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OPEN-FILE NO. 97-75

Title: *Surficial Geology of the North Windham 7.5-minute Quadrangle, Cumberland County, Maine*

Author: *Andreé M. Bolduc, Woodrow B. Thompson, and Andres Meglioli*

Date: *1999*

Financial Support: Funding for the preparation of this report was provided in part by the U.S. Geological Survey Cooperative Geological Mapping (COGEOMAP) Program, Cooperative Agreement No. 14-08-0001-A0520.

Associated Maps: Surficial geology of the North Windham quadrangle, Open-File 97-41
Surficial materials of the North Windham quadrangle, Open-File 98-192

Contents: 7 p. report

Maine Geological Survey
Open-File 97-75

Surficial Geology of the North Windham 7.5-minute Quadrangle, Cumberland County Maine

Andrée M. Bolduc[1]
Department of Geological Sciences
Lehigh University
Bethlehem, PA 18015

Woodrow B. Thompson
Maine Geological Survey
Augusta, Maine 04333

Andres Meglioli[2]
Department of Geological Sciences
Lehigh University
Bethlehem, PA 18015

[1]*Present address:*
Commission géologique du Canada
Sainte-Foy, Québec, Canada G1V 4C7

[2]*Present address:*
Geraghty & Miller, Inc.
Phoenix, Arizona 85044

INTRODUCTION

The North Windham 7.5-minute quadrangle is located in Cumberland County, southwestern Maine (Figure 1), approximately 20 miles northwest of the city of Portland. It covers an area of 52.75 mi^2, the northwestern corner of which is occupied by Sebago Lake. Maximum local relief is 380 ft. The lowest part of the map is in the southern portion of the quadrangle along the Presumpscot River (140 ft asl), while the highest elevation is located on Mount Hunger at the north edge of the map (520 ft asl). Much of the map area is at or below 300 ft (the approximate elevation of large delta plains formed during late-glacial marine submergence.)

The topography of the quadrangle consists of gently undulating terrain (Figure 2) with a few isolated hills (Mount Hunger, Freeman Hill, Baker Mountain). Most of the surface water occurs in lakes and ponds in the northern and western parts of the map area, as well as rivers and brooks that are tributary to the Presumpscot River. Some of the region, especially in the north, is poorly drained, and a number of wetlands occur in the quadrangle. Because of extensive development and the resulting presence of many sand and gravel pits, there generally were good exposures of surficial earth materials throughout the region. However, a lot of the terrain has been altered by human activities, and access to private properties to conduct geologic mapping was not always possible.

The bedrock of the North Windham quadrangle is composed of igneous and metamorphic rocks, which are exposed in numerous outcrops. Most of the surficial materials, including tills, glaciofluvial sediments, and glaciomarine sediments, are interpreted as having been deposited either during the late Wisconsinan glaciation, at a time when New England was covered by the Laurentide Ice Sheet, or during the subsequent recession of the ice sheet and accompanying marine transgression of southern Maine. There are also more recent deposits of alluvium, colluvium, wetland deposits, and beach sediments. Artificial fill resulting from human activities is widespread in minor quantities.

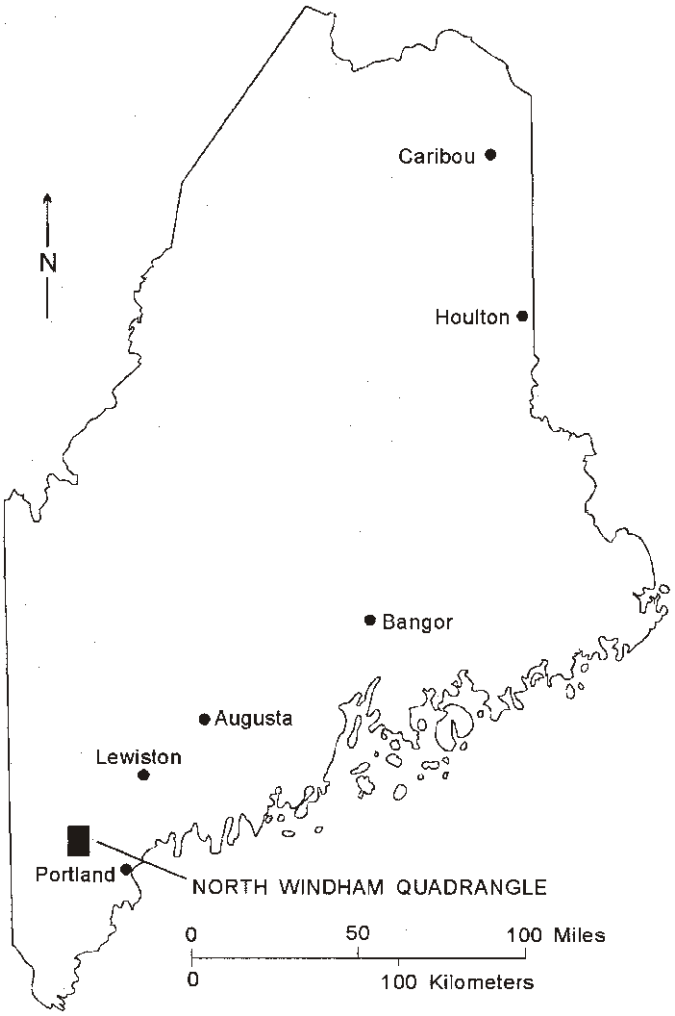

Figure 1. Location of the study area in southwestern Maine.

Figure 2. View near Baker Corner on U.S. Route 202, showing low undulating terrain in eastern part of quadrangle.

The area has been the subject of a number of surficial geologic studies, including reconnaissance mapping of the surficial deposits (Prescott and Thompson, 1976) and aquifer studies (Prescott, 1976; Williams and others, 1987). The quadrangle is also included in many regional academic studies such as those on glaciomarine deltas and crustal movements (Thompson and others, 1989), end moraines and glacial retreat (Smith, 1982), and glaciation and deglaciation of Maine (Thompson, 1982; Smith, 1985). The present study is part of the U. S. Geological Survey's Cooperative Geological Mapping (COGEOMAP) Program. In Maine this project includes the detailed mapping of surficial materials at 1:24,000 scale (Bolduc and others, 1998), and interpretation of the geologic history of these deposits.

BEDROCK GEOLOGY

The North Windham quadrangle is underlain by the Early Paleozoic Central Maine Terrane (Hussey, 1985), of which only the Vassalboro and Windham Formations are present in the map area (Figure 3). The northeast strike of these metamorphic rocks locally imparts a prominent grain to the topography. The northern third of the study area is underlain by a Carboniferous granite pluton, the Sebago batholith. The following section is summarized from Hussey (1985).

The Vassalboro Formation, of Late Ordovician and Early Silurian age, consists of quartz-plagioclase-biotite (-hornblende) granofels with local interbeds of calc-silicate granofels, all of which has been metamorphosed to staurolite and higher grade. The Vassalboro Formation is highly migmatized where it is in contact with the Sebago batholith.

The Windham Formation, of Early Silurian age, consists of a thin-bedded biotite-muscovite-garnet-quartz-plagioclase schist and biotite granofels, with staurolite, sillimanite, and kyanite depending on metamorphic grade. A member of the Windham Formation, consisting of ribbon metalimestone associated with calc-silicate granofels and biotite granofels, is located in the middle of the formation.

The Sebago batholith is a Carboniferous two-mica granite, which has been dated at approximately 325 MA by U/Pb on zircon and Rb/Sr on whole rock samples.

The Central Maine Sequence was deformed during the Acadian orogeny in Early Devonian time, first by large-scale recumbent folds and second by large-scale upright to slightly overturned folds. This deformation produced staurolite grade metamorphism. Instrusion of the Sebago batholith induced very minor folds and remetamorphism to kyanite grade.

SURFICIAL GEOLOGY

The study area is almost completely covered by a blanket of glacial sediments ranging from 0 to 107^{+} ft in thickness (Prescott, 1976; Williams and others, 1987), most of which were deposited during the expansion and retreat of the latest (Wisconsinan) ice sheet. Ice flow indicators (primarily striations

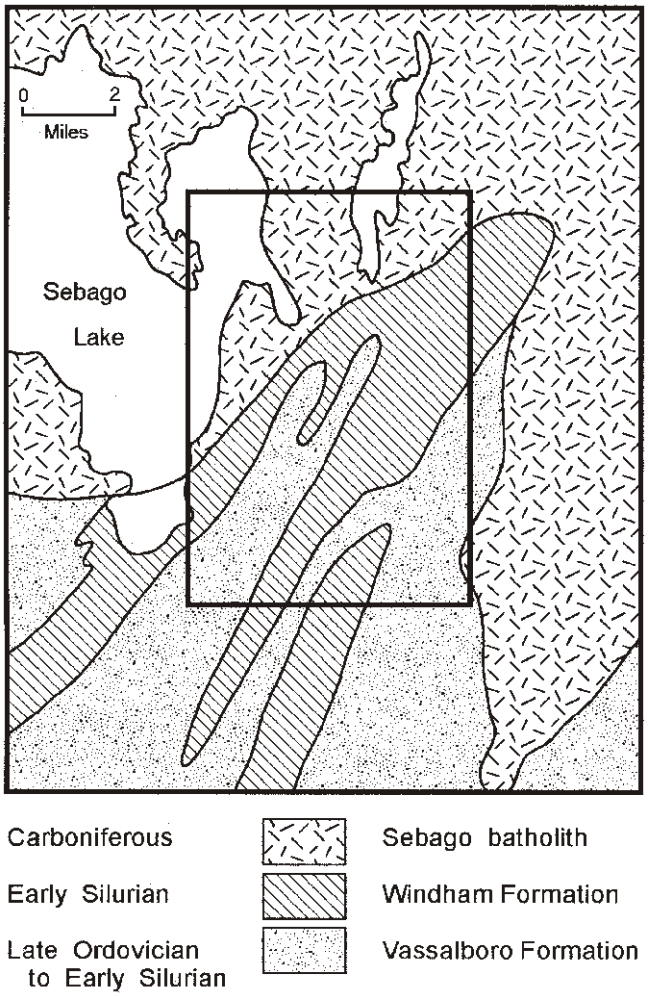

Figure 3. Bedrock geology in the North Windham quadrangle and adjacent areas (modified from Hussey, 1985 and Hussey and others, 1986).

and grooves on glacially scoured bedrock) demonstrate glacial movement from the northwest to the southeast (Figure 4). In stratigraphic order, the general sequence of Quaternary deposits consists of: till and end moraines deposited directly by glacial ice (Pt, Pem, Pemc); water-laid glacial sediments (Pgi, Pge, Pmf, Pmd, Pmdi); glaciomarine sediments of the Presumpscot Formation (Pp); marine nearshore deposits (Pmn); and alluvial (Ha) and lacustrine shoreline (Hls) deposits, as well as wetland deposits (Hw, Hwh, Hws, Hwsp, Hwfm, Hwfmp) of Holocene age. Artificial fill (af) is also present throughout the area and was mapped where possible at the scale of the project.

Till occurs at the surface in the higher areas, and is presumed to underlie many younger glacial and postglacial sediments in the lowlands, as seen where sections were exposed or described in well logs (Prescott, 1976; Williams and others, 1987). Coarse, ice-contact sand and gravel deposits (eskers, glaciomarine fans, and glaciomarine deltas) occur in contact with both till and fine-grained clayey to sandy glaciomarine sediments. The glaciomarine muds, known as the Presumpscot Formation, blanket the lower areas. The sea in which these sediments were deposited reached maximum local elevations of about 300-320 ft asl (Thompson and others, 1989).

Till

Two kinds of till are found in the study area. The first is a clayey to silty, compact, gray diamicton, interpreted as a lodgment till. It was seen only in a few places, as a blanket deposit over bedrock or in association with end moraines or glaciomarine fans. Its stratigraphic position, as well as its limited outcrop, did not allow mapping at the scale of this project.

The second till facies (map unit Pt) is a silty to sandy, loose to moderately compact, light olive-gray diamicton. The till consists of a non-sorted, non-stratified variable mixture of silt, sand, pebbles, cobbles, and boulders. It occurs at elevations above 300 ft over much of the northern and western parts of the quadrangle, in numerous small moraines, and at elevations below 300 ft in the southeastern part of the map area. Extensive boulder fields are associated with this till. The boulders are up to 5-10 ft in diameter and are quite angular. The predominant SE-trending glacial striations and NE-SW oriented moraines indicate that this till is most likely derived from the northwest.

Field identification of till deposits was made on the basis of hummocky topography associated with large boulders, natural and artificial exposures along roads and in pits, and examination of sediment from auger holes. The till is commonly less than 10 ft thick in areas shown by the horizontal ruled pattern on the geologic map. The morphology, sedimentary characteristics, and general distribution of much of the sandy, bouldery till suggest that it is an ablation facies deposited during the retreat of the ice sheet.

Figure 4. Striated bedrock near confluence of the Presumpscot and Pleasant Rivers. Striations at this locality trend 123° and 171°.

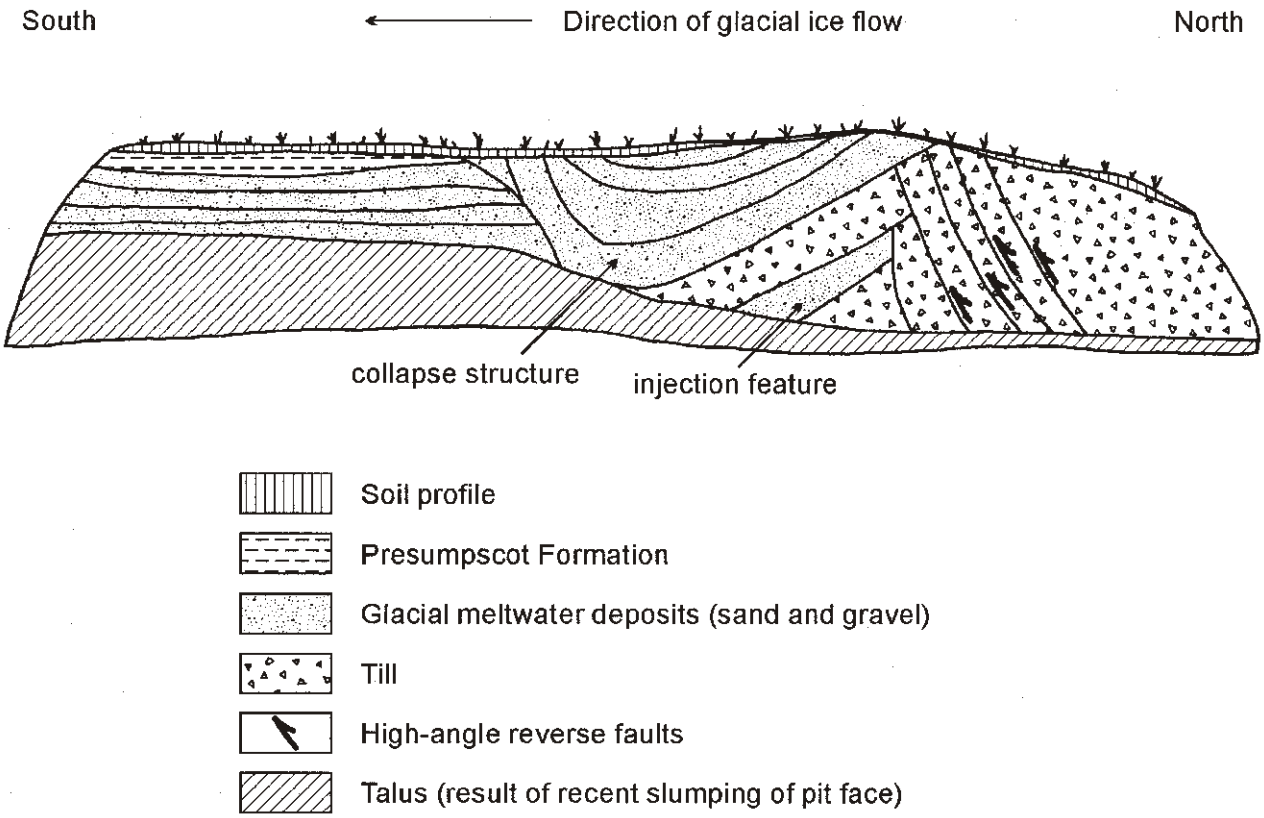

Figure 5. Schematic section through an end moraine in the southeastern part of the map area, showing features often seen in exposures of moraines.

There are numerous end moraines in the North Windham quadrangle. These are ridges of glacially deposited sediment that accumulated along the ice margin. Some of the larger examples are shown on the map as individual moraines (unit Pem). Clusters of moraines (end moraine complexes) are shown as map unit Pemc. Other moraines, especially those which barely protrude through the overlying marine sediments, are indicated only by the line symbols drawn along their axes. Many additional moraines may exist in the quadrangle, but are concealed beneath the Presumpscot Formation.

The end moraines are composed of a variety of sediment types, including not only till but also sand and gravel (glaciomarine fan deposits) and glaciomarine muds belonging to the Presumpscot Formation. These sediments may overlie or intertongue with till in various ways. Reverse faults indicating ice shove have been observed in pit exposures (Figures 5 and 6). All of the moraines are located in the zone of late-glacial marine submergence, typically at elevations less than 300 ft. As in other areas of coastal Maine, they preferentially formed in a subaqueous environment.

There is a bedrock topographic control of moraine distribution in the southeastern half of the quadrangle, where moraines are localized in north-northeast trending valleys whose orientation is due to the strike of local rock formations. The bedrock strike ridges in the eastern part of the quadrangle have also influenced the orientation of the retreating glacier margin, resulting in the more northeasterly trend of some of the moraines. Bedrock highs across the entire region acted as pinning points for the glacier and thus localized the deposition of other glacial features, especially deltas and glaciomarine fans (Thompson and others, 1989; Crossen, 1991).

Figure 6. High-angle reverse faults in the end-moraine complex southwest of Dundee Falls in Gorham.

Glacial Meltwater Deposits

Sediments deposited by glacial meltwater streams in the study area include eskers, glaciomarine deltas, and glaciomarine fans. These deposits are chiefly composed of sand and gravel. The eskers (unit Pge) were deposited by high-energy streams in tunnels within or beneath glacial ice. Deltas and fans formed where glacial streams entered the sea and dropped their sediment load, often at the mouths of ice tunnels. Other ice-contact sand and gravel deposits of uncertain origin that probably belong to one of the above categories are shown on the map as "Pgi". notably in the collapsed zone at the head of the North Windham delta.

Several esker systems have been identified in the North Windham quadrangle. Most of them are feeders to deltas: the Windham Hill delta, the North Windham delta, and the Dog Corner delta. Another esker feeds the glaciomarine fan at the south end of Dundee Pond. The eskers are rather short, the longest being approximately 1.5 miles long. They stand as high as 50 ft above the surrounding terrain, and are composed mainly of sandy pebble to boulder gravel. The coarse gravelly core of the esker is sometimes blanketed by an apron of laminated fine-grained sand (fan deposit), indicating deposition of the core by a confined stream (most likely in a subglacial tunnel), followed by deposition of the apron when the stream exited at the receding mouth of the esker tunnel (Bolduc and others, 1988). The esker feeding the Windham Hill delta is covered by approximately 3 m of fine-grained glaciomarine sediments, indicating the presence of the sea after the ice sheet had receded from the head of the delta.

Ice-contact and non-ice-contact glaciomarine deltas (units Pmdi and Pmd) are present in a belt running from northeast to southwest through the quadrangle. The largest delta is the one on which the town of North Windham is built. It has an elevation of approximately 300-310 ft asl, as do the Windham Hill, Canal Road, Dog Corner, and other unnamed deltas. Each delta consists of gravelly, horizontal "topset" beds deposited by meltwater streams flowing across the delta top, overlying sandy to gravelly inclined "foreset" beds that formed as sediment cascaded down the advancing delta front. The contact between topset(?) and foreset beds has been surveyed in the delta west of Canal Road as an indicator of the position of sea level at the time of delta deposition. The elevation of this contact is 306 ft asl. (W.B. Thompson, unpublished data). Since the gravelly unit on top of the Canal Road delta may have been reworked to some degree by marine processes, this elevation should be regarded as a minimum for the upper marine limit.

The largest delta in the quadrangle — the North Windham delta — is a composite delta in which a number of smaller deltas can be identified on the basis of morphology, the presence of an ice-contact head, and sedimentary characteristics. These features indicate a standstill of the glacier margin as each subdelta formed at the ice front, followed by retreat to the next recorded ice margin position. The North Windham delta comprises at least three subdeltas, located east, west, and southwest of Collins Pond. Others probably exist in the complex area around Pettingale Pond, since test borings reveal a thick zone of Presumpscot Formation in the vicinity of Chaffin Pond, located between Pettingale Pond and the large deltas at North Windham village. Some of the mapped deltas have been identified on the basis of their morphology and elevation, either because exposures were not available or disturbance by human activities has obscured internal sedimentary structures.

Numerous glaciomarine fans (unit Pmf) occur in the North Windham quadrangle. Examples can be seen in the Presumpscot River valley north and south of Dundee Pond. Like the deltas, fans were built at the glacier margin during brief standstills in the ice retreat. However, the duration of these pauses and/or the supply of sediment were insufficient for the fans to build up to the ocean surface and develop the horizontal graded tops characteristic of deltas. Some of the fans shown on the map just barely reached sea level and might be considered transitional forms. The fans are mainly composed of sand and gravel with foreset beds dipping generally to the southeast.

Both deltas and fans are partly covered by the Presumpscot Formation, which is described below. The interfingering of gravels and marine clays was clearly observed in a gravel pit located east of Windham Hill, indicating contemporaneous deposition during the marine incursion that accompanied deglaciation of the study area (Figure 7).

The glacial sand and gravel deposits of the North Windham quadrangle have been used extensively for road construction and fill. Many borrow pits have been opened for this purpose, providing good exposures that enable interpretation of the stratigraphy.

Fine-Grained Glaciomarine Sediments (Presumpscot Formation)

The Presumpscot Formation (unit Pp) consists mainly of a silt-clay mixture. A sandy facies occurs in places, but has not been separately mapped. The silt-clay mud consists of glacial rock flour (finely pulverized rock debris) that washed into the ocean from the melting glacier. Unit Pp is widely distributed over the quadrangle, and is generally found at elevations below 260-280 ft asl. It usually has a blue-gray color in fresh exposures, whereas its weathered color is olive-gray to brownish-gray. Dropstones are common, having fallen to the sea floor from icebergs. Stratification occurs in some exposures, but not in all cases. Marine shells are often found in the Presumpscot Formation, but shell localities were not encountered in the North Windham quadrangle during this study. A silt-sand deposit filling a small kettle in the southern extremity of the North Windhan delta contains abundant plant remains. However, it is not known whether the deposit in this kettle is marine or fresh water in origin.

The origin of the sandy facies of the Presumpscot Formation is unclear. It probably corresponds to beach or nearshore deposits produced by the reworking of older glacial sediments

Figure 7. Interfingering of debris flows (submarine fan deposits) with glaciomarine mud of the Presumpscot Formation. Exposure is located just east of the Pleasant River, between Windham Hill and Windham Center.

during recession of the sea. Such reworking by marine processes has occurred on the seaward sides of deltas in the area (see description of marine nearshore deposits). In other, less erodible materials, the postglacial uplift of the region was too rapid to allow the formation of well-developed shoreline features.

In the North Windham quadrangle, the Presumpscot Formation is used as a cap for landfills, as it meets the requirements of impermeability for that purpose.

Marine Nearshore Deposits

Unit Pmn (marine nearshore deposits) consists of sand and gravel resulting from marine erosion and reworking of glacial sediments. These deposits formed along former shorelines or in shallow marine waters during the regression of the sea in late-glacial time. They commonly form a thin patchy veneer on deltas and other glacial meltwater deposits, but have been tentatively differentiated as a separate map unit only in the Fosters Corner area of Windham.

Deposits of Uncertain Origin

In a few small areas, the composition and depositional environments of Pleistocene sediments were not determined because of insufficient exposure or lack of diagnostic landforms. These deposits are mapped as unit Pu.

Alluvial and Lacustrine Shoreline Deposits

A few Holocene (postglacial) alluvial deposits (unit Ha) have been recognized, mainly on the basis of air photo interpretation. These deposits consist of sand, gravel, and silt deposited on the flood plains of modern streams. They are the product of reworking of the glacial and glaciomarine sediments. The streams in the quadrangle have narrow, discontinuous flood plains, and there may be small deposits of alluvium that are not shown on the map.

Some colluvium (unit Hc) is present at the base and on the slopes of hills, such as Baker Mountain. This material originates from weathering and downslope movement of bedrock and also till in some places. It is often difficult to distinguish from till and thus has not been differentiated on the map.

Lacustrine shoreline sediments (unit Hls) are present along the shores of Sebago and Little Sebago Lakes, as well as on the shores of smaller ponds. However, the exposed portions of these deposits are so narrow that in most cases it was not feasible to plot them on the map. The distribution of Hls, therefore, should not be taken as the only modern beaches in the area, but rather as the larger beaches.

Wetland Deposits

Organic wetland deposits in the North Windham quadrangle were mapped at reconnaissance level for this study by John Lortie and the authors. These deposits include swamps (unit Hws), which in some cases are underlain by at least 5 ft of peat (unit Hwsp). Other wetland deposits in the region are freshwater marshes (unit Hwfm), locally underlain by a significant thickness of peat (unit Hwfmp), and heaths (unit Hwh). Undifferentiated wetlands are designated by unit Hw.

LATE WISCONSINAN GLACIAL HISTORY

In the North Windham quadrangle the surviving sedimentary deposits record only the most recent (late Wisconsinan) glaciation. However, Maine probably was glaciated repeatedly during Quaternary time. Other areas of the state have two tills in stratigraphic contact. The lowest of these tills has been assigned an early Wisconsinan or Illinoian age (Thompson and Borns, 1985; Weddle, 1992), while the upper till has been attributed to late Wisconsinan glaciation. Although we have identified two till facies in the North Windham area, we have not seen them in stratigraphic contact. The lodgment till in our study area, which presumably is lower in the sequence than the ablation facies, does not show the weathering characteristics attributed to the older till recognized elsewhere in Maine. Glacial and interglacial erosion are probably responsible for the absence of sediments related to earlier glaciations.

The last advance of the Laurentide Ice Sheet occurred during Late Wisconsinan time, when New England was entirely covered by ice, and reached as far south as Long Island, New York. Regionally, ice flow was from northwest to southeast, as shown by the orientation of striations and glacially streamlined hills. This movement may have been responsible for the deposition of much of the lodgement till. During the subsequent retreat

of the ice sheet, the receding glacier margin reached the present position of the southwestern Maine coast about 14,000 years ago (Thompson and Borns, 1985), and although no radiocarbon dates are available for the quadrangle itself, deglaciation presumably occurred by 13,000 years B.P. (Thompson and Borns, 1985). Minimum-limiting dates on shells and carbonate concretions south of the quadrangle are between 12,500 and 11,500 yr B.P. (Smith, 1985).

Recession of the ice margin across the quadrangle was accompanied by marine transgression and calving of the tidewater glacier margin. The ice retreat direction in southwestern Maine was generally toward the north or north-northwest. In the study area, successive ice margin positions are defined locally by discontinuous small end moraines. These types of moraines provide evidence for retreat of active ice (see Koteff and Pessl, 1981, for a review of active-ice retreat vs. regional stagnation). Although features indicating local stagnation are present in the quadrangle (eskers and kettled ice-contact deposits), push structures in moraines indicate movement of the ice sheet.

The Presumpscot Sea was sufficiently long-lived to allow the deposition of considerable thicknesses of silt, clay, and fine sand (Presumpscot Formation), sometimes completely covering earlier glacial deposits. As the sea regressed from the area (by about 12,000-11,000 yr B.P.) it reworked some of the glacial sediments into an offlap facies consisting of shoreline or nearshore sand and gravel. Since the complete emergence of the quadrangle, little modification of the terrain has occurred except for the evolution of the modern drainage system and the development of minor alluvium and wetland deposits. Perhaps the most important recent modification of the landscape comes from human activities, with removal, transport, and "redeposition" as artificial fill of a considerable amount of surficial material.

ACKNOWLEDGMENTS

We wish to thank the numerous land owners who allowed us onto their properties, as well as gravel pit operators who let us take a look at active pits, sometimes even as they were working. Without access to most of these places, it would have been very difficult to produce the map as presented here.

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