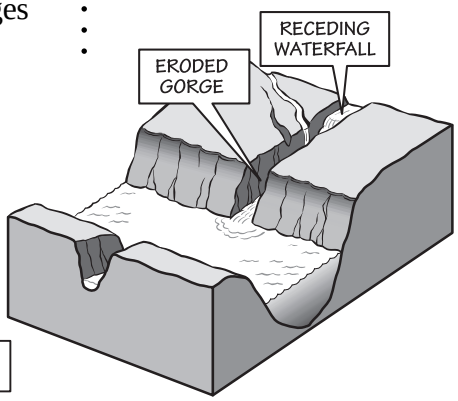


Figure 3.10: Development of a post-glacial gorge as in the Finger Lakes of central New York. Figure by J. Houghton.

Glacial Deposits

In addition to a blanket of till over the region, glacial deposits in the Inland Basin Region include abundant drumlins and moraines south of the Finger Lakes *(Figure 3.11)*. Between Rochester and Syracuse in the Ontario Lowlands are more than 10,000 drumlins. The drumlins are an important clue in determining the direction of flow of the most recent advance of the ice sheet. The Ontario Lowland drumlins are all generally oriented north to south, providing solid evidence that the glaciers flowed south over the landscape.

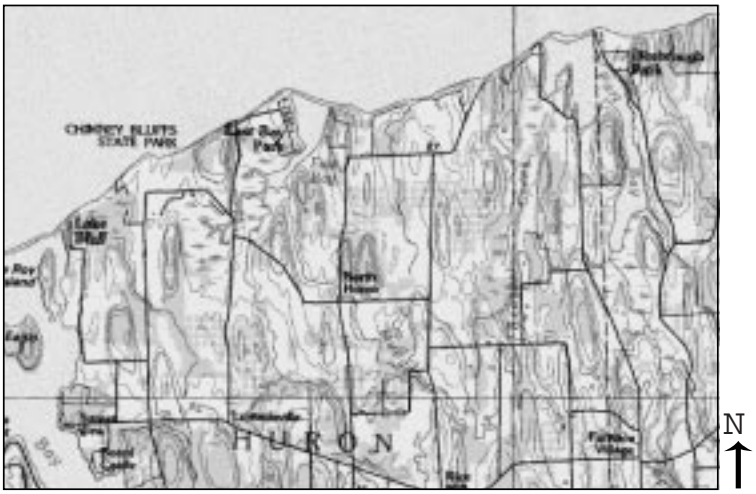
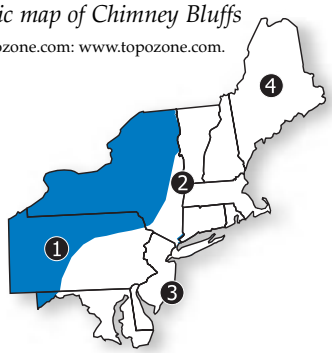


Figure 3.11: Drumlins on the topographic map of Chimney Bluffs State Park, New York. Image provided by Topozone.com: www.topozone.com.

The terminal moraines in the Inland Basin include the Kent and Olean Moraines in Pennsylvania and the Valley Heads Moraine in New York *(Figure 3.12)*. The Valley Heads Moraine is significant because it divides the St.



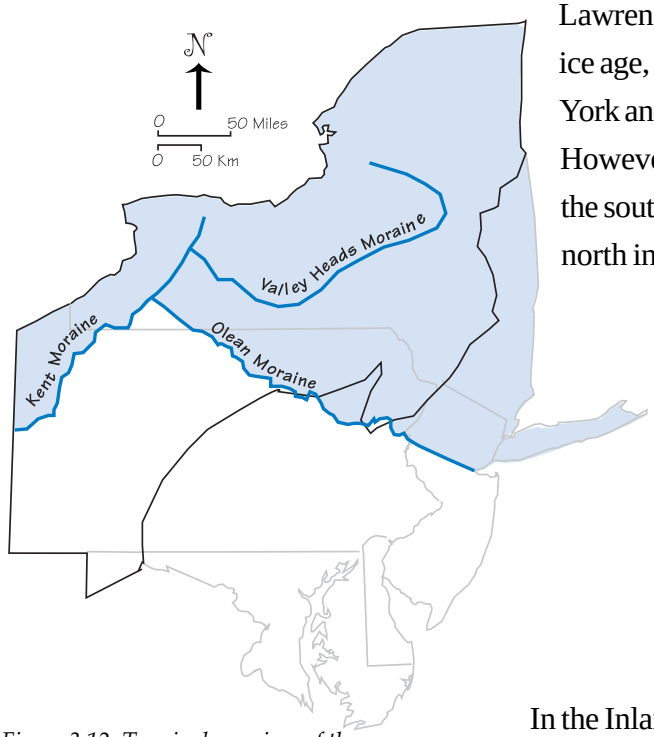


Figure 3.12: Terminal moraines of the Inland Basin. Light blue represents the maximum extent of the most recent ice sheet.

Lawrence and Susquehanna drainage basins. Before the most recent ice age, many streams of the Inland Basin region (especially in New York and Pennsylvania) flowed south into the Susquehanna River. However, the Valley Heads Moraine, blocked the flow of water to the south, damming the Finger Lakes and forcing streams to drain north into the St. Lawrence River Valley *(Figure 3.12)*.

Varves:
glacial lake deposits
Thinly bedded, very fine-grained sediments or clay characterize the deposits of glacial lakes that have shrunken considerably or disappeared. Coupled laminations of light and dark sediments, called varve deposits, are common lake-bottom features. The light bands represent summer deposits in the lake, whereas the dark layers represent winter deposits. The dark color in varved layers is attributed to an abundance of organic material.

Periglacial Features

In the Inland Basin, a small area of southern New York, most of Pennsylvania and all of Maryland were left ice-free. Much of this region not covered by the ice sheet was periglacial, showing characteristic features of permafrost *(Figure 3.13)*. Throughout Pennsylvania and parts of Maryland are evidence of solifluction (permafrost-area mudslides), patterned ground and boulder fields.

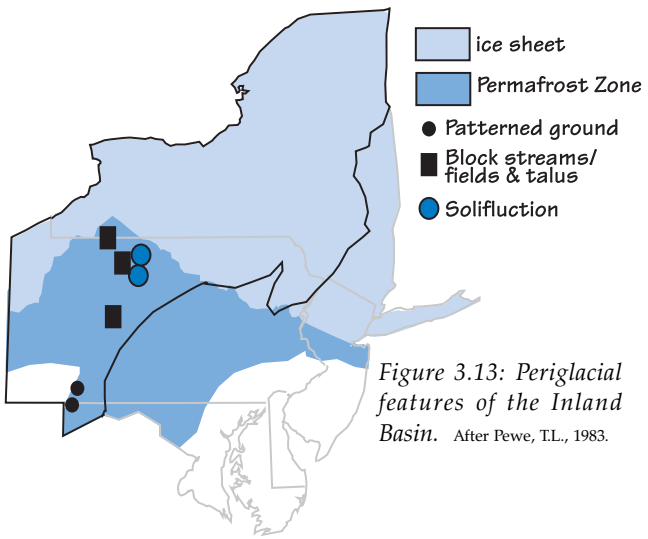
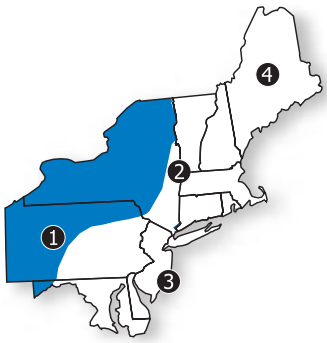


Figure 3.13: Periglacial features of the Inland Basin. After Pewe, T.L., 1983.



Glacial Features of the Appalachian/Piedmont

Region 2

Glacial Scouring

Glacial scouring, resulting from the scraping action of the glacial sediments, have formed two classic glacial features in the Appalachian/Piedmont region: potholes and lake basins. Archbald Pothole State Park near Scranton, Pennsylvania is one of the largest glacier-scoured ***potholes*** in the world, measuring approximately 13 meters wide and 12 meters deep. While not always caused by glacial runoff, smaller potholes are found throughout the once glaciated areas of the Appalachian/Piedmont as well as other regions of the Northeast.

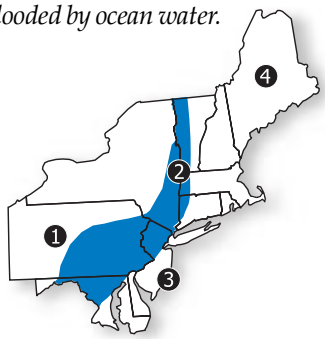
In order to form such an enormous **pothole**, *scouring conditions must last for quite some time.*

In the Appalachian/Piedmont, the glaciers of the Laurentide ice sheet scoured and the meltwater flooded two major lake basins: Lake Champlain and the former glacial Lake Albany. The edge of Lake Champlain was 15-30 kilometers east of its present shoreline during the ice age. The shoreline once extended as far east as the Green Mountains (and in some areas even beyond). Examination of the ancient shorelines left by the glacial Lake Champlain shows clear evidence for rebound of the land after the removal of the ice sheet. More than 150 meters of rebound is evident by looking at the once horizontal shorelines of glacial Lake Champlain. The Champlain Lowlands, with their low elevation and minimal relief, show the extent of the glacial Lake Champlain. Fourteen thousand years ago, the receding glaciers caused a rise in ocean levels. Because northern New England was just becoming ice-free, the crust was still depressed, not having had enough time to rebound. As a result, the St. Lawrence Seaway and Lake Champlain were flooded with encroaching ocean waters. Thus, it is not surprising that marine ***fossils*** were found in the lakebed sediments, such as Vermont's state fossil, the Charlotte Whale.

see Fossils, p.98, for other ice age **fossils.**

The Hudson River Valley, also deepened and broadened by the ice sheet advance, was likewise flooded when the glaciers began to melt. Glacial Lake Albany was formed when the lowlands flooded, though the lake does not exist today. *Evidence* of the lake does exist, however. The glacially scoured, narrow and deep Hudson River is a ***fjord***, similar to the fjords of the Netherlands. Ocean water extends up the river valley with the tides as far north as Poughkeepsie, New York.

A **fjord** *is a deep and narrow, glacially scoured valley that is flooded by ocean water.*



Glaciers

Glacial Deposits

The most significant glacial deposits in the Appalachian/Piedmont region are the moraines that stretch across northern Pennsylvania and New Jersey *(Figure 3.14)*.

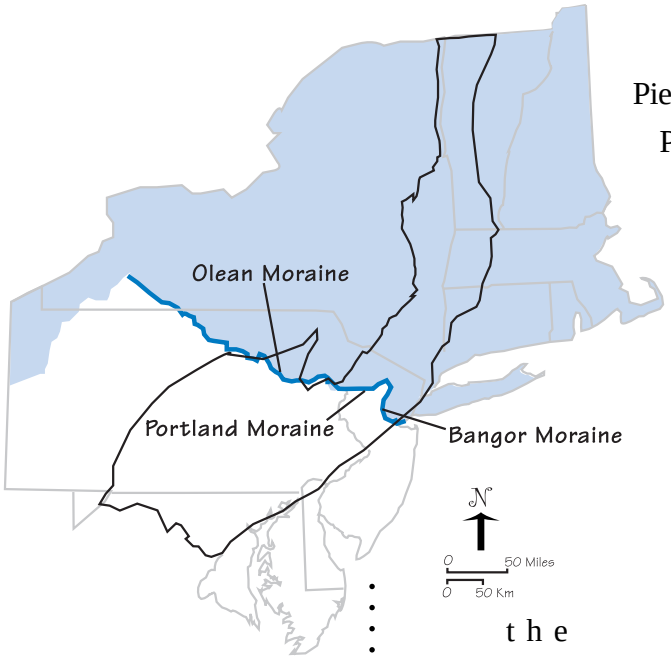


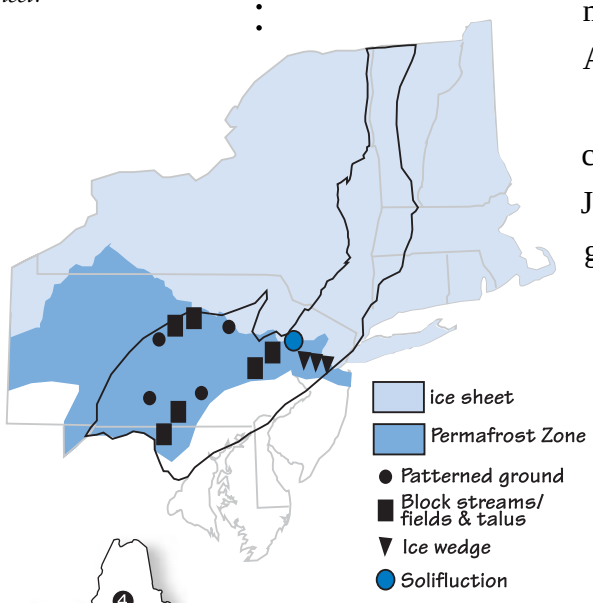
Figure 3.14: Terminal moraines of the Appalachian/Piedmont. Light blue represents the maximum extent of the most recent ice sheet.

Periglacial Features

The steep, mountainous topography of the Appalachian/Piedmont aided the glaciers in speeding up physical weathering of the rocks in the periglacial region *(Figure 3.15)*. Boulder fields, some deeper than 3 meters, formed when blocks of rock from nearby ridges were loosened by freezing and thawing water in fractures and cracks. The boulders tumbled down slope and were left as fields of rocks. The majority of boulder fields occur in the periglacial Appalachian/Piedmont region of Pennsylvania and Maryland. Some of the best examples of boulder fields in Pennsylvania include Hickory Run in Carbon County; Blue Rocks in Berks County; Ringing Rocks in Bucks County; and Devils Race Course in Dauphin County. There are many smaller boulder fields as well throughout the Appalachian/Piedmont in Maryland and Pennsylvania.

Another periglacial feature found in the Appalachian/Piedmont region are ice wedges. In northern New Jersey, ice wedge casts created polygonal patterns in the ground. The polygons range in diameter from 3-30 meters. When the ice melted, the wedges filled with sediment from glacial meltwater. The sediments in the cracks are able to hold more moisture, and thus are a better medium for plant growth. The polygon patterns were first recognized in agricultural fields because the crops grew much better in the wedge sediments than the surrounding sediments.

The Appalachian/Piedmont periglacial region also has evidence of solifluction. Becoming increasingly heavier with water from thawing in the periglacial environment, soils began to flow rapidly down slope in many areas.



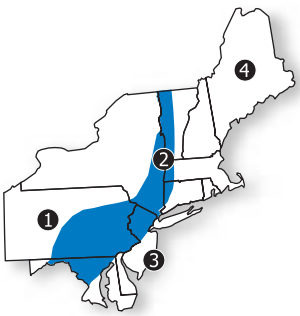


Figure 3.15: Periglacial features of the Appalachian/Piedmont. After Pewe, T.L., 1983.

Glacial Features of the Coastal Plain

Region 3

Glacial Deposits

Long Island, Cape Cod, Martha's Vineyard, Block Island and other islands off the New England coast are end moraines deposited during the most recent ice age that mark the maximum extent of the ice sheet 20,000 years ago. When the ice sheet paused in its advance over the Northeast, the melting ice deposited massive quantities of sand and gravel at its terminus *(Figure 3.16)*. Long Island serves to buffer the Connecticut coastline from storms, creating calmer water behind the island. The Ronkonkoma Moraine runs the length of Long Island and forms many of the smaller islands off the coast. The Harbor Hill Moraine stretches across northern Long Island and upwards to form the coast of Rhode Island and Cape Cod. As there is no buffering island for the Rhode Island coast, it is more severely affected by storms and high waves than the coast of Connecticut. There are no skyscrapers on Long Island because of the loose, unconsolidated glacial till that makes up the island. Till is not stable enough for very tall buildings. Not far away, however, tower the skyscrapers of Manhattan, such as the Empire State Building, built on the very resistant, metamorphosed Precambrian and Cambrian rocks of the Manhattan Prong.

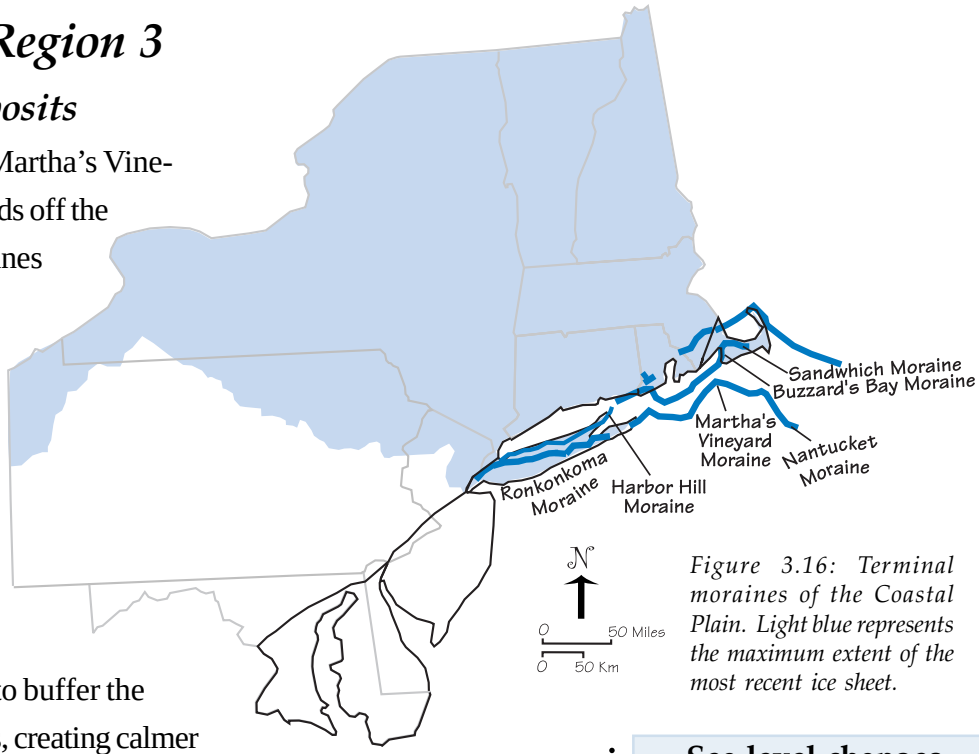


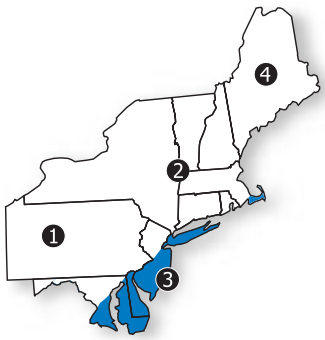
Figure 3.16: Terminal moraines of the Coastal Plain. Light blue represents the maximum extent of the most recent ice sheet.

Periglacial Features

The unconsolidated, loose nature of the Coastal Plain sediments made them particularly susceptible to movement during the freeze and thaw cycles of the periglacial environment. As the surface thawed in the summer and then refroze in the winter, the sediments in some areas were repeatedly settled and heaved upward. Though not covered by the ice sheet, some surficial layers of periglacial Coastal Plain sediment were thus still affected by the ice age.

Sea level changes

At the beginning of the ice age, sea level dropped about 100 meters because of the formation of the vast ice sheets. The drop in sea level caused rivers and streams to incise deep channels into the Coastal Plain sediments, eroding to the new sea level. These deep channels and canyons are now underwater because the melting of the glaciers caused sea level to rise. Flooding of river valleys such as the Chesapeake Bay resulted from the rising sea level.



Glacial Features of the Exotic Terrane

Region 4

Glacial Scouring

The most evident glacial scour features in the Exotic Terrane region are ***cirques***, scoop-shape bowls where valley glaciers have originated at high altitudes. At Mt. Washington in New Hampshire, and Sugarloaf Mountain, Mt. Katahdin and other Baxter Park peaks in Maine, cirques are visible today. The intense erosion by the glaciers removed many meters of bedrock from the New England mountains.

Glacial Deposits

On average, the moraines found in the Exotic Terrane region show approximately 30 meters of relief. Southeastern Maine in particular has hundreds of moraines formed where the ice sheet met the Atlantic Ocean *(Figure 3.17)*. The Connecticut Valley became a lake when an end moraine dammed the valley and blocked drainage. When the moraine-dam was broken, the 160-mile long lake drained away. The lake bottom sediments dried up and blew around, forming thick dune deposits of blown sand. Eventually these wind-blown deposits became vegetated to form the floor of the valley.

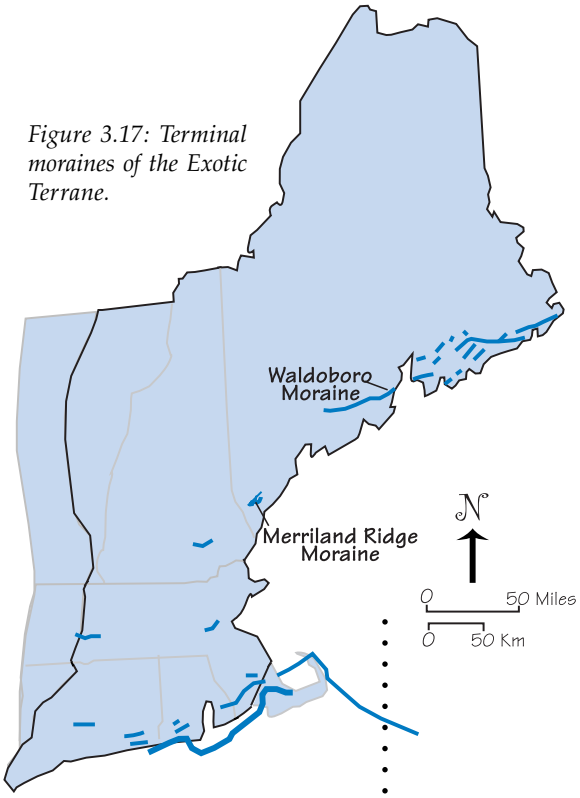
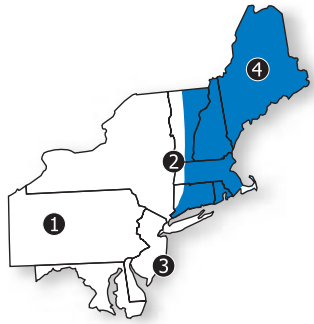


Figure 3.17: Terminal moraines of the Exotic Terrane.

Common throughout the Northeast are kettle lakes or the lakebed deposits of kettle lakes. Thoreau's Walden Pond in Cambridge, Massachusetts is actually a kettle pond, formed when a buried block of glacial ice melted and overlying sediments collapsed to form a depression that filled with lake water.

An enormous field of drumlins is found in southern New Hampshire and northern Massachusetts. These elongated, glacially sculpted hills of till were formed as the ice sheet moved over mounds of glacial sand and gravel. The orientation of drumlins is an excellent clue in deciphering the direction in which the ice sheet flowed. Also common in the Exotic Terrane region, particularly in Maine, are eskers. These features were deposited by streams of meltwater flowing under the glacier. Well-sorted sand and gravel were left behind as sinuous ridges, or eskers, when the ice sheet receded. The abundance



of sand and gravel that forms eskers has made them an easy target for mining. Many eskers no longer exist because the sand and gravel has been removed and sold. As it turns out, Maine has the longest eskers in the world.

see Non-Mineral Resources, p.167, for more on glacial deposit resources.

Sea level rise due to the melting ice sheet greatly affected the Exotic Terrane region. As the ice sheet began to retreat northwards, sea level rose faster than the crust was able to rebound from the weight of the glaciers. The result was a dramatic change in the shoreline of the Northeast, from one in which the continental shelf was exposed or ice covered to one in which the shelf was under water, with the coast even more covered by sea water in some places than it is presently. Coastal river valleys, such as Rhode Island's Narragansett Bay. The whole coast of Maine, however, was flooded beyond its present shoreline, leaving a blanket of clay deposited by the ocean waters inland and along the present day coast. The clays are known as the Presumpscot Formation, filled with a variety of ***fossil*** marine organisms that are clear evidence of the marine submergence.

see Fossils, p.98, for more on ice age fossils.