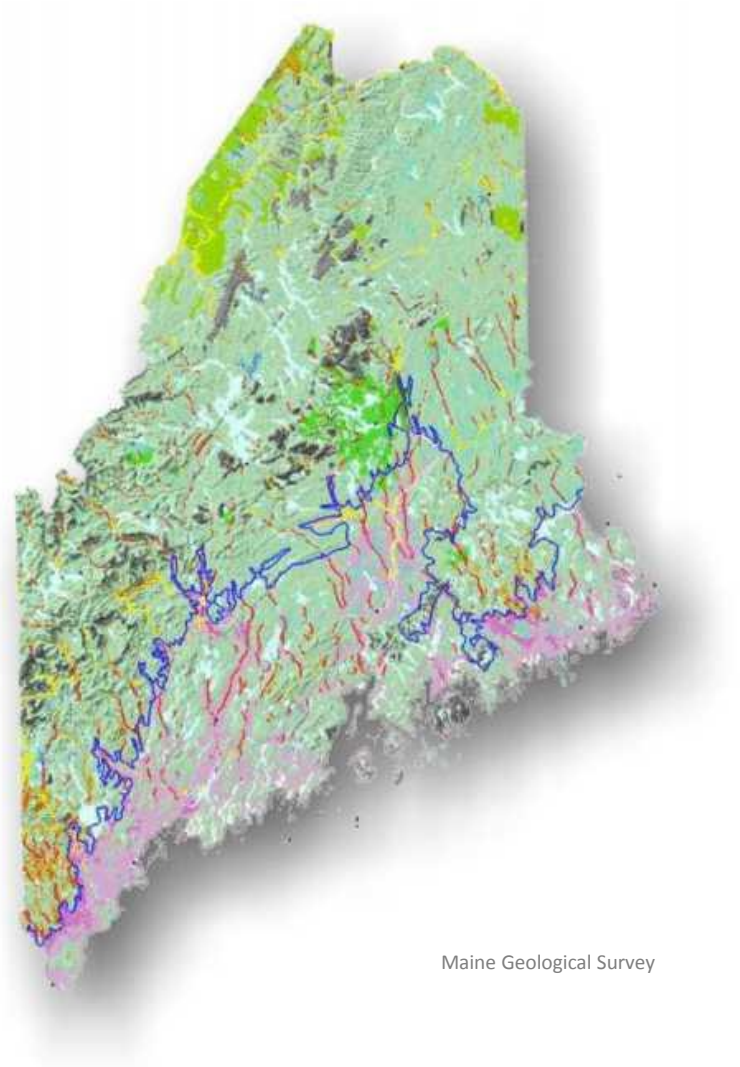
Virtual Tour

of

Maine's Surficial Geology

Introduction



Maine's bedrock foundation is covered in many places by surficial earth materials such as sand, gravel, silt, and clay. These sediments were transported and deposited by glacial ice, water, and wind. Many of them formed during the "Ice Age", which occurred between about two million and ten thousand years ago. Others were laid down more recently in stream, shoreline, and wetland environments. The colors on the map represent various kinds of surficial sediments. We will see examples of the most common types in the following photos.

Sand and Gravel

Surficial geology is important to Maine's citizens for economic and environmental reasons. Most of the sand and gravel used in construction, concrete, and sanding roads in winter was originally deposited by streams from melting glacial ice. Gravel pits are often located in these glacial deposits. The deeper parts of many sand and gravel deposits contain large quantities of water and are classified as aquifers. Yields from some aquifers are so large that they can supply water to municipal wells and the bottled water industry.

Planning Projects

Information about the type and thickness of surficial sediments is used in planning highway and building projects such as the new bridge across the Kennebec River in Augusta (shown here in an early stage of construction). Geologic maps and test borings help engineers to determine the depth to bedrock, foundation requirements, and possible stability problems.

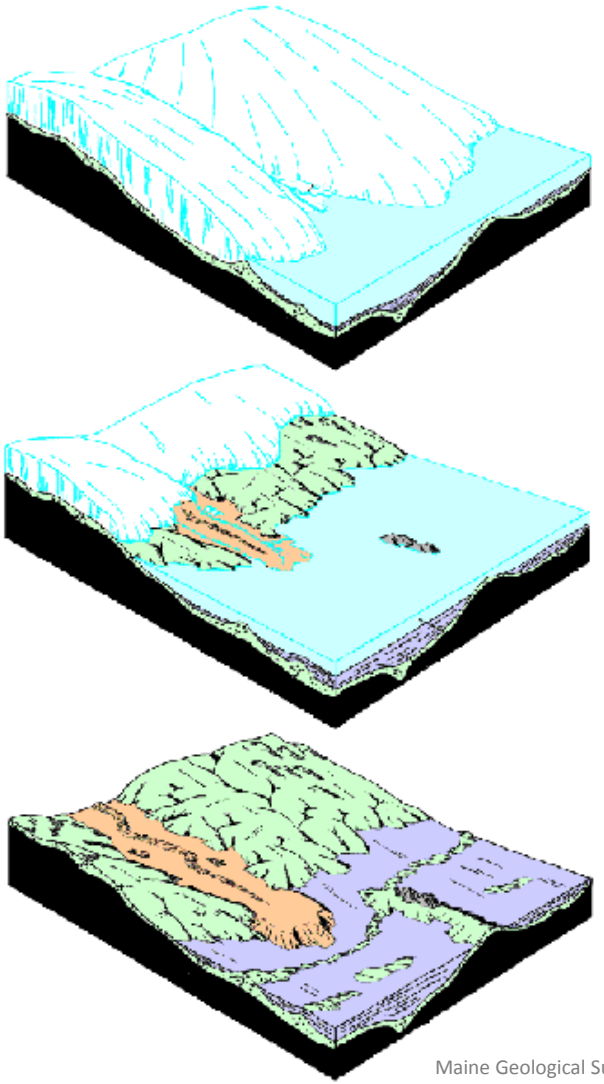
Siting Landfills

Many town dumps used to be situated near rivers and wetlands, and sometimes on sand and gravel aquifers. Contaminants from these dumps would often pollute both surface and ground waters. The old dump sites have usually been closed and replaced by engineered landfill operations. Geologic maps of surficial earth materials are useful in finding sites for landfills, so they will be located in less sensitive areas and capped with low-permeability material such as clay.

Landslides

Landslides in Maine commonly occur in marine clays known as the Presumpscot Formation. The clays are widespread along the coast and extend far inland in river valleys and other areas of low elevation. While many landslides are small or occur in unpopulated areas, there is occasional serious property damage like the house destruction seen here in Rockland. Surficial geologic maps include the distribution of the marine clays, and together with slope and drainage information, indicate areas that are vulnerable to this type of geologic hazard.

Continental Glaciation



Maine Geological Survey

The youngest glacier to cover Maine was the Laurentide Ice Sheet, which advanced from Quebec into northern New England about 35,000 years ago and expanded southward to Long Island and the continental shelf. These diagrams illustrate the subsequent retreat of the glacier margin from southern Maine, starting between about 16,000 and 15,000 years ago. Glacial processes created a variety of landforms and sediments which were exposed as the ice melted away and postglacial uplift raised the coastal zone above sea level.

Mount Katahdin

Continental ice sheets were the dominant force in shaping Maine's glacial landscape, through a combination of erosion and sediment deposition. A few high mountains hosted small alpine glaciers. This photo shows the east side of Mount Katahdin, where deep basins called "cirques" were eroded by local alpine glaciers prior to the invasion of the Laurentide Ice Sheet.

Glacial Erosion

This mountainside in Grafton Notch State Park is typical of places that were eroded by glacial ice, leaving areas of bare ledge. Natural fractures in the bedrock facilitated glacial erosion, as alternate freezing and thawing of meltwater in the cracks loosened blocks of rock. Areas of exposed ledge, called bedrock outcrops, are most common on hilltops and can be very extensive on high mountains. The blanket of glacial deposits tends to be thickest in valley bottoms, where gravity, running water, and glacial processes concentrated sedimentary debris. Exceptions occur along the Maine coast, where large areas of low-lying bedrock were washed clean by the ocean during the time of late-glacial marine submergence (see page 23).

The Bubbles

These hills, called "The Bubbles," in Acadia National park show rounded profiles caused by glacial sculpting of the bedrock. Jordan Pond occupies a glacially eroded valley that has been dammed by a glacial moraine ridge (foreground) formed where sediments accumulated at the glacier margin.

U-shaped Valley

The view south from "The Eyebrow" in Grafton Notch State Park shows the U-shaped cross section typical of glacially eroded valleys where ice streams passed through mountainous areas.

Glacial Polish and Striations

Freshly exposed granite bedrock often preserves a high degree of glacial polish, as seen on this ledge in a Westbrook gravel pit. Ice flow from lower right to upper left (as seen in photo) dragged sand and rock particles across the ledge, forming parallel scratches (striations) and scouring the rock surface so smoothly that it reflects sunlight with a bright luster.

Crescentic Fractures

Here is another example of glacially polished and striated granite, located east of The Tarn in Acadia National Park. The outcrop also shows crescentic fractures (center), which in this case are convex toward the direction of former ice flow. The arcuate cracks were produced by the great pressure exerted by thick glacial ice.

Striations

This bedrock outcrop in a Saco gravel pit records three successive ice flow directions. The shallow trough in the background preserves the oldest set, indicating ice flow to the southeast. A later flow moved toward the south (recorded by striations in lower-right part of photo), followed by the youngest flow to the south-southwest (lower left). The pens and pencils are positioned parallel to these sets of striations.

Meltwater Channel

Other erosional features resulted from meltwater drainage as the climate warmed and the last ice sheet receded from Maine. Channels were cut on hillsides, either by streams issuing directly from the ice or by water spilling out of glacial lakes. These channels on Red Hill west of Rumford probably have a glacial origin. They are now essentially dry.

Glacial Erratic

The Laurentide Ice Sheet carried large boulders which eventually melted out of the ice. Glacially transported boulders are called "erratics" if they traveled from their bedrock source to places where other rock types occur. This large granite boulder on Verona Island is very different from the rusty metamorphic rock on which it rests. The distribution of erratics from known sources can be useful in determining which way the ice flowed.

Boat Rock Erratic

Some glacial boulders have fanciful shapes, such as this rock in Canton that resembles a boat.

Daggett's Rock

Daggett's Rock in Phillips is the largest known erratic boulder in Maine. It is approximately 80 ft long, 25 ft high, and estimated to weigh as much as 8000 tons. Despite its huge size, the granite boulder was carried miles from its probable source in the Saddleback Mountain area to the northwest.

Glacial Transport

Glacial ice picked up and transported rock debris of all sizes as it flowed across Maine. Some of this material was deposited directly from the glacier, either when it was plastered against the ground beneath the ice sheet, or when melting released it from higher in the glacier. The resulting sedimentary deposit - called till - is a more or less non-stratified mixture of everything from microscopic clay particles to big boulders like those shown in the previous photos. The stony, sand-rich till seen in this Albany pit is typical of the material released from melting ice in areas of coarse igneous and metamorphic rocks across southwestern Maine.

Lodgement Till

Rock debris at the bottom of the ice sheet was ground into a fine-grained, less stony mixture and deposited under great pressure. The resulting "lodgement till" can be extremely compact and difficult to excavate. This till in Liberty has been deeply weathered to a brownish color and perhaps was deposited by an earlier glaciation prior to the Laurentide Ice Sheet. Traces of gray unweathered till are seen near the bottom of the pit face.

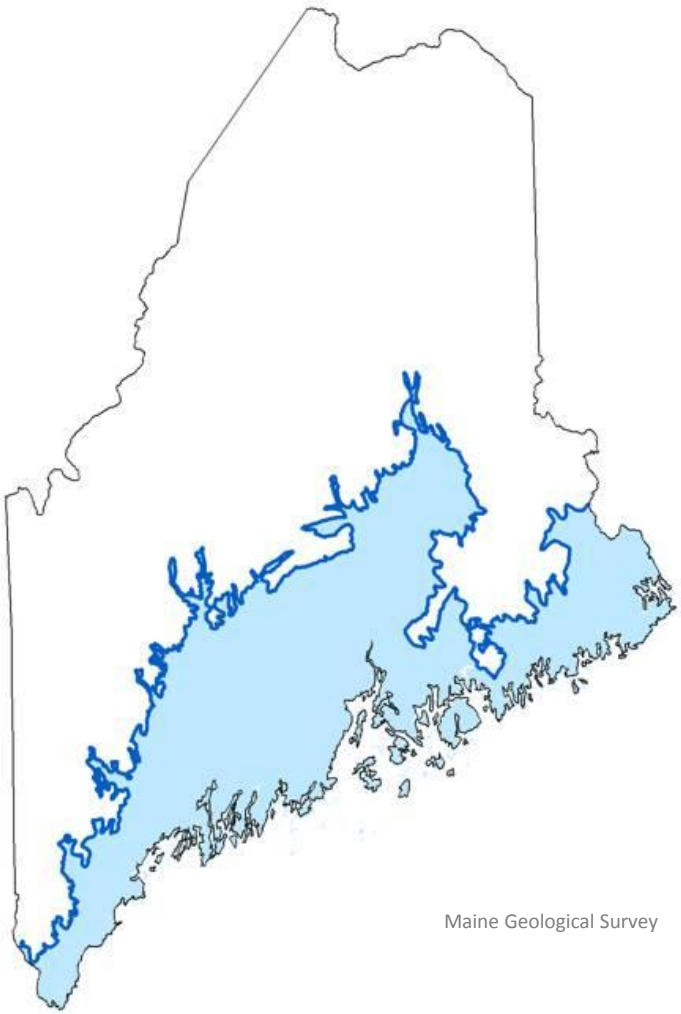
Drumlins

Till thicknesses may exceed 100 ft, especially in areas of smooth, glacially moulded topography. Oval-shaped hills called drumlins are elongated parallel to ice flow and are likely to contain thick till deposits. This example is Great Hill in Eliot, which is part of a group of drumlins in southern York County.

Thin Drift

In other areas the till cover is very thin, as seen in this road cut along Route 17 south of Rangeley. These areas of abundant bedrock exposure and meager sediment cover are called "thin-drift areas" on surficial geologic maps.

Marine Submergence



A continental ice sheet is so thick and heavy that it actually depresses the Earth's bedrock crust. When the Laurentide Ice Sheet receded from Maine, the land remained depressed for a few thousand years. Global sea level was lower than today, but the crustal downwarp was so great that ice retreat was accompanied by marine submergence of the coastal lowland. The blue line on the map shows the inland limit reached by the ocean in late-glacial time. High areas (over 300-400 ft in elevation) seaward of this line were islands at the time.

Painting of Submarine Fan

Figure courtesy of Ross Powell, Northern Illinois University, and the National Park Service

This view shows Johns Hopkins Glacier in Glacier Bay National Park, Alaska. It helps visualize the Laurentide glacier margin in contact with the sea during its retreat from southern Maine. The artist has clarified the water (which actually would be muddy) to show sediment washing out of tunnels at the glacier margin and accumulating as a fan-shaped deposit on the sea floor. These submarine fans are common in Maine, where they form important sand and gravel resources.

Diagram of End Moraines

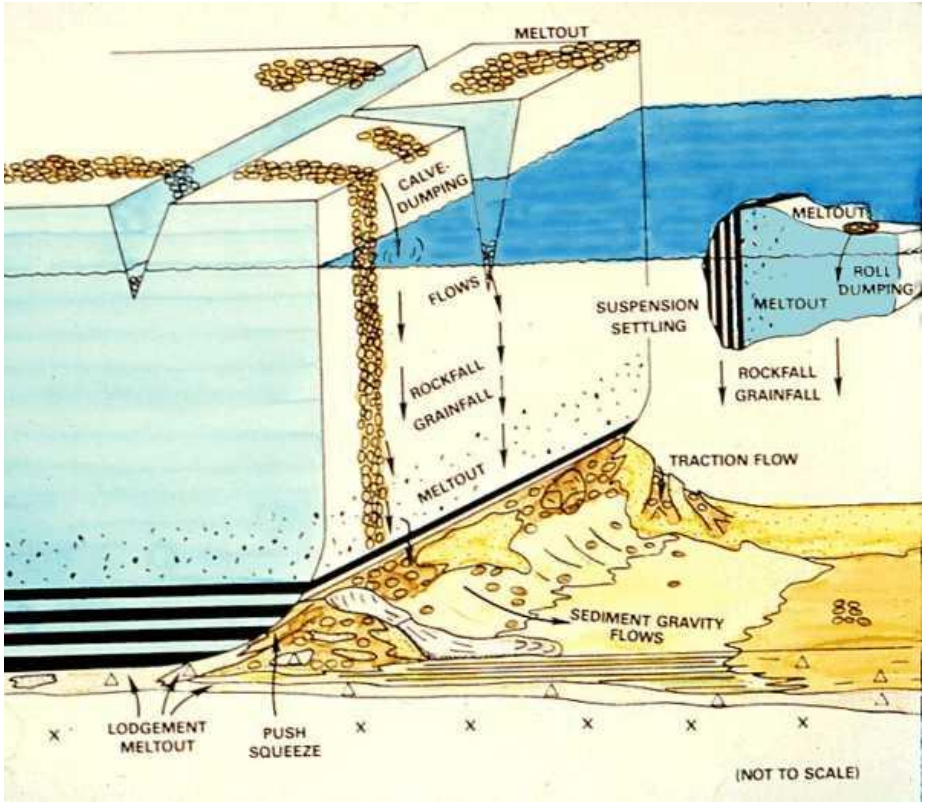
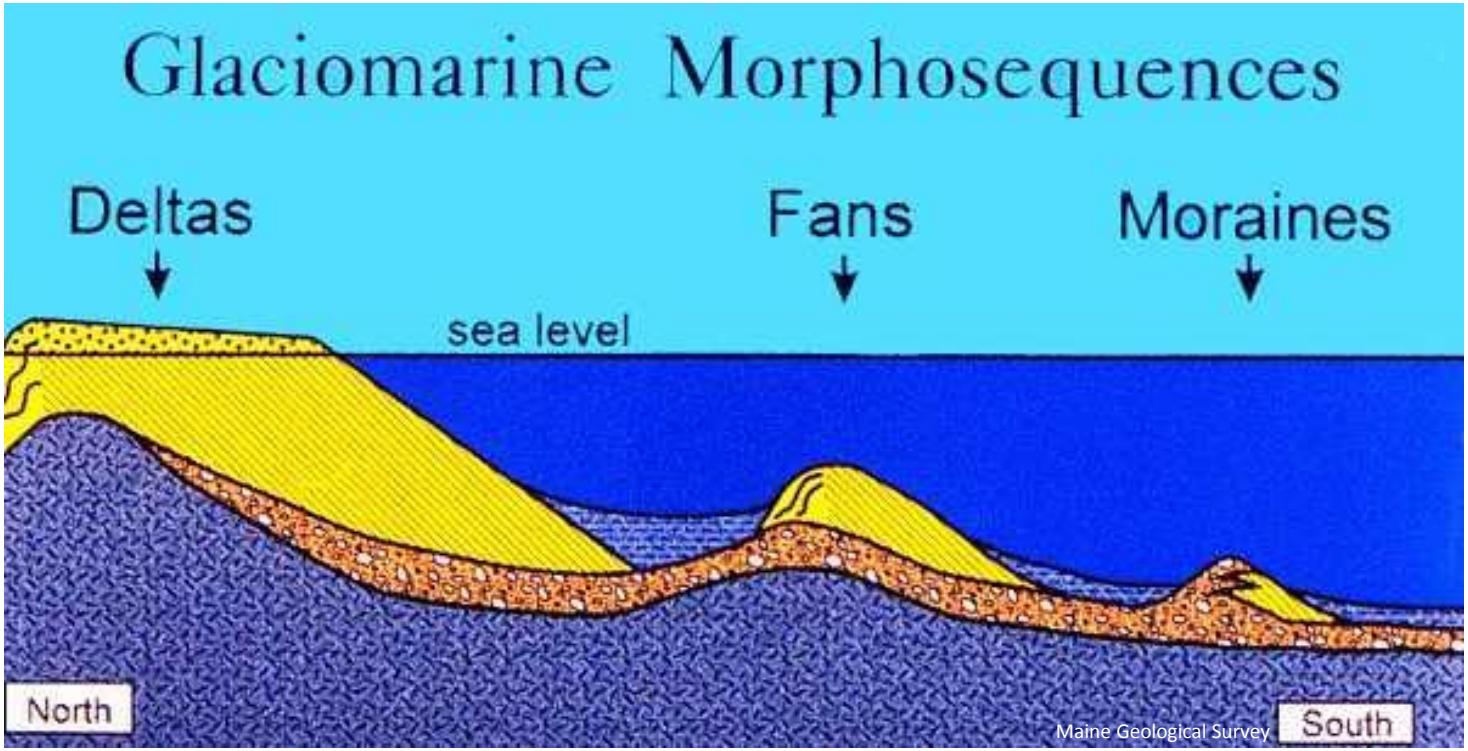


Figure courtesy of Ross Powell, Northern Illinois University.

Ice melted and broke away as icebergs where the glacier margin stood in the sea. Sediments washed or avalanched into the water by the various means shown in this diagram. Debris was also pushed up and otherwise accumulated at the bottom edge of the ice, forming ridges known as end moraines (simply called "moraines" later in this tour).

Glacial-marine Deposits



Several types of glacial-marine deposits formed during the deglaciation of southern Maine. The orange unit is till, which occurs as a widespread blanket over bedrock, and also as a component of moraine ridges. Yellow represents coarse waterlaid sediments (mostly sand and gravel) that washed into the ocean at the mouths of subglacial tunnels at the ice margin. In some places the sand and gravel built up to the ocean surface, resulting in flat-topped deltas. A discontinuous cover of marine mud (lavender unit) drapes over the older glacial sediments.

Moraine Ridge

Moraine ridge in Cherryfield. Groups of bouldery moraines such as this one are common in coastal Washington County. They mark successive positions of the glacier margin during its overall retreat. Sandy soils on moraines, submarine fans, and deltas are extensively cultivated for blueberries. The blueberry plants turn bright red in fall, rivaling the tree foliage for color.

Moraines – Fold Structures

The large stratified moraines in Washington County are important sources of commercial sand and gravel. Pit excavations often expose interesting features typical of the ice-marginal environment. For many years, this pit in Addison showed spectacular overturned fold structures caused by the glacial ice front shoving against the moraine (from left to right, as seen in photo). The folding exemplifies the "push-squeeze" condition shown on page 25.

Moraines

This aerial view shows several bouldery moraines crossing a blueberry field in Sedgwick, east of Penobscot Bay. The ice margin retreated from right to left (northward). The close spacing of these and other moraines suggests that they may be annual features, with the space between them indicating how far the ice margin receded during the summer melt season.

Buried Moraine

Moraines commonly are buried under younger glacial-marine sediments. This pit in Lyman shows a cross-section of a moraine composed of stony till, overlain by marine silt and sand of the Presumpscot Formation.

Glacial-marine Delta and Kettle

Over 100 glacial-marine deltas are scattered across the formerly submerged areas of Maine. Some of them are very large and among the most important sources of sand and gravel, as well as being major aquifers. Along with other sandy glacial deposits, deltas also host extensive blueberry fields. This delta is located in Franklin. Its flat top approximates the position of sea level when the delta formed at the glacier margin. The hole in the foreground is a "kettle" that developed when buried ice remnants were engulfed by the growing delta. The ice blocks later melted and part of the flat delta surface collapsed into the depression.

Glacial-marine Delta

This gravel pit in Whitefield exposes the inside of a typical glacial-marine delta. It has two principal parts. The horizontal gravelly layers are called "topset beds". They were laid down by glacial meltwater streams washing across the top of the delta. The topset gravels overlie "foreset beds," which are inclined in a seaward direction. These foresets consist of sand and gravel that cascaded down the front of the expanding delta and eventually were covered by the topsets. The boundary between the two units marks the position of sea level.

Submarine Fan

Marine sand and gravel deposited near the glacier margin may grade upward into silt and clay that settled to the ocean floor when the ice retreated and quiet-water conditions prevailed. This photo shows one such transition in a submarine fan in Topsham.

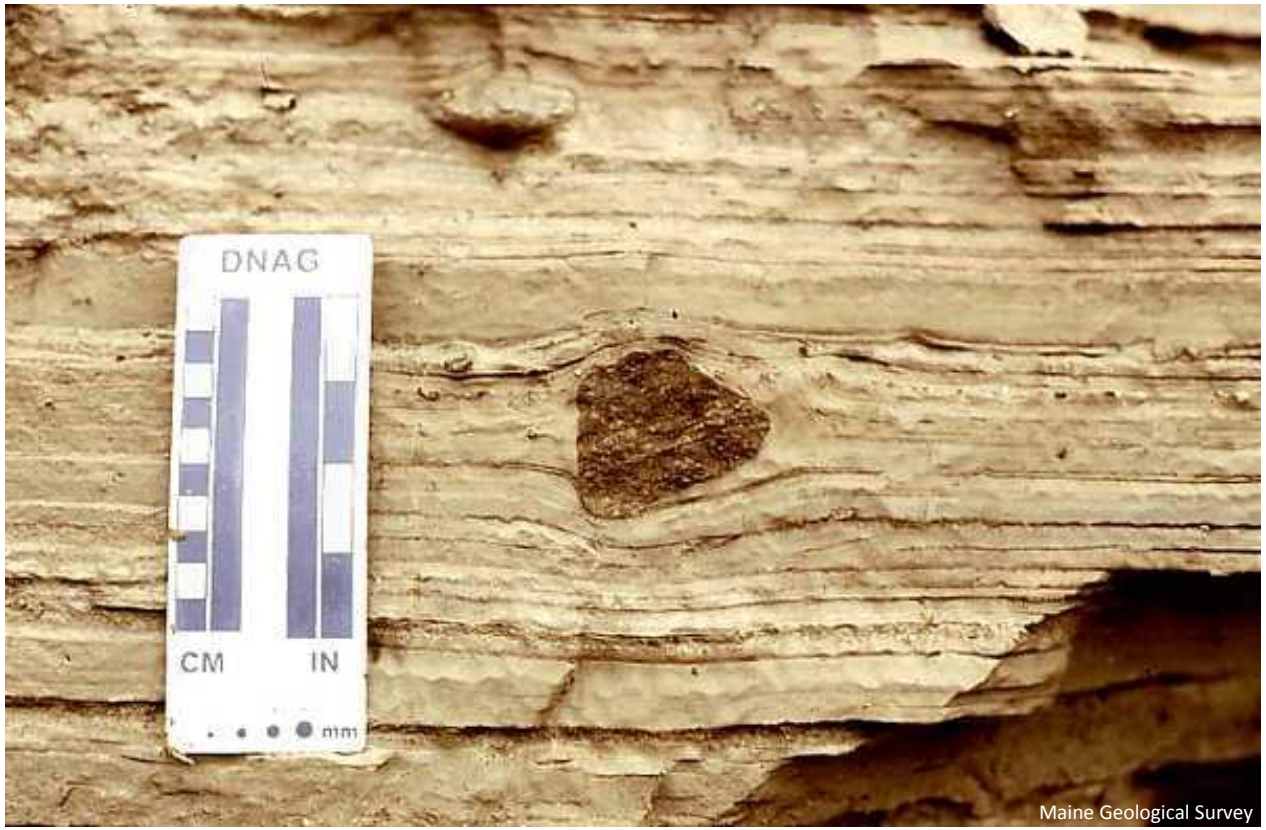
Presumpscot Formation

The clayey to silty marine muds are called the Presumpscot Formation, named after the Presumpscot River near Portland. These clay deposits gave rise to numerous brickyard operations in Maine. They also provide raw material for making pottery in Wayne, Blue Hill, and elsewhere. The geologists seen here were mapping glacial-marine sediments in the Windham area.

Marine Clay

Aerial view of the west side of Kennebec River valley in Farmingdale. The large field in the center of the photo was part of the ocean floor in late-glacial time. Thick deposits of marine clay occur beneath the surface in this area. As the river eroded down through these deposits, branching networks of steep-sided gullies were formed.

Dropstone



Much of the Presumpscot Formation was deposited when glacial ice was still nearby. Stones dropped to the sea floor from floating icebergs and became buried in the mud. The impact of this dropstone is recorded by deformation of the underlying sediment layer, and a younger layer is draped over the top of it.

Walrus Bone Fossil

Well-preserved fossils are often found in the unweathered "blue clays" of the Presumpscot Formation. Ray Webb is holding a walrus toe bone found at his gravel pit in Prospect.

Fossil Shells

Shells are the most common macrofossils in the Presumpscot clays. This collection from Prospect includes species of clams, mussels, scallops, and barnacles. Some species still live on the Maine coast, while others typically inhabit colder North Atlantic waters near Greenland. Radiocarbon ages obtained from shells are usually between 14,000 and 11,000 years.

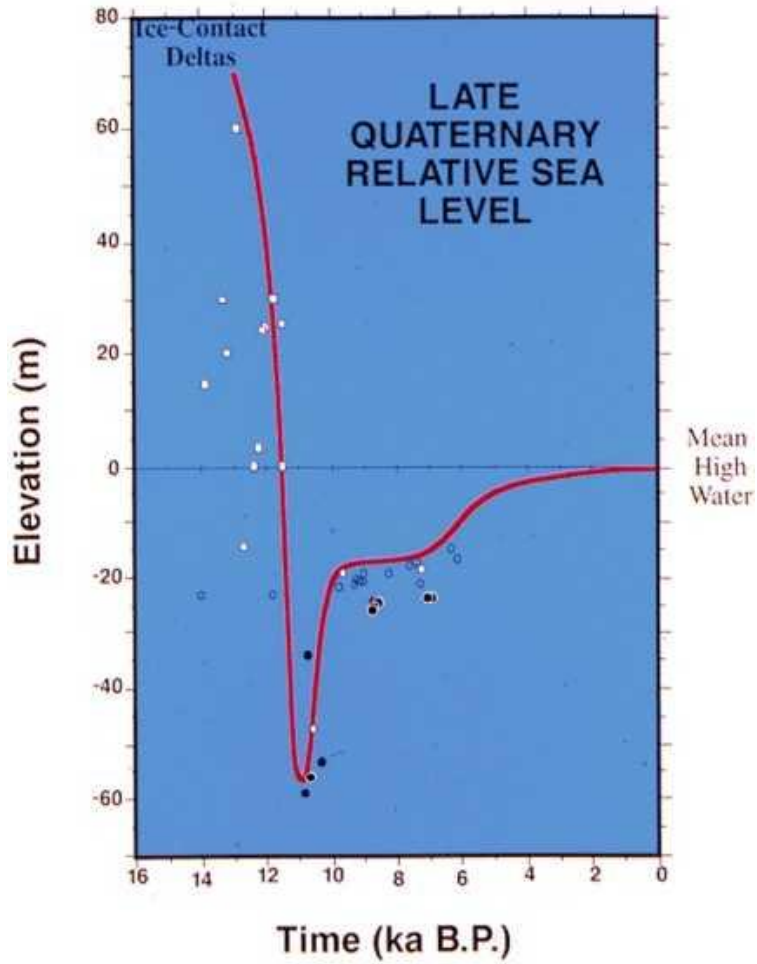
Fossil Spruce Logs

Fossil plant material is rarely found in the Presumpscot Formation, but in 1976 fossil spruce logs were discovered at this site in Portland. Twigs, needles, and cones occurred with the logs, and some of the needles were so well preserved in the clay that they were still green!

Close-up of Fossil Spruce Wood

A closer view of fossil spruce wood from Portland shows how fresh it looks after over 11,000 years of burial.

Relative Sea Level



Maine Geological Survey

This is a plot of relative sea level in coastal Maine vs. time (in thousands of years before present, as measured by radiocarbon dating). It shows a rapid drop in sea level in late-glacial time, due to uplift of the Earth's crust after the weight of the ice sheet was removed. In more recent millennia, global sea-level rise has become dominant due to continued melting of the world's glaciers.

Raised Beach in Marshfield

Eventual uplift left glacial shorelines high and dry. This raised beach in Marshfield shows gravel derived from wave washing of older glacial sediments.

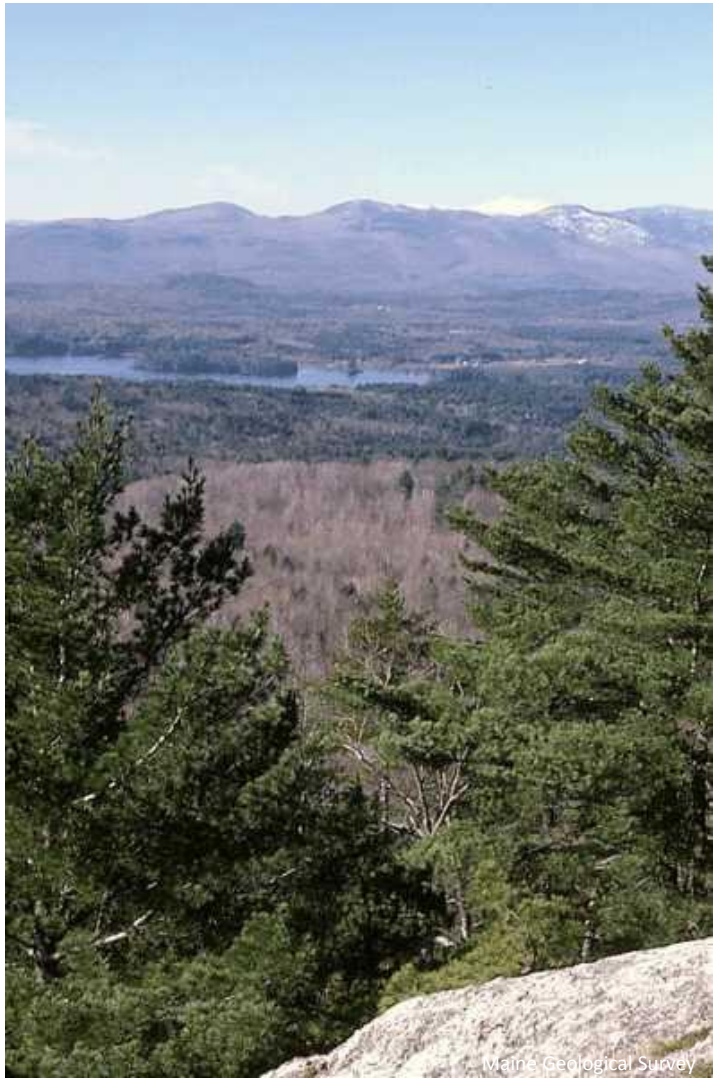
Raised Beach on Day Mountain

A spectacular raised beach is located on the side of Day Mountain in Acadia National Park. The granite boulders have been rounded by tumbling in the surf.

Coastal Bluff

This coastal bluff just north of Popplestone Beach in Jonesport reflects the ups and downs of sea level. A stony till ridge (possibly a moraine) is overlain by clay deposited during the marine submergence that immediately followed deglaciation. When the site emerged from the sea, the till and clay units were eroded and a freshwater peat bog (black layer) formed on top of them. Sea level is now slowly rising against the Maine coast and eroding the "soft" glacial and postglacial sediments. Shoreline erosion of this sort may cause rapid loss of waterfront property, roads, and buildings.

Above the Marine Limit



Farther inland, above the limit of marine submergence, the surficial geology is quite different from Maine's coastal lowland. Till-mantled hills and mountains alternate with valleys containing the sedimentary deposits of glacial streams and lakes. This view looks westward across Kezar Lake from Sabattus Mountain in Lovell. Snow-clad Mount Washington appears in the far distance.

Bouldery Moraine Ridge

Moraines are uncommon over most of western and northern Maine, but they do occur in some places. The photo shows a frontal view of a bouldery moraine ridge in the town of Norway.

Androscoggin Moraine

The Androscoggin Moraine is the most spectacular moraine system in northern Maine. It was deposited by a tongue of the Laurentide Ice Sheet extending eastward from the White Mountains. This view looks southwest across the Androscoggin River valley on the Maine-New Hampshire border. The left-center part of the photo shows a moraine ridge sloping gently down the valley from Stock Farm Mountain. This moraine is about 100 ft high. In the foreground, other large moraines cross the field of view and connect with Hark Hill (lower right).

Esker

Eskers are common in southern and central Maine. They consist of sand and gravel deposited by glacial meltwater streams in tunnels at the base of the ice sheet. When the ice melted away, the sediments that had choked the tunnels were exposed as narrow ridges. Unlike moraine ridges, eskers rarely contain till and usually are oriented perpendicular to the former ice margin. This esker cuts through the Five Kezar Ponds in the Stoneham-Waterford area.

Esker Illustration 1899

This figure is from George Stone's 1899 U. S. Geological Survey monograph titled Glacial Gravels of Maine. It shows an esker (then called an "osar") passing through a gap in the hills in Woodstock. The subglacial streams were able to climb uphill in places because they were confined and driven by pressure under the ice.

Esker Ridge

Eskers are important sources of sand and gravel, and many pits have been excavated in them. The pit shown here exposes a cross-section through an esker ridge in the upper Kennebago River valley. Ground-water supplies commonly exist in the deeper portions of these deposits.

Gravel Stones in Esker

Gravel stones in eskers tend to be well rounded from tumbling along and impacting each other in rushing streams beneath the glacier. The earliest tunnel-filling material is likely to be gravel, since finer-grained sediments were swept away by fast currents. However, in many eskers this gravel core is overlain by sand or mixed sand and gravel that was laid down as current velocities subsided.

Offsets in Glacial Lake Deposits

Eskers and other water-laid sediments emplaced next to glacial ice are called "ice-contact deposits". Their characteristic features include disturbances resulting from melting of adjacent ice that had supported them on one or more sides. Folds and faults are common, such as this series of offsets in glacial-lake sands in Lovell. The vertical pit face was scraped clean with the shovel blade, highlighting the faults and revealing subtle details in the sand beds.

Ice-contact Deposits

This pit face in Newry shows a sharp discontinuity between collapsed ice-contact sand and gravel (bottom) and undisturbed alluvial fan gravel that washed across the top when buried ice remnants had completely melted.

Outwash Deposits

Meltwater streams from the receding glacier carried sediments down the river valleys that sloped away from the ice front. These outwash deposits generally include more or less gravel. Very coarse outwash, like the boulder gravel seen here in the Crooked River valley in Albany, was deposited closest to the ice.

Channel Fillings

Streams shifted back and forth across the surface of an outwash plain, alternately eroding channels and then filling them with sand and gravel. The photo shows several sets of channel fillings, each with inclined cross-bedding.

Glacial Lake

Water drainage in valleys that sloped toward the glacier margin (generally northward) was temporarily trapped in ice-dammed glacial lakes. One such lake existed here in the Pleasant River valley in Bethel, which was blocked by ice remaining in the Androscoggin Valley to the north.

Glacial Delta

Streams flowing into glacial lakes formed deltas with topset and foreset beds, similar to the marine deltas mentioned earlier. This delta is southeast of Tumbledown Mountain in Weld.

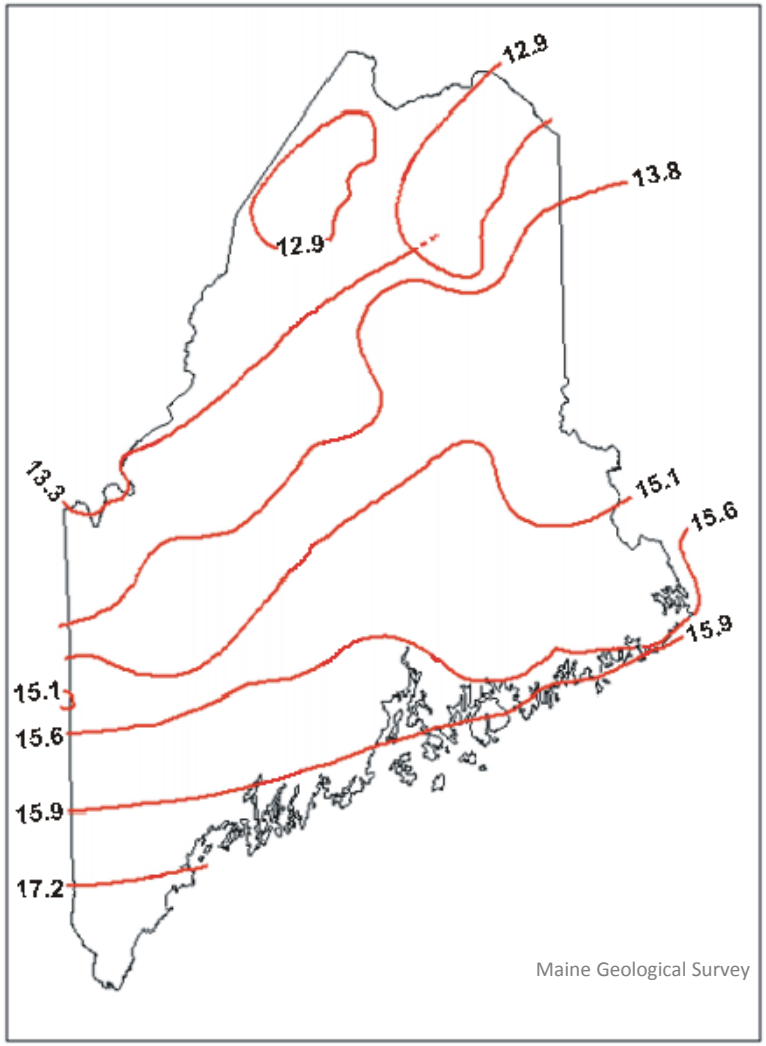
Climbing Ripples

Climbing ripples record the flow directions of water currents in stream and lake sediments. These ripples were found in sandy bottom sediments of glacial Lake Pigwacket in Waterford. They indicate westward current flow (right to left in photo).

Varves

Annual layers called varves may occur in glacial lake-bottom deposits. Each varve has two parts: a clayey unit formed when very fine-grained sediment settled to the lake floor during quiet winter months, and a coarser silty-sandy unit deposited in the warmer months when streams were active. Varve thickness varies with factors such as the amount of yearly rainfall and glacial melting. In some parts of New England, varves have been measured and matched over long distances to establish the duration and sequence of glacial lakes and ice retreat in years. A few recent discoveries of organic material in varved clays have enabled radiocarbon dating of the New England varve series. The exposure shown here is located in the Crooked River valley in Naples.

Glacial Margin Position



This map shows generalized positions of the glacier margin, during recession of the last ice sheet. Ages of the time lines are in thousands of years ago in calendar years as determined by radiocarbon dating of fossil organic material. Late-glacial marine submergence not only flooded southern Maine, but also extended up the St. Lawence Lowland to the north in Quebec. This marine invasion caused the isolation of a large remnant ice cap over northern Maine between about 13,000 and 12,000 years ago. Ice flow was reversed on the north side of the ice cap, and flowed north toward the Canadian border.

Glacial Till

At some point in time, glacial ice advanced over older outwash deposits in northern Maine. This pit shows till overlying gravel in the Aroostook River valley. The till may have been deposited during an expansion of the local ice cap which probably occurred during a cold-climate interval between 11,000 and 10,000 years ago, called the Younger Dryas.

Desert of Wayne

The Maine landscape was sparsely vegetated immediately after the ice sheet disappeared. Strong winds blew sand out of river valleys and deposited it as dunes on hillsides to the east. Some extensive dune fields have been reactivated in historic time due to poor farming practices. These barren areas are locally called "deserts," such as the Desert of Wayne (shown here) and the Desert of Maine in Freeport. Other major, but lesser known, dune fields are now tree-covered.

Eolian Sand and Till

This striking exposure in Sweden, Maine, shows light-colored eolian (windblown) sand overlying gray till.

Ventifacts

A close look at eolian sand usually reveals thin planar beds and textures ranging from very fine to very coarse sand. Some of these deposits resemble waterlaid sand, but often can be distinguished by dune topography and the absence of stones or sedimentary structures found in lake and stream environments. The stones in this photo protrude from the surface of the underlying till. Their surfaces feel smooth due to sandblasting. Such wind-polished stones are called ventifacts.

Flooding

Rivers have been important agents of geologic change in postglacial time, as they erode down through glacial sediments. Old flood plains form terraces along valley sides, at elevations higher than most modern flood levels. This photo shows flooding along the Kennebec River in Augusta.

Stream Transport

Gravel bar on Sunday River, Newry. Streams in mountainous regions tend to have steeper gradients and can transport coarser alluvium compared to their more sluggish reaches in the lowlands. Gravel ranging from pebbles to boulders is carried by these streams, though the largest rocks may move infrequently and only during major floods.

Flood Deposits

Flood deposits along Maine's larger rivers often consist of sand and silt. This photo shows freshly deposited sand on the inside of a meander bend along the Androscoggin River at Rumford Point. It was taken soon after the great flood of April 1, 1987.

Sand Beach - Acadia

Waves and currents affect the geology of lakes and the Maine coast, eroding various shoreline materials ranging from peat to bedrock. Wave energy is focused on projecting points of land, while material eroded from headlands is carried onto beaches in the coves. The photo shows Sand Beach in Acadia National Park.

Ice Push

Lake ice shoves against the shoreline, heaving sediments into low ridges called ice-push ramparts. These features are best developed where lake shores consist of glacial till and bouldery ridges several feet high have been pushed up by the ice.

Wetland

Bog Brook valley, north of Hebron Station. Wetlands are very common across Maine. They include both salt-water and freshwater varieties, including marshes, swamps, and peat bogs. Wetlands have developed in poorly drained areas such as flood plains and places where drainage is impeded by glacial-marine clay. These areas are important wildlife and plant habitats and generally restricted from development. A few Maine bogs have been harvested for peat in the past.

Peat Bog

The Maine Geological Survey has conducted statewide peat resource evaluations in cooperation with the U. S. Geological Survey. Bogs such as this one were cored to determine the thickness of the peat.

Core Sample

Pollen and other fossils in sediments on the bottoms of Maine lakes provide a continuous climate record reaching back to late-glacial time. Postglacial organic-rich muck is seen in the upper (left) part of this core from Lower Black Pond in Oxbow Twp., near the Quebec border. The deepest part of the core (right) is relatively barren gray mud which was deposited in the lake basin soon after melting of glacial ice. Insect remains from the mud yielded a radiocarbon age of 11,500 years, which is thought to be very close to the time of ice retreat.