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Author: *Andres Meglioli*

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Surficial Geology of the Waterboro 7.5-minute Quadrangle, York County, Maine

Andres Meglioli
Geraghty & Miller, Inc.
8222 South 48th St., Suite 140
Phoenix, Arizona 85044

INTRODUCTION

Mapping of surficial geology in the Waterboro quadrangle was carried out during the summer of 1990, as part of the COGEOMAP Program of the Maine Geological Survey and the U.S. Geological Survey. As part of this project, two 1:24,000 maps were prepared: a surficial materials map (Meglioli, 1998) which shows the thickness, texture, and composition of surficial material at points where the observations were made, and a surficial geologic map (Meglioli, 1999c) which shows the distribution of geologic units and features that can help to reconstruct the glacial and postglacial geologic history of the quadrangle. The surficial deposits mapped in the Waterboro quadrangle are described in detail in this report.

PREVIOUS WORK

Surficial deposits in the Waterboro quadrangle were mapped at a scale of 1:62,500 by Smith and Thompson (1977) based on reconnaissance field mapping and air photo interpretation. The information was used to prepare a reconnaissance surficial geologic map of the Buxton 15-minute quadrangle (1977) and was later incorporated in the Surficial Geologic Map of Maine (Thompson and Borns, 1985a). The elevation of glaciomarine deltas and other indicators of the marine limit were measured and reported by Thompson and others, 1989.

INVESTIGATION PROCEDURES

Field observations were made by the present author in numerous active and inactive gravel pits, building excavations, and road cuts throughout the area. This information was complemented with field descriptions of bedrock outcrops and surficial deposits. Subsurface information was obtained through the use of hand augers and shovels, and from the analysis of boring logs provided by the Maine Department of Transportation. The analysis of aerial photographs was useful in refining the contacts of wetland areas and terrace scarps. Glacially streamlined hills and ice-contact deposits, including moraines and esker ridges, were inferred from the analysis of air photos and topographic maps. Their identity was later confirmed by field work. All colors mentioned in the description of soils and sediments were described according to the Munsell Soil Color Chart, 1990 Edition.

LOCATION AND GENERAL PHYSIOGRAPHY

The study area is the Waterboro 7.5-minute quadrangle, located in York County, southwestern Maine (Figure 1). The Waterboro quadrangle extends from 43° 30'N to 43° 37'30"N and from 70° 37'30"W to 70° 45'W and covers an area of 54 square miles (approximately 142 square kilometers).

Elevations in the study area range from 270 feet above sea level (ASL) at South Hollis, on the east side of the quadrangle, to 1,028 feet ASL on the unnamed mountain just south of Ossipee Hill, in the northwest corner of the quadrangle. Maximum local relief is approximately 700 feet, between the summit of this mountain and Little Ossipee Pond. Most of the quadrangle is characterized by moderately high topographic relief. The topographic gradient decreases markedly from northwest to southeast.

Bedrock outcrops are scattered throughout the area, such as along the western border of Little Ossipee Pond. The quadrangle is covered by unconsolidated sedimentary deposits of Quaternary age of variable thickness, with the central part presenting a low area occupied by wetlands and ponds, including Little Ossipee, Roberts, Bunganut, Kennebunk, and Swan Ponds. Several bedrock ridges are covered with only a thin veneer of till. The whole study area has a drainage pattern characterized by a poorly integrated drainage network with many small streams and brooks sluggishly flowing predominantly to the south - southeast. Some of the ponds are closed basins with centripetal drainage.

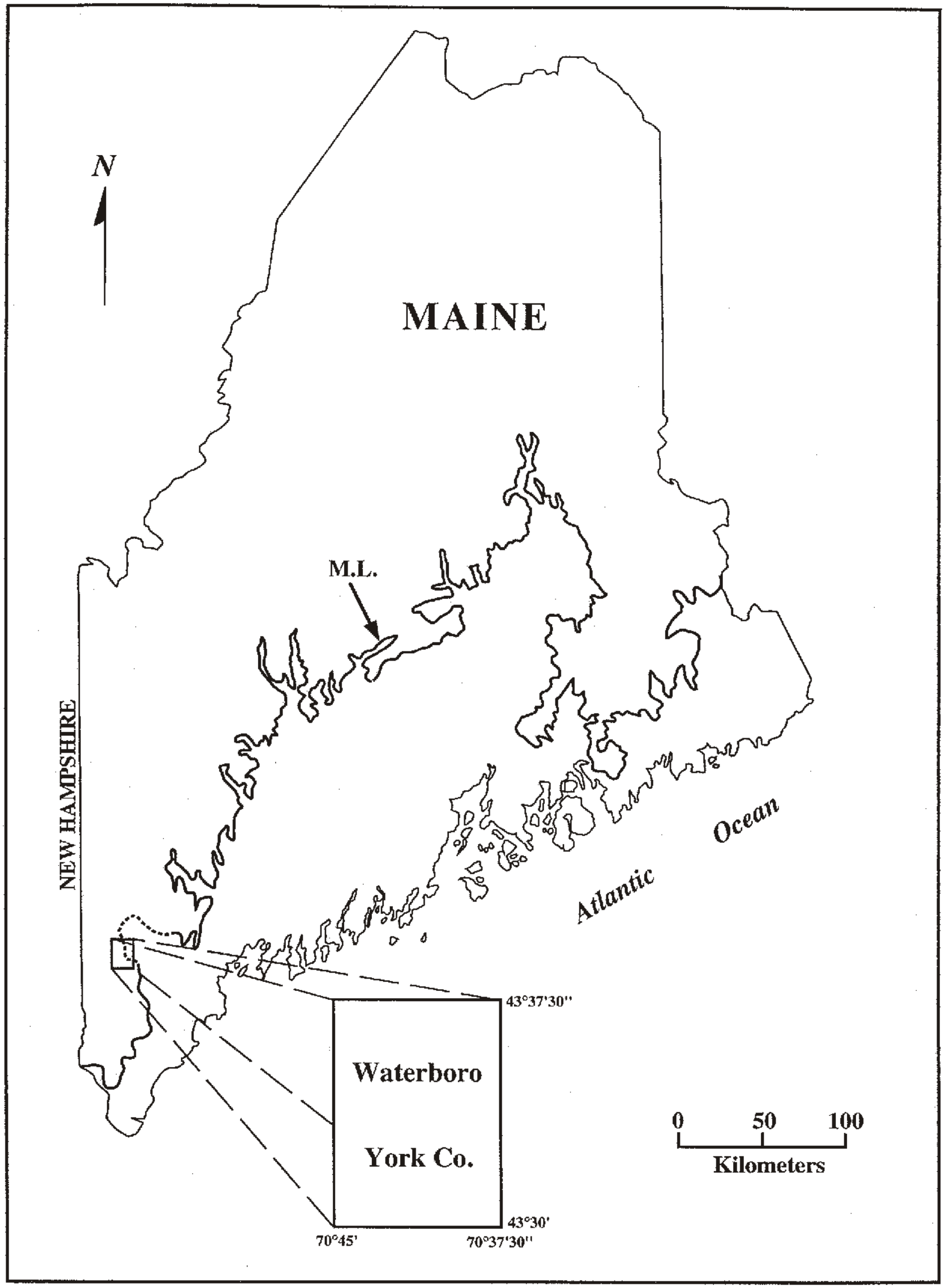

Figure 1. Location map of the Waterboro quadrangle, York County, Maine.
Line marked M.L. indicates the limit of marine transgression.

BEDROCK GEOLOGY

The distribution of the bedrock units in the Waterboro and neighboring quadrangles was mapped by Hussey (1985). Bedrock outcrops exposed in the study area include a variety of igneous and metamorphic rocks. Metamorphic lithologies include rocks of the Vassalboro formation that range in age from Ordovician to lower Silurian, and gneiss and marble of the Shapleigh Group. Igneous lithologies are represented by the Lyman pluton composed primarily of intrusive rocks such as two-mica granites of Mississippian age. The rocks found in the area and their ages are (Hussey, 1985):

Vassalboro Formation: Thin to medium (2-30 cm) bedded, fine to medium grained, quartz-plagioclase-biotite-hornblende granofels and slightly schistose granofels. The Vassalboro Formation is regarded to be Ordovician to Lower Silurian in age.

Shapleigh Group: Represented by a lower unnamed subunit at the base of the lower Rindgemere Formation. It is described as a thin, discontinuous quartz-feldspar-biotite and calc-silicate granofels.

Lyman Pluton: The Lyman pluton is lithologically characterized by fine-grained, light gray, weakly to moderately foliated biotite-muscovite granite. Pegmatite bodies are common throughout the area.

Rocks of the Vassalboro Formation and Shapleigh Group have undergone several phases of deformation that resulted in folding and thrusting. Major structures in the area are chiefly oriented north-south. Several plunging folds identified in the area are clearly related to the emplacement of the Lyman pluton.

SURFICIAL DEPOSITS

The quadrangle is almost completely covered by a blanket of glacial, glaciofluvial, and glaciolacustrine sediments, which are believed to be mainly related to the last glacial advance and retreat over the area during late Wisconsinan time. The composition and distribution of the mapped surficial units are briefly described in the following paragraphs.

Thin Drift

Many upland areas in the quadrangle mapped as Pt (Pleistocene till) have a generally thin cover of surficial sediments and are shown on the map with a horizontal ruled pattern. These areas are chiefly underlain by till deposits less than ten feet in thickness. In the field many of these areas are characterized by an abundance of bedrock outcrops. Often the underlying structure of the bedrock is distinguishable on air photos. In areas with very thin drift cover, the till matrix is almost absent and the deposits are limited to large angular boulders. Only two striated bedrock surfaces were found in the quadrangle. The first, located near the southern end of Deering Ridge has a measured azimuth of 140 degrees (S40E); the second locality is Ossipee Hill, with a measured azimuth of 160 degrees (S20E). These striae indicate a general flow direction of glacial ice from northwest to southeast.

Wisconsinan Till

Till (map unit Pt), which typically is a non-sorted, non-stratified sediment deposited by a glacier, occurs throughout the quadrangle, especially in high-elevation areas. The main criterion for separating the thicker till deposits from thin drift areas is the absence of bedrock outcrops and generally a more subdued topography.

Two kinds of genetically different till deposits were recognized in the study area. Lodgement till, consisting of a dark gray to bluish gray, very well consolidated, fissile, silt-rich diamicton, was found in few localities. Confirmed lodgement till deposits were too small to map, and were usually found at the base of the sedimentary pile, plastered against bedrock. Although not systematically measured, a preferred orientation or fabric of stones is evident in the lodgement tills. The most common type of till is represented by a loose to moderately compact sandy-silty diamicton of light brown to dark yellow (oxidized) color, which consists of a non-sorted, non-stratified mixture of silt, sand, pebbles, cobbles, and boulders with no obvious fabric. Clay-size sediment is mostly absent. In some places this till evidences weathering and oxidation to a yellow-orange color. Fresh unweathered till is typically dark gray to olive in color. The morphology as well as the sedimentary characteristics suggest that most of the till unit can be classified as an ablation till. The lithology of the till in the Waterboro quadrangle is largely derived from the local bedrock. Large (1m) granitic boulders are common throughout the area. To some extent the random distribution of the boulders may indicate lag deposits left behind after the finer material was carried away by glacial meltwater. The angularity of the boulders indicates that they have not been transported great distances from their source. Accumulations of boulders occur in lower areas or on hillsides. Huge boulders (3m across) are abundant to the west of Swan Pond, and to the north of Grant Hill. Where till thickness is greatest, the morphology of the land surface is characterized by a hummocky topography (map unit Phm). The till in the hummocky areas generally consists of a sandy, massive and poorly consolidated, non-stratified diamicton. Pockets of well stratified glaciofluvial deposits, and occasionally glaciolacustrine deposits, are common within the till unit. Where the stratified deposits are large enough to be differentiated at the scale of the quadrangle, they were mapped separately as stratified drift (map units Pgi, Pgo, etc.).

It is inferred that most of the till in this area was deposited by the last major glaciation and deglaciation of Maine, referred to here as the late Wisconsinan glaciation.

Pleistocene End Moraines

End moraines (Pem) were mapped chiefly on the basis of air photo interpretation and topographic map analysis, although most localities were field checked. Most of the end moraines are located in the central to southern parts of the quadrangle. Another cluster of moraines is located in the northeast corner of the quadrangle; and a short moraine ridge was recognized in the southeast corner of the quadrangle, near the eastern outlet of Kennebunk Pond. These end moraines consist of till ridges formed at the ice margin.

Most moraine ridges in the study area are small, with heights rarely exceeding 4 meters (12 feet), widths on the order of 30 meters (100 feet), and lengths of approximately 300 meters (usually less than 1,000 feet). The ridges are generally oriented from southwest to the northeast, parallel to the regional trend of moraines in this part of Maine. That direction is perpendicular to the predominant ice flow direction in the Waterboro quadrangle. Most exposures of unit Pem showed till with lesser amounts of ice-contact sand and gravel, with the water-laid sediments generally located on the flanks of the moraine ridges. Moraines have been used to reconstruct the ice marginal positions indicated on the map.

Glaciofluvial and Glaciolacustrine Sediments

Glaciofluvial sediments are deposited by glacial meltwater streams. Glaciofluvial sediments in the Waterboro quadrangle include eskers and eskers systems (map unit Pge), outwash sand and gravel (map unit Pgo), and ice-contact sediments (map unit Pgi). Glaciolacustrine sediments (deposited in lakes adjacent to glacial ice) are present in the area as lacustrine deltas (Plad). However, deltas are genetically distinct and will be described in a separate section.

Esker ridges (map unit Pge) are sinuous ridges comprised of massive to well stratified sand, waterworn cobble-pebble gravel, and subordinate boulders, which formed in tunnels within or underneath glaciers. The deposits commonly form ridges of highly variable length. The most prominent esker system crosses the quadrangle diagonally from the northwest to the southeast. Its continuation to the north can be found in the Lake Arrowhead area of the Limington quadrangle (Meglioli, 1999a,b). It can be easily recognized on maps and air photos in Roberts Pond, where one of the ridges forms a long narrow island in the middle of the pond. This esker system in the Waterboro quadrangle is rather fragmented and can be traced for approximately 10 kilometers. The maximum measured ridge elevation is 20 meters above the surrounding terrain at Roberts Pond. Shorter esker ridges have also been recognized running parallel to the main esker. This esker system will be referred to here as the Arrowhead esker. Some very good exposures found in gravel pits near the town of East Waterboro and in the vicinity of Little Ossipee Pond revealed that the local esker ridges are composed of well-bedded gravel with subrounded cobbles and boulders. Some of the boulders are larger than 2 meters in diameter. The matrix is composed of fine gravel to very coarse sand. Pockets of very fine to medium, well-sorted sand are common. High-angle normal faults were observed on the sides of the eskers. Typically eskers occupy lowlands and valleys; the ridges are usually interrupted where the subglacial streams crossed knobs and highlands. The general direction of the eskers in the quadrangle is coincident with the predominant ice flow direction in the area. That is north-south near the northern boundary of the Waterboro quadrangle and northwest-southeast in the central to southern portion of the study area.

Outwash sand and gravel (unit Pgo) were mapped in large areas of the quadrangle. The most prominent outwash deposit is an outwash plain. Proximal (near-ice) outwash deposits are located immediately to the south of Little Ossipee Pond, and are characterized by very well-rounded cobbles and small boulders, with coarse matrix. At the pond shore the outwash deposits reach an elevation of 310 feet ASL and they drop 40 feet southward towards the town of Waterboro, where the plain reaches an elevation of approximately 276 feet ASL. Distal outwash deposits are incised into and stratigraphically overlie delta deposits near Waterboro. The distal outwash deposits are characterized by finer gravel, and small, very well-rounded pebbles and cobbles. Boulders are absent. South of Waterboro, the outwash deposits narrow considerably before ending at Shaker Pond. Other smaller deposits of outwash where recognized in the central part of the quadrangle. Exposures revealed deposits composed predominantly of medium to coarse gravel with a sandy matrix. The grain size decreases markedly from north to south.

Ice-contact stratified sediments (unit Pgi) are predominantly sandy gravel and gravelly sand that has been deposited in contact with glacial ice. Although the majority of these deposits were formed in contact with the glacier margin, ice-contact deposits were also deposited next to isolated ice blocks separated from the main glacier, and therefore are found around kettle lakes. Ice-contact deposits were found around the margins of Roberts, Swan, Bartlett, and Little Ossipee Ponds. Some of these deposits show collapse structures and are associated with ice-disintegration and stagnation features. Ice-contact deposits are associated with esker ridges in the Roberts Pond area, and around Little Ossipee Pond. Kettles in the outwash are the consequence of the melting of buried ice blocks.

Glaciolacustrine Deposits

Glaciolacustrine deposits (map unit Plad) have been identified in the Waterboro quadrangle around Little Ossipee Pond, and around Lake Arrowhead in the Limington quadrangle to the north. Lacustrine delta sediments typically form flat areas underlain by coarse to medium sand, with lesser amounts of medium to fine gravel commonly interbedded as lenses within the sand. The general orientation of the foreset beds in the glacial Lake Arrowhead delta indicate a predominant sediment transport to the southeast. The village of North Waterboro is located on this delta, which is the only lacustrine delta recognized in the quadrangle. The average elevation of the delta top is 350 feet asl. The glaciolacustrine deposits in the Little Ossipee Pond area extend to the north into the Arrowhead Lake area of the Limington quadrangle. In the Limington quadrangle this glacial lake has been named glacial Lake Arrowhead (Meglioli, 1999a,b). Therefore this name will be also utilized in this report.

The Lake Arrowhead deltaic deposits extend to the north into the Limington quadrangle, where they connect with esker deposits, which would indicate that this glaciolacustrine delta was esker-fed. The stratigraphic relationship between the deltas and the esker was not completely established. Some esker ridges are higher than the surrounding delta plain; however in the Lake Arrrowhead area the inverse has been observed, with deltaic deposits overlapping esker ridges.

Glacial Lake Arrowhead formed north of an ice block centered at Little Ossipee Pond. Here the ice dam melted gradually while the main glacier retreated northward from the quadrangle. The elevation and position of glaciolacustrine deltas provide information needed for the reconstruction of ice margins during deglaciation (Koteff and Pessl, 1981). Probable spillways for at least two glacial lake levels have been identified on the basis of channel features and spillway elevations correlative to delta surfaces for a particular lake level. An early spillway for glacial Lake Arrowhead was located to the east of Little Ossipee Pond and to the north of Roberts Ridge at an elevation of approximately 340 feet ASL. Topset deposits of the Lake Arrowhead delta were exposed during the operation of the gravel pit on the eastern side of the pond, but have been largely removed. Coarse topset deposits were recognized here. The second possible spillway is at the southern tip of Little Ossipee Pond at an elevation of about 320 feet, although this outlet may have been blocked by remnant ice in the pond basin. Here, finer-grained topset deposits were examined during field mapping. A third lacustrine level, not recognized in the Waterboro quadrangle, formed to the north when the eastern side of Lake Arrowhead was dammed during continuous retreat of the glacier in this area.

The foreset sediments of an eroded marine delta plain in the Waterboro area are overlain unconformably by outwash comprised of fine gravel and sand. Unfortunately no good exposures were found to establish clearly the stratigraphic relationships.

Glaciomarine Deposits

Three glaciomarine deltas (map unit Pmd) were mapped in the study area: the South Hollis delta, a probable delta north of Bunganut Pond, and the much smaller Waterboro delta. Deposits of a fourth delta, the Kennebunk delta, were identified in the southeast corner of the quadrangle and are indicated on the map. However, most of the Kennebunk delta deposits are located in the Alfred quadrangle to the south. The average elevation of the eastward-sloping surface of the South Hollis delta is approximately 280 feet asl. No contact between the delta topset and foreset beds was exposed in the shallow, abandoned gravel pits investigated near the village of South Hollis. In marine deltas such as the South Hollis delta, the topset-foreset contact closely approximates former sea level in the area. The predominant sediments on the delta plains are well-bedded, well-sorted, loose medium gravel with coarse sandy matrix. Pebbles are well rounded, and boulders and cobbles almost absent. Beds were observed dipping gently to the northeast. Field work revealed that the apex of the delta is connected to an esker ridge. To the south of South Hollis, the delta topset beds have been directed by the Cooks Brook valley. It is possible to observe few good exposures of the medium to coarse gravel topset beds along the terraces of the brook. The lower elevation of the South Hollis delta in comparison to the Waterboro delta may be attributed to postglacial marine erosion of the upper topset beds.

The Waterboro delta is located approximately one mile northwest of Waterboro Village. An exposure observed in an abandoned gravel pit located to the south of Straw Mill Brook Road shows a well defined topset-foreset contact. The elevation of the contact is 297 feet above present mean sea level. This elevation is slightly higher than expected from other measured elevations of marine deltas in the region, and suggests that this small delta may actually have formed in an ice-marginal pond (Koteff and others, 1993). The foreset beds dip 10-15 degrees to the south-southeast. Other similar contacts were observed nearby to the north and to the south. However, the elevation of these contacts is 10 to 20 feet lower than the contact measured in the gravel pit. These seemingly anomalous elevations may indicated the lower contact is actually between eroded foreset beds and younger outwash deposits that have replaced the original delta topset sediments. The outwash deposits are inset below the original delta surface. Alternatively, the eroded foreset deposits could represent submarine fans.

Fine sands, silt, and lesser amounts of clay identified to the south of Dayton and east of the Massabesic Experimental Forest were mapped as a regressive marine deposit (map unit Pmrs). Direct observation indicates that these sediments discomformably overlie till. Clay has been reported by drillers and residents throughout the area, and may indicate the presence of buried marine muds of the Presumpscot Formation.

Postglacial Alluvium, Shoreline, and Wetland Deposits

A few alluvial deposits (map unit Ha) of restricted areal extent were identified in the quadrangle. They are always associated with modern streams and rivers and usually consist of reworked glacial sediments characterized by coarse to medium gravel and sand (e.g. along Hamilton Branch and Carll Branch of Shaker Brook). Pebbles in the gravels are usually imbricated. Alluvial deposits mainly composed of coarse to fine sand are associated with small fluvial terraces of flat topography (map unit Qst). The best developed alluvial terrace is located alongside Cooks Brook. Some terraces were not mapped because of their small size.

Holocene wetland deposits were mapped over large areas within the quadrangle. They typically form in areas of poor drainage. Some of these wetlands hold water only during the wet season and after snow melt. Wetland areas that are more or less covered with bushes and trees were classified as swamps (map unit Hws). Marshes (map unit Hwm) were distinguished from other wetlands by the dominance of grasses, while heaths (unit Hwh) are covered by shrub vegetation. The largest wetland is in the central part of the quadrangle (The Heath). Many wetland boundaries on the map were approximated from aerial photograph interpretation, so these boundaries should not be considered definitive for regulatory purposes.

Modern lake beach deposits (map unit Hls) were mapped on the shores of Kennebunk Pond. Other beach deposits were too small for mapping at the scale of the quadrangle. The lacustrine beaches are predominantly composed of coarse sand and fine gravel.

Often the steeper hillsides are covered by a veneer of colluvium, however because the colluvium generally originates from till, it is difficult to distinguish the two, and therefore it has not been mapped in this quadrangle as a separate unit.

ICE FLOW DIRECTION IN THE WATERBORO QUADRANGLE

The glacial ice flow direction in the study area was inferred from glacial striae and streamlined hills. The azimuths of the striae measured indicate flow directions ranging from southeast to south-southeast (140 to 160 degrees). Regional ice flow was from the northwest to the southeast as indicated by the glacial striations and by the orientation of the long axes of some ice-shaped hills, as indicated on the map. The predominant orientation of the moraine ridges (SW-NE), and of the esker ridges, supports the dominant ice flow direction to the southeast, and indicates ice withdrawal in a general north to northwest direction. These ice flow directions are interpreted as recording late Wisconsinan ice flow, since no evidence of earlier glaciation was found in the Waterboro quadrangle.

GLACIAL AND POSTGLACIAL HISTORY

As noted above, the glacial deposits of the Waterboro quadrangle provide evidence of only one episode of glaciation, although it is almost certain that Maine was affected by more than one glaciation. The deposits in the quadrangle are attributed to the late Wisconsinan glaciation, which was the most recent glacial episode.

Regional studies indicate that ice entirely covered the Gulf of Maine during the last glacial advance. Ice retreat began approximately 17,000 yr B.P. and although radiocarbon dates indicating the time of deglaciation are not available from the Waterboro quadrangle, dates obtained from nearby areas indicate that the study area was almost completely ice-free by about 13,000 yr B.P. (Smith, 1985; Thompson, 1982; Thompson and Borns, 1985b). Most sand and gravel deposits in the Waterboro quadrangle were formed during the recession of the last Wisconsinan ice sheet. Ice margin positions indicated by glaciomarine deltas and moraines suggest that glacier retreat was not continuous; rather, it was interrupted by stillstands, and perhaps minor local readvances. Marginal stagnation occurred, as indicated by features such as kettles.

The weight of the ice caused subsidence of the land mass of more than 100 meters (330 feet). As the glacier ice thinned and retreated, the Atlantic Ocean inundated the subsided land (Bloom, 1960; Stuiver and Borns, 1975; Smith, 1985). Ice-contact glaciomarine deltas indicate that in the southern and eastern parts of the quadrangle the receding glacier was in contact with the sea. Deltaic deposits suggest that the inland limit of late-glacial marine submergence is located in Waterboro, and not east of South Hollis as shown on the Surficial Geologic Map of Maine (Thompson and Borns, 1985a).

The absence of marine shorelines suggests that postglacial uplift of the land was rapid. The ice thinned and retreated, depositing coarse debris as till and outwash gravel. Local stagnation, with the formation of debris-covered ice blocks, formed many of the ponds and kettles in the area. The stratigraphic positions of the esker ridges indicate that most of the activity related to the formation of eskers and esker-fed deltas occurred during deglaciation. The distribution of ice-contact deposits suggests that the position of the glacier margin was strongly controlled by the local topography. Topographically higher areas were free of ice before the lowlands, and meltwater activity was then concentrated along the valleys. This can be observed in the distribution of sand and gravel deposits. Moraine ridges locally indicate ice marginal positions, that is stillstand positions during deglaciation.

Till continued to be deposited as ice melted across the quadrangle, and in some areas detached ice blocks were left by the rapidly retreating glacier. The ice blocks covered by glacial sediments slowly melted, forming kettle lakes (e.g. Bartlett Pond). Esker ridges were deposited in subglacial and englacial tunnels. The esker tunnels also fed sediment to proglacial water bodies forming deltas (e.g. South Hollis delta).

The advancing sea progressively inundated the southern portion of the quadrangle reaching elevations close to 91 m (300 ft) in the Waterboro area. Glacial lakes formed in front of the glacier where remnant ice bodies or the adjacent terrain blocked the drainage of meltwater. Glaciolacustrine deltas formed (e.g. Lake Arrowhead delta complex), and once the ice blockage disappeared, outwash deposits were laid down.

Postglacial activity in the area includes erosion caused by the incision of the local drainage network, which was probably enhanced by uplift resulting from glacio-isostatic rebound. Erosion of the glacial deposits provided material for the deposition of stream alluvium and terraces. Low, poorly drained areas favored the formation of wetland deposits. Most of these deposits are still forming today.

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