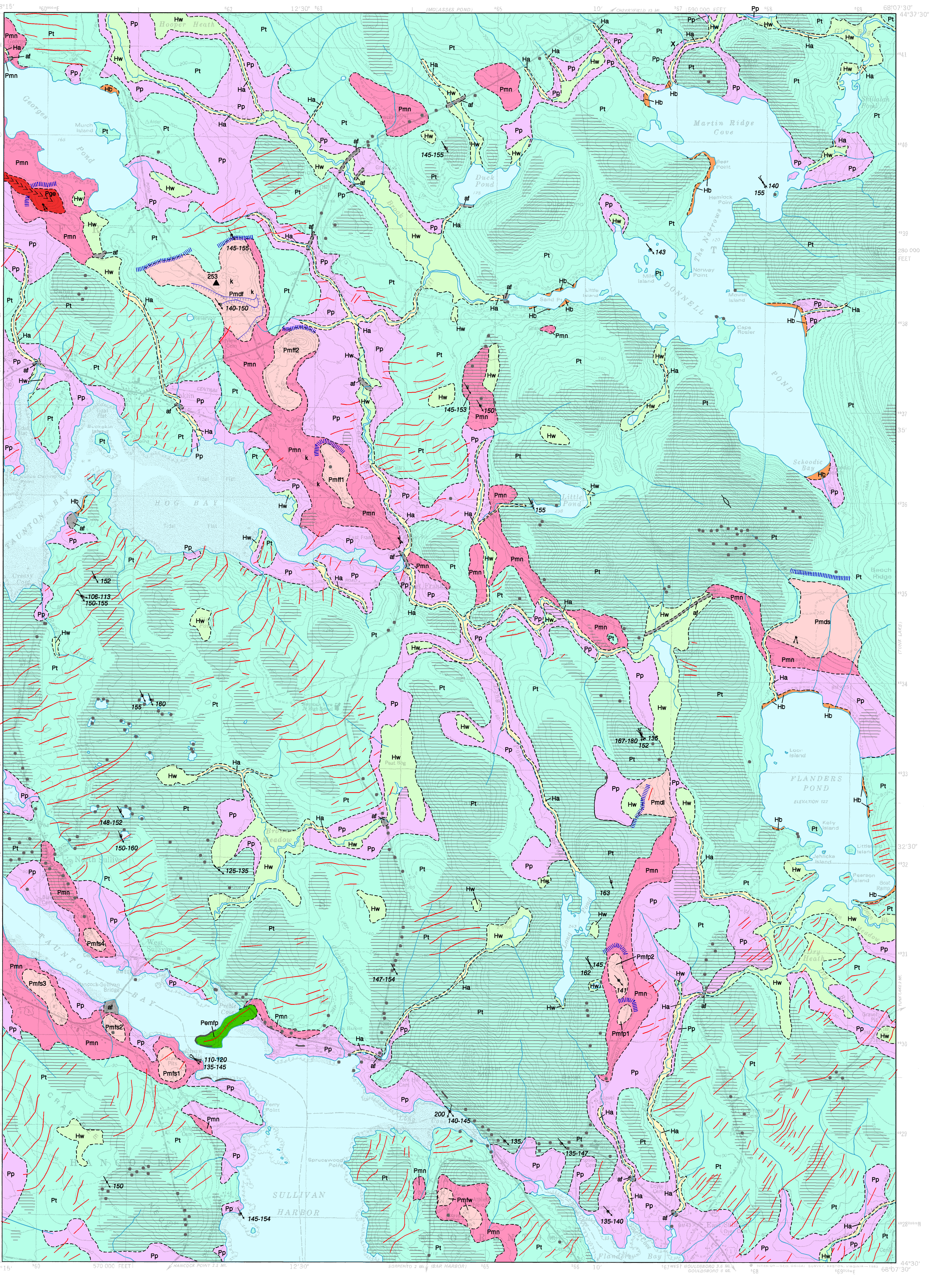
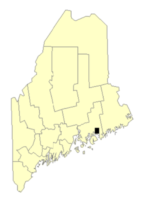
Surficial Geology



SOURCES OF INFORMATION

Surficial geologic mapping of the Sullivan quadrangle was conducted by C. T. Hildreth during the 2011 field season. Funding for this work was provided by the U.S. Geological Survey STATEMAP program.



Quadrangle Location

SCALE 1 : 24,000

CONTOUR INTERVAL 20 FEET

TRUE NORTH

Topographic base from U.S. Geological Survey Sullivan quadrangle, scale 1:24,000 using standard U.S. Geological Survey topographic map symbols.

The use of industry, firm, or local government names on this map is for location purposes only and does not impute responsibility for any present or potential effects on the natural resources.

Sullivan Quadrangle, Maine

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SURFICIAL GEOLOGY OF MAINE

Continental glaciers like the ice sheet now covering Antarctica probably extended across Maine several times during the Pleistocene Epoch, between about 1.5 million and 10,000 years ago. The slow-moving ice superficially changed the landscape as it scraped over mountains and valleys (**Figure 1**), eroding and transporting boulders and other rock debris for miles (**Figure 2**). The sediments that cover much of Maine are largely the product of glaciation. Glacial ice deposited some of these materials, while others washed into the sea or accumulated in meltwater streams and lakes as the ice receded. Earlier stream patterns were disrupted, creating hundreds of ponds and lakes across the state. The map at left shows the pattern of glacial sediments in the Sullivan quadrangle.

The most recent "Ice Age" in Maine began about 30,000 years ago, when an ice sheet spread southward over New England (Stone and Borns, 1986). During its peak, the ice was several thousand feet thick and covered the highest mountains in the state. The weight of this huge glacier actually caused the land surface to sink hundreds of feet. Rock debris frozen into the base of the glacier abraded the bedrock surface over which the ice flowed. The grooves and fine scratches (striations) resulting from this scraping process are often seen on freshly exposed bedrock, and they are important indicators of the direction of ice movement (**Figure 3**). Erosion and sediment deposition by the ice sheet combined to give a streamlined shape to many hills, with their long dimension parallel to the direction of ice flow. Some of these hills (drumlins) are composed of dense glacial sediment (till) plastered under great pressure beneath the ice.

A warming climate forced the ice sheet to start receding as early as 21,000 calendar years ago, soon after it reached its southernmost position on Long Island (Ridge, 2004). The edge of the glacier withdrew from the continental shelf east of Long Island and reached the present position of the Maine coast by about 16,000 years ago (Borns and others, 2004). Even though the weight of the ice was removed from the land surface, the Earth's crust did not immediately spring back to its normal level. As a result, the sea flooded much of southern Maine as the glacier retreated to the northwest. Ocean waters extended far up the Kennebec and Penobscot valleys, reaching present elevations of up to 420 feet in the central part of the state.

Great quantities of sediment washed out of the melting ice and into the sea, which was in contact with the receding glacier margin. Sand and gravel accumulated as deltas (**Figure 4**) and submarine fans where streams discharged along the ice front, while the finer silt and clay dispersed across the ocean floor. The shells of clams, mussels, and other invertebrates are found in the glacial-marine clay that blankets lowland areas of southern Maine. Ages of these fossils tell us that ocean waters covered parts of Maine until about 13,000 years ago. The land rebounded as the weight of the ice sheet was removed, forcing the sea to retreat.

Meltwater streams deposited sand and gravel in tunnels within the ice. These deposits remained as ridges (eskers) when the surrounding ice disappeared (**Figure 5**). Maine's esker systems can be traced for up to 100 miles, and are among the longest in the country.

Other sand and gravel deposits formed as mounds (kames) and terraces adjacent to melting ice, or as outwash in valleys in front of the glacier. Many of these water-laid deposits are well layered, in contrast to the chaotic mixture of boulders and sediment of all sizes (till) that was released from dirty ice without subsequent reworking. Ridges consisting of till or washed sediments (moraines) were constructed along the ice margin in places where the glacier was still actively flowing and conveying rock debris to its terminus. Moraine ridges are abundant in the zone of former marine submergence, where they are useful indicators of the pattern of ice retreat (**Figure 6**).

The last remnants of glacial ice probably were gone from Maine by 12,000 years ago. Large sand dunes accumulated in late-glacial time as winds picked up outwash sand and blew it onto the east sides of river valleys, such as the Androscoggin and Saco valleys (**Figure 7**). The modern stream network became established soon after deglaciation, and organic deposits began to form in peat bogs, marshes, and swamps. Tundra vegetation bordering the ice sheet was replaced by changing forest communities as the climate warmed (Davis and Jacobson, 1985). Geologic processes are by no means dormant today, however, since rivers and wave action modify the land (**Figure 8**), and worldwide sea level is gradually rising against Maine's coast.

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Figure 1: "The Bubbles" and Jordan Pond in Acadia National Park. These hills and valleys were sculpted by glacial erosion. The pond was dammed behind a moraine ridge during retreat of the ice sheet.

Figure 2: Daggett's Rock in Phillips. This is the largest known glacially transported boulder in Maine. It is about 100 feet long and estimated to weigh 8,000 tons.

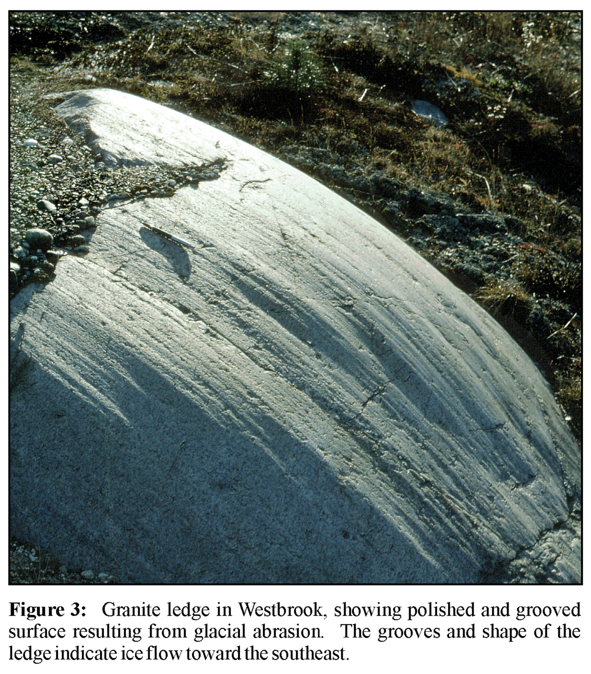

Figure 3: Granite ledge in Westbrook, showing polished and grooved surface resulting from glacial abrasion. The grooves and shape of the ledge indicate ice flow toward the southeast.

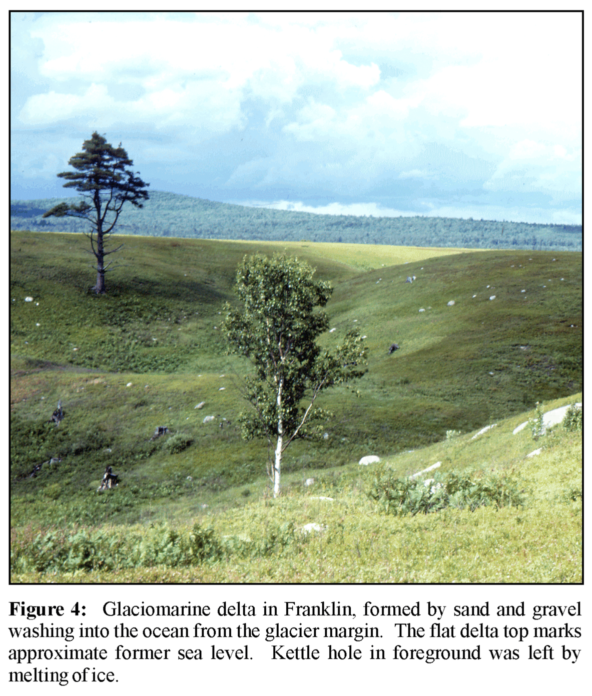

Figure 4: Glaciomarine delta in Franklin, formed by sand and gravel washing into the ocean from the glacier margin. The flat delta top marks approximate former sea level. Kettle hole in foreground was left by melting of ice.

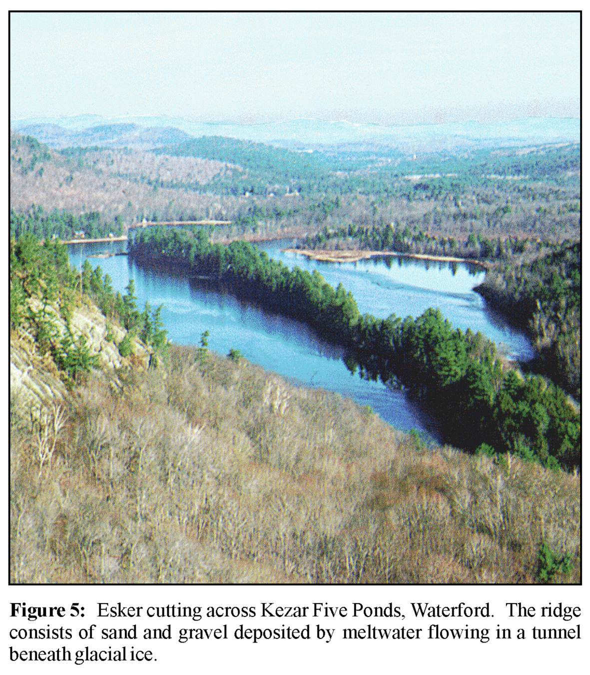

Figure 5: Esker cutting across Kezar Five Ponds, Waterford. The ridge consists of sand and gravel deposited by meltwater flowing in a tunnel beneath glacial ice.

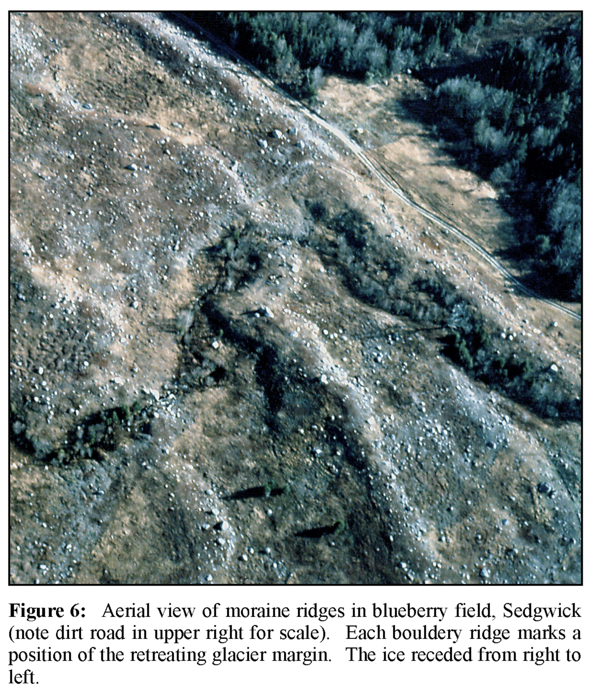

Figure 6: Aerial view of moraine ridges in blueberry field, Sedgwick (note dirt road in upper right for scale). Each bouldery ridge marks a position of the retreating glacier margin. The ice receded from right to left.

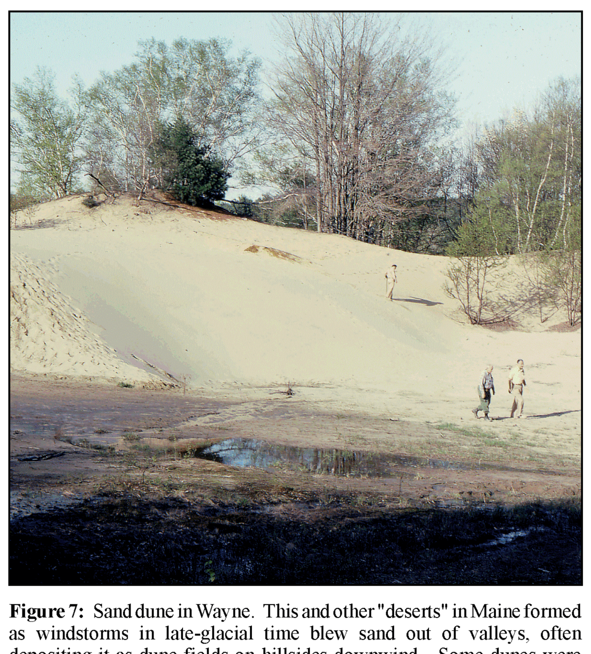

Figure 7: Sand dune in Wayne. This and other "deserts" in Maine formed as windstorms in late-glacial time blew sand out of valleys, often depositing it as dune fields on hillsides downwind. Some dunes were reactivated in historical time when grazing animals stripped the vegetation cover.

Figure 8: Songo River delta and Songo Beach, Sebago Lake State Park, Naples. These deltas are typical of geological features formed in Maine since the Ice Age.

Note: The first letter of each map unit indicates the general age of the unit:
H = Holocene (postglacial deposit formed during the last 10,000 years).
Q = Quaternary (deposit of uncertain age, but usually late-glacial and/or postglacial).
P = Pleistocene (deposit formed during glacial to late-glacial time, prior to 10,000 years B.P. [years before present]).

af — **Artificial fill** - Variable mixtures of surficial sediment, rock fragments, and artificial materials, transported and dumped to build up roads, lowlands, landfills, etc.

Ha — **Stream alluvium** - Sand, gravel, silt, and organic sediment. Deposited on flood plains of modern streams. Unit may include some wetland areas (Hw). Generally corresponds to the lower terrace levels and current flood plain of the major streams in the quadrangle.

Hb — **Beach** - Coarse to fine-grained sand shoreline deposit.

Hw — **Freshwater or saltwater wetland deposit** - Peat, muck, silt, clay, and sand. Deposited in poorly drained areas. Unit may include some stream alluvium areas (Ha).

Pmn — **Glaciomarine nearshore and undifferentiated deposits** - Massive to stratified and cross-stratified sand, silt, and gravel with local boulders. This map unit includes late-glacial sea-floor sediments (Presumpscot Formation), beach and nearshore deposits formed in shallow water, and in places some glacial meltwater deposits. These sediments were reworked by wave and current action as sea level fell. They overlie bedrock and older glacial sediments.

Pp — **Presumpscot Formation** - Glaciomarine silt, clay, and sand deposited on the late-glacial sea floor. Locally overlain by small unmapped patches of sand and gravel formed by waves and currents as sea level fell.

Pmd — **Glaciomarine delta deposits** - Sand, gravel, and minor silt deposited in the sea. Formed at or near the glacier margin by meltwater issuing from within the ice. Marine deltas were identified east of Schoodic Mountain, in Franklin, and north of Long Pond Hill. The Long Pond Hill delta (Pmdl) has a surface elevation between 240-260 ft (73.2-79.3 m); a small NE-trending moraine ridge lies near its northern margin. The Franklin delta (Pmdf) includes a few kettle holes; a meltwater channel floor on the delta top has an elevation of 253 ft (77.1 m) (Thompson and others, 1989), which approximates sea level when this delta formed. The Schoodic delta (Pmds) has a surface elevation of 260-270 feet (79.3-82.3 m), with pit face showing 1-3 ft of topset gravel beds overlying foreset sand beds.

Pmds - Schoodic Mountain delta
Pmdf - Franklin ice-contact delta
Pmdl - Long Pond Hill ice-contact delta

Pmff — **Glaciomarine ice-contact fan deposits.** Sand, gravel, and minor silt deposited at the glacier front margin by meltwater issuing into the late-glacial sea. Fan deposits were laid down below the sea surface. In Franklin, they define a series of NE-trending ice-margin positions that are successively younger to the northwest, with the last deposit at the southern edge of the Franklin delta (Pmdf).

$Pmff_x$ - Franklin fans 1-2
$Pmfp_x$ - Punkinville Road fans 1-2
$Pmfs_x$ - Sullivan fans 1-4
Pmfw - Waukeag Neck fans

Pge — **Esker** - Sand and gravel deposited by glacial meltwater flowing in tunnels within or beneath the ice, buried in places by glacial marine deposits. Chevron symbol shows inferred direction of meltwater.

Pemfp — **End moraine deposits** - Complex association of glacial till and coarse-grained ice-contact stratified sand and gravel. Forms a NE-trending ridge (overlying bedrock) that marks a former position of the glacier margin at Falls Point (Weddle and others, 2010).

Pt — **Till** - Light to dark-gray, nonsorted to poorly sorted mixture of clay, silt, sand, pebbles, cobbles, and boulders. A predominantly sandy to silty diamicton that may include lenses of washed sand and gravel. Generally underlies other surficial deposits.

Bedrock exposures - Not all individual outcrops are shown on the map. Gray dots indicate individual outcrops; ruled pattern indicates areas of abundant exposures and areas where surficial deposits are generally less than 3 m (10 ft) thick.

Contact - Boundary between map units. Dashed where approximately located.

Glacially streamlined hill - Symbol shows trend of long axis, which is parallel to former glacial ice-flow direction. Schoodic Mountain is also an example of "ramp-and-pluck" topography, with the northern slope being the glacially scoured ramp and the steep southern cliff being the glacially plucked slope.

225 135 — **Glacial striation locality** - Arrow shows ice-flow direction indicated by striations on bedrock. Headless arrow indicates striation trend where definite flow direction could not be determined. Dot marks point of observation. Number is azimuth (in degrees) of flow direction. At sites with multi-directional striations, progressively older sets of striations are indicated by the addition of barb(s) on the arrows.

Measured elevation of meltwater channel floor on Franklin delta (from Thompson and others, 1989).

Moraine ridge - Line shows inferred crest of moraine ridge composed of mostly till and/or minor water-laid sediments (sand and gravel) interpreted to have formed in the marginal zone of the glacier, perpendicular to the ice-flow direction. Most of these were deposited on the sea floor; the majority have only a few feet or meters of relief and are rarely noticeable in the field and were identified on recent LIDAR maps of part of the quadrangle. A few are partly based on interpretation of Borns and Andersen (1982).

Direction of meltwater flow - As indicated by foreset bed dip direction or crossbedding.

Ice-margin position - Shows an approximate position of the glacier margin during ice retreat, based on meltwater deposits, moraines, and/or positions of meltwater channels.

135 — **Roche moutonnée** - Small bedrock ridge streamlined by glacial abrasion in the direction of ice flow.

k — **Kettle hole** - Depression created by melting of large mass of buried glacial ice and collapse of overlying glacial sediments.

Wave-cut scarp - Formed during the recession of the glacial sea.

x — **Boulder** - Unusually large glacially transported boulder.

USES OF SURFICIAL GEOLOGY MAPS

A surficial geology map shows all the loose materials such as till (commonly called hardpan), sand and gravel, or clay, which overlie solid ledge (bedrock). Bedrock outcrops and areas of abundant bedrock outcrops are shown on the map, but varieties of the bedrock are not distinguished (refer to bedrock geology map). Most of the surficial materials are deposits formed by glacial and deglacial processes during the last stage of continental glaciation, which began about 25,000 years ago. The remainder of the surficial deposits are the products of postglacial geologic processes, such as river floodplains, or are attributed to human activity, such as fill or other land-modifying features.

The map shows the areal distribution of the different types of glacial features, deposits, and landforms as described in the map explanation. Features such as striations and moraines can be used to reconstruct the movement and position of the glacier and its margin, especially as the ice sheet melted. Other ancient features include shorelines and deposits of glacial lakes or the glacial sea, now long gone from the state. This glacial geologic history of the quadrangle is useful to the larger understanding of past earth climate, and how our region of the world underwent recent geologically significant climatic and environmental changes. We may then be able to use this knowledge in anticipation of future similar changes for long-term planning efforts, such as coastal development or waste disposal.

Surficial geology maps are often best used in conjunction with related maps such as surficial materials maps or significant sand and gravel aquifer maps for anyone wanting to know what lies beneath the land surface. For example, these maps may aid in the search for water supplies, or economically important deposits such as sand and gravel for aggregate or clay for bricks or pottery. Environmental issues such as the location of a suitable landfill site or the possible spread of contaminants are directly related to surficial geology. Construction projects such as locating new roads, excavating foundations, or siting new homes may be better planned with a good knowledge of the surficial geology of the site.

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