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Surficial Geology of the Hiram 7.5-minute Quadrangle, Oxford and Cumberland Counties, Maine

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INTRODUCTION

This report describes the surficial geology and Quaternary history of the Hiram 7.5-minute quadrangle in southwestern Maine. Surficial earth materials include unconsolidated sediments (such as sand and gravel) of glacial and nonglacial origin. Most of these deposits formed during and after the latest episode of glaciation in Maine, within the last 25,000 years. Surficial sediments cover the bedrock over much of the quadrangle and are subject to many uses and environmental considerations. These include sand and gravel extraction, development and protection of ground-water supplies, siting of waste disposal facilities, and agriculture.

The detailed mapping of the surficial geology of the Hiram quadrangle was begun by William R. Holland in 1983, for the state/federal Significant Sand and Gravel Aquifer Project and the Maine Geological Survey's (MGS) geologic mapping program. The aquifer map was included in a report by Williams and others (1987), but the geologic map was not finished due to the untimely death of the author. W. B. Thompson completed the field mapping of the Hiram quadrangle in 1994-95 and prepared the present report for the STATEMAP program, supported by MGS and the U. S. Geological Survey.

Two maps are associated with this report. The *geologic map* (Thompson and Holland, 1999) shows the distribution of the sedimentary units, and discusses their age, composition, and origin. It also includes information relating to the geologic history of the quadrangle, such as features that indicate the flow direction of glacial ice. This map, along with mapping done by Thompson and other workers in adjacent quadrangles, provides the basis for the discussion of glacial and postglacial history presented here. The *materials map* (Thompson and Holland, 1998) shows specific site data used to help compile the geologic map. These data include observations from gravel pits, shovel and auger holes, construction sites, and natural exposures along stream banks. Sand and gravel aquifer studies by the Maine Geological Survey and U. S. Geological Survey provided additional data on the map area, including seismic logs and depth-to-bedrock information (Williams and others, 1987). Supplemental depth-to-bedrock data was obtained from MGS well inventories.

Field work for this project consisted of driving the road network in the quadrangle and hiking across some of the off-road areas to examine borrow pits and other exposures of surficial materials. The authors also used a shovel and hand auger to identify near-surface materials in some places where exposures were lacking. The materials map mainly shows these types of localities, where information was obtained from beneath the original ground surface. However, there were many other places where the authors could readily distinguish map units on the basis of topography, boulder fields, surface scrapings, and other such clues. In remote parts of the Hiram quadrangle, such as the Boston Hills in Denmark, the authors relied on interpretation of aerial photographs to supplement field work.

Geographic Setting

The Hiram quadrangle is located in the White Mountain foothills of southwestern Maine. The map area extends in latitude from 43°52'30" to 44°00'00" N, and in longitude from 70°45'00" to 70°52'30" W. It includes sizable parts of the towns

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of Brownfield, Denmark, and, Hiram, as well as small portions of Baldwin, Bridgton, and Sebago. The principal population centers in the quadrangle are the villages of Denmark and Hiram.

The most significant geographic feature in the Hiram quadrangle is the Saco River, which has figured prominently in the geologic and human history of the region. The Saco Valley is much narrower here than in the Fryeburg and Conway areas, located farther upstream. It receives drainage from the Moose Pond Brook and Hancock Brook valleys in the central and eastern parts of the quadrangle, and the north-draining Tenmile River valley to the west. The terrain over most of the area is hilly. Elevations in the quadrangle range from 350 ft above sea level (where the Saco River leaves the map) to 1300 ft on Robbins Hill (likewise at the south edge of the map).

Bedrock Geology

The central to northern part of the quadrangle is underlain by igneous rocks, including three major units: (1) Devonian granodiorite; (2) Carboniferous two-mica granite of the Sebago pluton; and (3) a small Mesozoic syenite body in the Boston Hills (Gilman, 1977; Hussey, 1985; Osberg and others, 1985). The latter intrusion is a medium-grained brownish syenite. If this syenite is sufficiently distinct from the Pleasant Mountain syenite to the north, it may be useful for tracing glacial transport directions of erratic boulders.

The southern part of the quadrangle is underlain by metasedimentary rocks assigned to the lower member of the Rindgemere Formation, which probably is of Silurian age (Hussey, 1985). In the study area, this member generally consists of high-grade schists and migmatites (Gilman, 1977). Dikes of basalt and granite pegmatite have locally intruded the above rock units.

PREVIOUS WORK AND ACKNOWLEDGMENTS

Stone (1899) conducted an early reconaissance of the surficial geology of the Saco Valley region as part of his statewide study of Maine's glacial gravel deposits. However, he did not provide much information on the Hiram area. Leavitt and Perkins (1935) commented briefly on the area in their "Survey of Road Materials and Glacial Geology of Maine." The latter authors noted the presence of glacial-lake deposits in the Ten Mile River valley, as a consequence of meltwater drainage being dammed by ice in the Saco Valley to the north (Leavitt and Perkins, 1935, p.95). Prescott (1979) compiled well and test hole data, and carried out preliminary surficial and gravel aquifer mapping (Caswell, 1979; Prescott, 1980). Holland compiled a more detailed aquifer map that included the Hiram quadrangle as part of the Significant Sand and Gravel Aquifer Project sponsored by the Maine Geological Survey, U. S. Geological Survey, and Maine Department of Environmental Protection (Williams and others, 1987).

The authors are grateful to the numerous landowners and pit operators who granted access to their properties and often provided us with useful information about the local sand and gravel deposits. J. Louis Bauer (Denmark, Maine) directed us to some interesting glacial deposits along the east side of Moose Pond. Peter Chase called attention to a series of excellent glacially striated bedrock outcrops located on the fairways of the Allen Mountain Golf Club. Thanks also to John Gosse for reviewing this report.

DESCRIPTION OF GEOLOGIC MAP UNITS

The surficial deposits of the Hiram quadrangle have been represented on the geologic map as a series of units on the basis of their age and origin. These map units are designated by letter symbols, such as "Pt." The first letter indicates the age of the unit:

"**P**" - Pleistocene (deposits formed during the "Ice Age," i.e. between about 2 million and 10,000 years ago)
"**H**" - Holocene (postglacial, i.e. formed during the last 10,000 years)
"**Q**" - Quaternary (encompasses both the Pleistocene and Holocene epochs)

The majority of Pleistocene sediments in New England were emplaced during the most recent (late Wisconsinsan) glacial episode. In Maine this glaciation began approximately 25,000 years ago (Stone and Borns, 1986; C. C Dorion, personal communication).

The Quaternary age is assigned to units which overlap the Pleistocene-Holocene boundary, or whose ages are uncertain. The other letters in the map symbol indicate the origin and/or assigned name of the unit, e.g. "t" for glacial till and "lpb" for sediments deposited on the bottom of Lake Pigwacket. Surficial map units in the Hiram quadrangle are described below, starting with the older deposits that formed in contact with glacial ice.

Till (Pt)

Till is a glacially deposited sediment consisting of a heterogeneous mixture of sand, silt, and gravel-size rock debris. It blankets much of the hilly terrain in the upland portions of the quadrangle, where it is the principal surficial material; and test borings in other parts of the state show that till commonly underlies younger deposits in the valleys. Some of it probably was derived from glacial erosion of older surficial sediments (either glacial or nonglacial), while the remainder was freshly eroded from nearby bedrock sources during the latest glaciation. Well data shown on the materials map indicate that till deposits in the Hiram quadrangle are up to 100-150 ft thick.

Till is, by definition, a poorly sorted sediment (diamicton) in which there is a very wide range of rock and mineral particle sizes. However, the texture and structure of individual till deposits vary depending on their source and how they were formed. In the Hiram area, till includes a small percentage of clay, but it usually has a sandy or silty-sandy matrix as a consequence of having been eroded from coarse-grained bedrock. Till has little or no obvious stratification in some places. Elsewhere it is crudely stratified, with discontinuous lenses and laminae of silt, sand, and gravel resulting from sorting by meltwater during the depositional process.

Stones are abundant in this unit, and boulders scattered across the ground surface often indicate the presence of till. The geologic map shows concentrations of many large boulders, and these areas are probably much more extensive in some areas than what we observed during our field work. Till stones in the quadrangle chiefly consist of coarse-grained igneous and metamorphic rocks, especially lithologies of granitic composition, predominantly derived from local bedrock sources. Many till stones are more-or-less angular, and some have smooth, flat, striated surfaces due to subglacial abrasion. These faceted surfaces are best developed on dense, fine-grained rocks such as basalt.

Tills deposited under great pressure beneath the ice sheet tend to be more compact and finer-grained than those formed by ablation processes on the surface of the melting glacier. Subglacial till facies include lodgment and basal melt-out tills. Lodgment tills are usually very compact ("hardpan") and difficult to excavate, with a platy structure (fissility) evident in their upper, weathered zones. Basal melt-out tills may be difficult to identify with certainty, but typically show a crude stratification inherited from debris bands in the lower part of the glacier. Ablation facies tend to be loose-textured, stony, and contain numerous lenses of washed sediment. More than one of these till facies may occur at a single locality. A thin veneer of stony ablation till commonly overlies lodgment till in southwestern Maine.

Field evidence in the nearby Fryeburg area (Thompson, 1999a,b), coupled with studies elsewhere in New England (e.g. Koteff and Pessl, 1985; Thompson and Borns, 1985b; Weddle and others, 1989), suggest that till deposits of two glaciations are present in the Oxford Hills region of southwestern Maine. The "upper till" is clearly the product of the most recent, late Wisconsinan glaciation, which covered southern Maine between about 25,000 and 14,000 years ago. Exposures of the upper till can be seen in many shallow pits, road cuts, and temporary excavations. It is nonoxidized (except in the near-surface zone of modern soil formation) and usually light olive-gray in color. Most till deposits seen by the authors in the Hiram quadrangle have a sandy, stony texture, and probably are the ablation facies of the upper till (**ta** on the materials map).

The "lower till" consists chiefly of compact, silty-sandy lodgment deposits. In southwestern Maine, as in other parts of New England, it is likely to occur in smooth, glacially streamlined hills where a considerable thickness of till has accumulated. These thick deposits often form "ramps" on the gentle northwest-facing slopes of hills, while bedrock is exposed on the steeper, glacially plucked slopes to the southeast. The lower till has not been observed in the Hiram quadrangle, but it may be present in some of the apparently thick till deposits, such as the area west and south of Granger Pond.

End Moraines (Pem)

End moraines are ridges of sediment deposited at the margins of glaciers. They may form in many different ways, but generally result from the accumulation of sediments derived from the adjacent glacial ice (or shaped by glacial processes at the ice margin). Moraine ridges that occur above the zone of late-glacial marine submergence in southwestern Maine commonly are strewn with boulders on the surface. Their interiors are seldom well exposed, but surface indications and pits suggest that most end moraines are comprised largely of till with locally abundant lenses of sand and gravel.

True end moraines (which are useful markers of ice-margin positions) may be difficult to distinguish from areas of hummocky moraine (q.v.) or ribbed moraine, both of which occur in this part of Maine. The ribbed moraine consists of groups of till ridges located in the bottoms of valleys that are more-or-less parallel to glacial flow directions (Holland, 1986). There has been much debate about where (and how) these ridges formed relative to the glacier margin (Davis, in Thompson and others, 1995, p. 46-48).

Several bouldery ridges in the eastern part of the Hiram quadrangle are thought to be end moraines. The ridges occur in areas mapped as till, and stand apart from the larger clusters of mounds and ridges that form the hummocky moraine complexes of unit Phm. These end moraines are shown in two ways on the geologic map. The broader ones are separately mapped as unit Pem. They are located in a narrow valley north of Hiram village (along Route 117) and north of Perley Pond (east border of map). Thompson and others (1995, p. 58-59) described the group of prominent moraine ridges that cross Route 117 less than a mile north of Hiram. Two narrow end moraines, whose crests are indicated by heavy lines, were found on the sides of the valley south of Hancock Pond.

The end moraines occur in topographically low areas. This is probably the result of meltwater and debris-flow processes focusing the deposition of glacial sediments in front of narrow ice tongues as the ice sheet retreated northward from the valleys. The thick sediment accumulations in the moraines suggest the presence of active ice during deglaciation of the Hiram quadrangle. However, it is curious that the moraines are not more plentiful in other parts of the map area.

Hummocky Moraine (Phm)

Several valleys in the quadrangle contain extensive deposits of "hummocky moraine." These deposits are distinguished in the field by their knobby topography and abundance of large boulders. The relative scarcity of bedrock outcrops, together with the topographic relief, suggests that the thickness of this unit may be typically on the order of tens of feet. The few available exposures indicate that the hummocks and ridges of unit Phm vary in composition from diamicton to sand and gravel, but diamicton seems to be the most abundant constituent. The materials may change very abruptly, both horizontally and vertically.

An excellent exposure of unit Phm has been observed intermittently over the last ten years in a small pit in the valley between Picket Hill and the unnamed hill just west of Moose Pond. It was first described by Holland (1986, Stop 10, p. 112-113) as an example of "ice-disintegration moraine." The pit currently exposes about 35 ft of sand and gravel with irregular discontinuous bedding, lenses of sandy diamicton (flowtill), and scattered boulders (see materials map).

Hummocky moraine is concentrated in the lowlands, but usually occurs on the sides of valleys at higher elevations than adjacent glacial-lake deposits, which consist of well sorted and stratified sand and gravel. As proposed by Holland (1986), the location, composition, and topography of unit Phm suggest that it formed during the melting of stagnant debris-rich ice in a late stage of deglaciation. However, it is possible that live ice was present nearby to the north as unit Phm was being deposited. A few moraine ridges were mapped among the Phm deposits south and west of Moose Pond (see geologic map), though it is not certain how they formed. In any case, ice-contact outwash heads and series of meltwater channels are common in the Hiram quadrangle, and they clearly indicate a systematically northward-retreating ice margin, regardless of the degree to which the ice remained active.

Eskers (Pge)

Eskers are ridges of sand and gravel deposited in tunnels within and beneath glacial ice. As the tunnels became choked with sediment and the surrounding ice melted, the tunnel-filling deposits were left behind with their characteristic ridge shape. Individual esker segments in Maine typically range in length from a few hundred feet to over a mile and can be up to a hundred feet or more in height. Many of them are aligned in linear series (esker systems) that can be traced for great distances on regional maps (Thompson and Borns, 1985a).

Two discontinuous esker systems cross the Hiram quadrangle. One enters the northwest corner of the map area and can be traced southward across the Saco Valley and up the valley of the Tenmile River. The other system follows the valley south of Hancock Pond. Although esker systems such as these may have been deposited in successive segments, it has been suggested that glacial meltwater initially flowed simultaneously through entire networks of branching tunnels in eastern Maine (Ashley and others, 1991).

Some of the ridges that are interpreted as eskers in southern Maine were at least partly deposited in narrow channels that were open to the sky (in contrast to subglacial streams driven by hydraulic pressure gradients), and hence might be given the more general name of "ice-channel fillings." Certain eskers in the Hiram quadrangle probably fit the latter category. They have coarse gravelly cores deposited in subglacial tunnels, overlain by finer-grained glacial lake sediments (fan and delta deposits) that were emplaced at the tunnel mouths as the glacier receded. This stratigraphic sequence has been noted in the gravel pit just south of Beaver Brook (West Denmark area).

Ice-Contact Deposits (Pgi)

There are a few areas of sand and gravel in the Hiram quadrangle whose origin is not well understood due to lack of diagnostic exposures, but their topographic setting indicates deposition in contact with melting glacial ice. These areas are mapped as undifferentiated ice-contact deposits (unit Pgi). They include two deposits close to Route 117 in Denmark, in which old pits have shown sand and gravel that is probably not thicker than about 20 ft. The location of the latter deposits suggests they may have formed in short-lived meltwater ponds trapped between north-sloping hillsides and the adjacent glacier margin.

Glacial Lake Hancock Deposits (Plh)

In the eastern part of the Hiram quadrangle, there is a north-south trending valley (here called the "Hancock Valley") that includes Walden, Hancock, and Barker Ponds. This valley contains extensive deposits of sand and gravel emplaced by glacial meltwater. The topography of the deposits ranges from irregular ice-contact mounds and terraces (e.g., north of Barker Pond) to flat-topped plains (northeast of Walden Pond). Their internal structure is not well exposed, but their composition and locally flat, graded surfaces suggest that they are glacial lake deltas and/or outwash deposits. A pit north of Hancock Pond exposed lacustrine sand and silt beneath a fluvial sand and gravel unit, most likely indicating a deltaic sequence (W. Holland field notes; see materials map). Assuming that most of the water-laid deposits in the valley are lacustrine, they are tentatively grouped as a single map unit called "glacial Lake Hancock deposits" (unit Plh).

The outlet for glacial Lake Hancock is thought to have been located at the southwest corner of Barker Pond, where an esker ridge may have temporarily blocked the Hancock Valley drainage and dammed the lake. Eventually this dam was incised by water spilling across it (into the upper end of Hancock Brook), and the lake level dropped to leave the several smaller lakes that exist today.

It is uncertain whether the original glacial lake in the Hancock Valley was a single long water body or a series of disconnected ponds separated by masses of stagnant glacial ice. Elevations of the delta tops range from approximately 515 ft at the southeast end of Barker Pond to 535 ft northeast of Walden Pond, over a glacial retreat distance of 5 mi. Thus the gradient on this series of deposits is 4 ft/mi, which is slightly less than the postglacial crustal tilt of 4.75 ft/mi recorded in north-central New England (Koteff and others, 1993). The Hancock Valley deposits would be expected to show steeper gradients if they consisted of one or more fluvial morphosequences. (Morphosequences are groups of contemporaneously-deposited water-laid glacial sediments, each group having been deposited from a particular position of a glacier margin. See Koteff and Pessl (1981) for a discussion of the morphosequence concept.)

Judging from their morphology and surface textures, it is likely that the glacial Lake Hancock deposits formed over time from successive positions of the retreating glacier margin. Several of these ice-margins are indicated by ice-contact delta heads, meltwater channels, and moraines (see geologic map).

Glacial Lake Tenmile Deposits (Plt)

Another temporary lake developed in the southwestern part of the quadrangle during the early stages of glacial retreat from the Hiram area. A broad tongue of ice receding northward in the Saco Valley initially blocked the lower part of the Tenmile River valley. This impoundment of meltwater drainage formed a water body called "glacial Lake Tenmile," which is discussed below in the section on glacial history. The sediments deposited into the two stages of this lake (map units Plt_{1-2}) consist mostly of deltaic sand and gravel, although some short eskers and other fluvial deposits are included. Unit Plt formed in contact with decaying ice masses, as shown by numerous kettles, ice-contact slopes, and knobby topography. These features are pronounced in the area bordering the Tenmile River where it crosses the west edge of the quadrangle. The topographic relief of the Plt deposits indicates that they are up to at least 50 ft thick.

The Plt deposits are grouped into two morphosequences based on their elevations. Unit Plt_1 reaches elevations up to about 480 ft, corresponding to an early high level of Lake Tenmile. Deposits of this stage of the lake extend west into the Brownfield quadrangle, and thence south into the northeast corner of the Kezar Falls quadrangle. The lake level in Plt_1 time was controlled by a spillway through a rock-walled ravine on the drainage divide between Little Clemons Pond and Jaybird Pond, a short distance southwest of the Hiram quadrangle.

Unit Plt_2 deposits have upper surfaces to about 440 ft in elevation, indicating a lower lake level than unit Plt_1. The water level fell to this elevation when ice retreat opened a lower spillway for Lake Tenmile. The probable new outlet was the meltwater channel in the gap located one mile south of Pequawket Pond. Exposures of deltas built into the low stage of the lake can be seen in the gravel pits in unit Plt_2 adjacent to Route 5/113, but most of these pits had not been recently worked when the authors visited them.

Willett Brook Deposits (Plwb)

A small area of sand and gravel occurs in the northeast corner of the Hiram quadrangle. This unit has been traced into the adjacent map areas to the north and east, where it is continuous with deposits in the north-draining Willett Brook valley, after which it is named (misspelled as "Willis Brook" on the Bridgton quadrangle). There are no fresh exposures of unit Plwb in the Hiram quadrangle, but the orientation of the Willett Brook valley suggests that it was dammed by retreating glacial ice, and that the sand and gravel were deposited in a glacial lake. Examination of the neighboring Bridgton and North Sebago quadrangles reveals that this lake reached an elevation of at least 530-540 ft and may have been a northward extension of glacial Lake Hancock.

Moose Pond Valley Deposits (Pmv)

Discontinuous terraces of sand and gravel (unit Pmv) occur along the east side of Moose Pond and adjacent to Moose Pond Brook in the vicinity of Denmark village. Ice-contact slopes and internal collapse structures indicate that these sediments were deposited adjacent to remnant glacial ice masses that occupied the lowest parts of the Moose Valley. The gravel pits just south of Denmark expose deltaic foreset beds in the 440-ft terrace, so unit Pmv is at least partly lacustrine in origin.

The terraces next to Moose Pond may be deltas, too, or they may be kame terraces deposited by ice-marginal streams. They are generally lower (430+ ft) than the delta east of Moose Pond Brook, and thus suggest a lowering of base level as the valley was deglaciated. This drop in lake or stream level could have resulted from erosion of ice and/or sediment obstructing the lower part of the valley, perhaps in the constriction at the south end of Little Pond. Alternatively, since the Moose Valley deposits are at essentially the same elevation as the Lake Pigwacket deposits (unit Plp) in the Saco Valley (400-430 ft), they may have been deposited into a narrow arm of Lake Pigwacket that reached the Moose Pond area.

Outstanding examples of glacial meltwater channels are incised into till slopes on the east side of the Moose Valley. The slope and parallel grouping of these channels leads us to infer that they mark successive positions of a receding ice tongue. They were used, together with some moraine ridges among the Phm deposits, as the basis for drawing several ice-margins on the geologic map.

Lake Pigwacket Deposits (Plp)

Thick deposits of lacustrine sand, gravel, and silt are very widespread in the Saco River valley. They extend from Great Falls (just south of the Hiram quadrangle) upvalley through Brownfield and Fryeburg, and into the Conway, New Hampshire, area. The large lake, or succession of lakes, in this region has been named "Lake Pigwacket" by Thompson (1991; 1999a,b). The lake was named in honor of the Pigwacket band of Abenaki Indians, who were the early inhabitants of the upper Saco Valley (Calloway and Porter, 1989).

Some of the earlier Lake Pigwacket deposits formed in ice-contact glacial lakes, but the lake system persisted into postglacial time in the Fryeburg area. Deeply buried plant remains were recovered from test borings in lake sediments near Fryeburg village. These materials have radiocarbon ages of 11,255-11,680 years (Thompson, 1999a,b). The Lake Pigwacket deposits in the Hiram quadrangle have not been dated, but some of them may likewise be postglacial.

Pleasant Mountain Stage Deposits (Plpp). This unit occurs in the northwestern part of the study area; most of it is located in the adjoining Pleasant Mountain quadrangle to the north. Unit Plpp is a series of sandy glacial deposits in a narrow north-south valley between the Saco River and Pleasant Mountain. The Plpp deposits flank a long esker system that passes down the middle of this valley and can be traced discontinuously through the western part of the Hiram quadrangle. The deposits of unit Plpp are not well exposed, and there is little information from test borings. In the Pleasant Mountain quadrangle they typically have uneven ice-contact topography, though a few are flat-topped (having been graded to former water levels).

Unit Plpp is interpreted as a complex of glaciolacustrine deltas, subaqueous fans, and lake-bottom deposits. Individual morphosequences are not clearly defined, but at least five ice-margin positions have been recognized by Thompson (1999c,d) in the Pleasant Mountain quadrangle, and two others are shown on the present map. This unit is assigned to a late-glacial stage of Lake Pigwacket, defined here as the Pleasant Mountain stage. It was deposited in an area of ponded meltwater between the hills to the east and a large remnant mass of glacial ice in the Saco River lowland to the west. Delta(?) elevations west of Pleasant Mountain suggest a lake level of about 450 ft, while similar Plpp deposits in the Hiram quadrangle reach 440 ft. This small difference in elevation may be the result of postglacial crustal tilt (Koteff and others, 1993).

Undifferentiated Lake Pigwacket Deposits. Many Lake Pigwacket deposits in the quadrangle have flat upper surfaces at elevations of 410-430 ft (unit Plp). Exposures of these deposits in cut banks along the Saco River reveal thick, sandy delta foreset beds, indicating their lacustrine origin. It would be desirable to find a section in unit Plp showing a complete deltaic sequence, in which the contact between fluvial topset beds and the underlying foresets would indicate the former level of the lake surface. No such exposures have been located, and in many places the upper surfaces of the deltas have probably been downcut by the Saco River in early postglacial time.

Apparent remants of the original delta tops in unit Plp suggest a former lake level of about 430 ft in the west-central part of the quadrangle. They are slightly lower than the 440-ft level indicated by unit Plpp, and may reflect a drop in the lake surface when ice obstructions melted in the valley and/or the drift dam at Hiram Falls was downcut. Alternatively, the lower downvalley elevations of Lake Pigwacket deltas may reflect the tilt of the land surface which occurred as Maine was deglaciated and the earth's crust uplifted.

There are large kettles in the Plp deposits of the Pequawket Pond area (including the pond basin itself) which may indicate a former ice-margin zone. If so, the concentration of kettles probably marks the head of a morphosequence, and the Plp deposits upvalley from there would belong to a younger sequence. However, there is so little difference in elevation of Plp deposits across the quadrangle, that it is difficult to determine whether they were all deposited contemporaneously. Interpretation of the glacial geomorpholgy along the Saco Valley is further complicated by the postglacial river terracing mentioned above.

Lake-Bottom Deposits. Fine-grained, silty to sandy deposits of Lake Pigwacket occur in some of the small tributary valleys of the Saco River, such as Beaver Brook and Dragon Meadow Brook. These sediments are thought to have been deposited on the lake floor in low-energy environments. They formed in backwater areas relative to the esker and Saco Valley glacial drainage systems that deposited units Plpp and Plp.

Stream Terrace Deposits (Qst)

Lake Pigwacket sediments have been partly eroded as the postglacial Saco River cut down to its present level. This downcutting produced terraces along the river (unit Qst), at intermediate elevations between the original glaciolacustrine delta tops and the modern flood plain. The material underlying the terraces consists of sand and gravel (in part the remains of Lake Pigwacket deposits, but probably capped in many places by postglacial river alluvium). A typical terrace, including an abandoned river channel, can be seen just east of the Saco River in Hiram village, along Route 117. The major road intersection in the center of town is located on flat-surfaced Lake Pigwacket sediments at an elevation of about 400 ft. Driving west toward the Saco River, Route 117 drops onto the Qst terrace at 380-390 ft (old channel is north of road), and finally onto a more recent alluvial surface at 360 ft next to the river.

Eolian Deposits (Qe)

As the last glacial ice sheet receded from Maine, extensive deltas and other sandy outwash deposits formed in the southwestern part of the state. Large areas of these deposits probably dried up on the surface and remained barren for some time before a vegetation cover was established. Strong winds swept across this landscape and reworked the glacial sands to form dunes and other eolian deposits. The dune fields typically occur on the east (downwind) sides of valleys such as that of the Saco River. They tend to be patchy and irregular in thickness, and consist of well-stratified very fine to very coarse sand. A deposit of eolian sand (unit Qe) has been mapped in the northwestern part of the Hiram quadrangle, on a hill north of Route 160. Other windblown deposits may occur in the quadrangle, but they are easily overlooked in wooded areas or where they rest on top of water-laid sand.

Lacustrine Delta (Hld)

Streams entering modern lakes may build alluvial deltas, though these deposits are often small in comparison to glaciolacustrine deltas. For example, a tiny delta (unit Hld) has accumulated where the outlet stream from Moose Pond enters Little Pond (south of Denmark village). The source area for this delta is very small, being limited to the glacial sediments along the short stream segment between the two ponds. Small unmapped deltas may occur at other lake inlets in the quadrangle.

Beach Deposits (Hlb)

Sandy to gravelly beaches on modern Maine lakes generally are formed by waves and currents reworking nearby glacial deposits, which provide a source of easily eroded sediment to nourish the beaches. These beaches are not always differentiated on surficial geologic maps, because they may be very small or grouped with adjacent sand and gravel deposits of glacial origin. They probably could be found bordering units Plh and Pmv along the shorelinesof Barker, Hancock, Walden, and Moose Ponds. A prominent example, shown on the geologic map, occurs at the narrows between Hancock and Walden Ponds. This beach appears to have formed as a spit derived from the neighboring glacial Lake Hancock (Plh) deposits.

Wetland Deposits (Hw)

Unit Hw consists of fine-grained and organic-rich sediments deposited in low, flat, poorly drained areas. In the Hiram quadrangle this unit occurs along streams and in small upland basins. The boundaries of unit Hw were mapped primarily from aerial photographs. These boundaries are approximately located and should not be used rigorously for land-use zoning. The distinction between "wetland" and "stream alluvium" in the Saco Valley is often subtle and arbitrary. The Saco flood plain is shown as alluvium (unit Ha) on the geologic map since it is presumed to be underlain largely by inorganic sediments deposited by floods. However, large parts of the alluvial unit are poorly drained and may have vegetation typical of wetlands, as suggested by the marsh-grass pattern printed on the topographic map.

Stream Alluvium (Ha)

Extensive alluvial deposits (unit Ha) have accumulated during postglacial time on the flood plains of the Saco River and its tributaries. Most of these deposits consist of fine-grained sediments and organic material that have been carried by flood waters onto the low, flat areas next to stream channels. Numerous test borings in the Saco flood plain near Fryeburg show that the alluvium is commonly up to 20 ft thick (Thompson, 1999a,b), so deposits of comparable thickness are presumed to exist in the Hiram quadrangle. Along the Saco, the alluvium forms sizable ridges (natural levees) where it has piled up immediately adjacent to the river.

GLACIAL AND POSTGLACIAL GEOLOGIC HISTORY

The following reconstruction of the Quaternary history of the Hiram quadrangle is based on the interpretations of surficial earth materials described in this report, together with glacial landforms and ice-flow indicators. It is integrated with the glacial history of surrounding areas of Maine, the understanding of which continues to improve through the efforts of many earth scientists working in the region.

Glaciation History

It is uncertain how many episodes of glaciation have affected the Hiram area during the Pleistocene Ice Age. Till deposits in southwestern Maine clearly record the most recent (late Wisconsinan) glaciation, and probably one earlier event. A deeply weathered "lower till" found elsewhere in central and southern New England has also been recognized in southern Maine (Thompson and Borns, 1985b; Weddle and others, 1989). Although it is not well-dated, the lower till was deposited during the penultimate glaciation, probably of Illinoian age.

Data summarized by Stone and Borns (1986) indicate that the late Wisconsinan Laurentide Ice Sheet expanded out of Canada and spread into Maine approximately 25,000 years ago. As the glacier continued to flow across the state for the next 10,000 years, it reshaped the surface of the land by eroding, transporting, and depositing tremendous quantities of sediment and rock debris. The combined effects of erosion and deposition have given some hills a streamlined shape. Those in southwestern Maine have long axes parallel to the south-southeastward flow of the ice. To some extent, this shaping can be seen on several of the hills in the northeastern part of the Hiram quadrangle.

The late Wisconsinan glaciation produced the stony till deposits that blanket the upland areas of the quadrangle. Glacial plucking on the summits and lee sides of some hills formed steep southeast-facing slopes and cliffs, such as those seen west of Moose Pond and on the unnamed hill just north of Route 160 in the western part of the quadrangle. Rocks torn from these hills were scattered in the direction of glacial transport, and many were dumped in the areas of hummocky moraine (Phm) when the ice melted.

Abrasion by rock debris dragged at the base of the glacier polished and striated the bedrock surface. The striations are not easy to see in the Hiram area because they are either concealed beneath the surficial sediment cover or have been destroyed by weathering where the coarse-grained bedrock is exposed at the ground suface. The best places to find them are on ledge surfaces where the sediment cover has recently been scraped off, such as along logging roads or where other excavations have reached bedrock. On glacially smoothed outcrops of coarse granite (pegmatite), fine striations may be revealed by rubbing a pencil across the rock surface in a general east-west direction. Striation localities encountered during this study are shown on the geologic map.

The trends of striations in the study area and other nearby quadrangles indicate ice-flow directions ranging from southeast to south-southwest. Azimuths in the range of 145-165^o in this part of Maine, together with streamlined hills having a similar trend, are presumed to be the product of the main phase of the most recent (late Wisconsinan) glaciation. Overlapping striation sets have been recorded in several places, and where their relative ages can be determined, the more southerly striations (170-190^o) usually are younger. This southward flow is believed to have been a late-glacial event resulting from widespread reorganization of ice flow in Oxford County as the glacier thinned and receded across southwestern Maine (Thompson, 1991, 1995).

Recession of the Last Ice Sheet

Radiocarbon ages of shells from glaciomarine sediments in Maine show that during the waning phase of the late Wisconsinan ice sheet, the glacier margin receded into central Maine by 13,000 years ago (Thompson and Borns, 1985a,b; Anderson and others, 1992). This age, along with other ages given here, is based on radiocarbon dating. [The actual "calendar ages" of late-glacial events are perhaps at least 2,000 years older than the radiocarbon ages (Bartlein and others, 1995)]. The Hiram quadrangle probably was likewise deglaciated by this time, though isolated masses of stagnant ice may have lingered in valleys. The Maine portion of the Saco Valley was certainly ice-free by 12,000 years ago, judging from the dated plant remains in Fryeburg (Thompson, 1999a,b).

In coastal Maine it is possible to trace the retreat of the glacier margin in detail because there are hundreds of end-moraine ridges, submarine fans, and deltas that were deposited at the edge of the ice during its recession in a marine environment. End moraines are relatively uncommon in the interior of southwestern Maine, but the few that were found in the Hiram quadrangle are helpful in reconstructing the pattern of deglaciation. The ice-contact sand and gravel deposits left by meltwater streams flowing into glacial lakes provide further clues to the history of ice retreat from the study area.

It is fortunate that so many meltwater channels occur in the quadrangle. The position and slope of these channels suggest that many of them formed at the terminus and lateral margins of receding glacial ice lobes in the valleys. They have been used along with the other evidence mentioned above to locate the ice-margin positions shown on the geologic map. The inferred ice-margins are generally consistent with striation data indicating that late-glacial ice flow was southward.

As the glacier margin began to recede from the Hiram area, the earliest part of Lake Pigwacket developed in the Saco Valley. This lake system ultimately expanded far up the valley to Bartlett, New Hampshire. It was dammed behind a thick accumulation of glacial sand and gravel that plugged the narrow part of the valley in the vicinity of Great Falls (just south of the quadrangle). Numerous deltas (map unit Plp) were built into Lake Pigwacket in the Hiram-Brownfield area.

At the same time that Lake Pigwacket was expanding up the Saco Valley in contact with the receding glacier, glacial lakes also formed in the Tenmile River and Hancock valleys (tributaries of the Saco) in the southwestern and eastern parts of the quadrangle. Glacial Lake Tenmile was ponded against the ice tongue in the Saco Valley. It first drained southwestward through a spillway in the northeast part of the Kezar Falls quadrangle, with the outflow reaching the Ossipee River at South Hiram. At this time, the ice margin that held the lake at the higher (480 ft) level probably stood at the Plt_1 position shown on the geologic map. Subsequent retreat of the ice margin to the Plt_2 position allowed Lake Tenmile to drain eastward into the Saco Valley at a level of about 440 ft. This was only slightly higher than Lake Pigwacket, and the two lakes soon merged when the ice withdrew from the Plt_2 position.

During and shortly after deposition of the Lake Tenmile deposits, progressive deglaciation of the Hancock Valley resulted in the initiation and northward expansion of glacial Lake Hancock. Three ice-margin positions in this valley have been drawn on the geologic map. Their locations are based on meltwater channels, end moraines, and the heads of ice-contact sand and gravel deposits. A prominent series of meltwater channels were carved on a hillside northwest of Barker Pond as the ice receded from the higher ground just west of Lake Hancock. Dissipation of the ice also produced the bouldery deposits of hummocky moraine (unit Phm) on valley sides near the lake.

The youngest meltwater deposits are in the northern part of the Hiram quadrangle. As noted above, unit Plpp appears to have been deposited when there was still considerable remnant ice in the Saco Valley, though the ice-margin positions inferred from these deposits suggest that much of the map area was now ice-free. Glacial retreat from the Moose Pond and Willett Brook valleys resulted in deposition of units Pmv and Plwb. A great quantity of sediment and meltwater was focused in the Moose Pond valley, where there is thick hummocky moraine as well as the sand and gravel of unit Pmv. A network of meltwater channels indicates that glacial streams issued from a receding ice margin in the East Denmark area and poured down into the Moose Pond basin. These streams reworked some of the earlier Pt and Phm sediments, forming unit Pmv among remnant ice masses in the bottom of the valley.

Postglacial History

At some point in late-glacial or early postglacial time, the part of Lake Pigwacket in the Hiram-Brownfield area completely filled with sediment and/or drained in response to erosion of the drift dam at Great Falls. The Saco Valley is relatively narrow in the Hiram quadrangle, and it seems likely that this part of Lake Pigwacket was filled with the deltaic Plp sediments washing out of ice in the Brownfield area. However, remnants of open water may have persisted farther up the valley, in the vicinity of Lovewell Pond and Fryeburg.

Breaching of the Great Falls dam, together with crustal uplift in response to deglaciation, helped establish the postglacial Saco River on the former lake bed. This erosional regime is recorded by stream terraces (unit Qst) that were carved in the Lake Pigwacket deposits as the river cut down through them. There is also a clear record of lowering base level in the form of channels and terraces cut into the broad Lake Pigwacket delta in the east-central part of the Brownfield quadrangle (Davis, 1999a,b).

Postglacial sedimentation continues today on the flood plains of modern streams. Organic-rich deposits have accumulated in wetlands throughout postglacial time, and sediments are continually being deposited on lake bottoms.

Economic Geology

Abundant deposits of sand and gravel occur in the Hiram quadrangle. The largest volumes are concentrated in the western part of the quadrangle, including the Tenmile River valley, parts of the Saco Valley along Route 5/113, and the West Denmark area. Other large deposits are scattered throughout the Hancock Valley. Numerous borrow pits already exist in these areas, though many of them were inactive when the quadangle was mapped.

Gravel is most likely to be found in the cores of esker ridges (map unit Pge), and the upper few feet of glacial-lake deltas (units Plp, Plt, and Plh) and stream terraces (Qst). The bulk of the deltas, beneath the cap of fluvial gravel, is more likely to consist of large amounts of sand. Some of the loose, sandy till deposits (Pt) compact well and are good fill material. Given proper drainage conditions, they may also be very good for domestic leach fields.

Most surficial materials in the quadrangle should be fairly easy to excavate, except for areas with many large boulders (Phm and some Pt deposits) or occurrences of dense lodgment till (“hardpan”). Areas indicated with the thin-drift pattern on the geologic map generally have a lot of bedrock outcrops, or only a thin cover of surficial sediments on top of the bedrock. Drainage problems may occur in the latter areas and certainly in the wetlands.

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APPENDIX. GLOSSARY OF GEOLOGIC TERMS THAT MAY APPEAR IN THIS REPORT.

Ablation till: till deposit formed by release of debris from melting glacial ice, accompanied by variable amounts of slumping and meltwater action. May be loose and stony, and contains lenses of washed sand and gravel.

Basal melt-out till: till deposit resulting from melting of debris-rich ice in the bottom part of a glacier. Generally shows crude stratification due to included sand and gravel lenses.

Clast: pebble-, cobble-, or boulder-size fragment of rock or other material in a finer-grained matrix (q.v.). Often refers to stones in glacial till or coarse-grained water-laid sediments.

Clast-supported: refers to sediment that consists mostly or entirely of clasts, generally with more than 40% clasts. Usually the clasts are in contact with each other. For example, a well-sorted cobble gravel.

Delta: a body of sand and gravel deposited where a stream enters a lake or ocean and drops its sediment load. Glacially deposited deltas in Maine usually consist of two parts: (1) coarse, horizontal, often gravelly *topset beds* deposited in stream channels on the flat delta top, and (2) underlying, finer-grained, inclined *foreset beds* deposited on the advancing delta front

Deposit: general term for any accumulation of sediment, rocks, or other earth materials.

Diamicton: any poorly-sorted sediment containing a wide range of particle sizes.

Drumlin: an oval-shaped hill, often composed of glacial sediments, that has been shaped by the flow of glacial ice such that its long axis is parallel to the direction of ice flow.

End moraine: a ridge of sediment deposited at the margin of a glacier. Usually consists of till and/or sand and gravel in various proportions.

Englacial: occurring or formed within glacial ice.

Eolian: formed by wind action, such as a sand dune.

Esker: a ridge of sand and gravel deposited by meltwater streams in a tunnel within or beneath glacial ice.

Fluvial: Formed by running water, for example by meltwater streams discharging from a glacier.

Glaciolacustrine: refers to sediments or processes involving a lake which received meltwater from glacial ice.

Glaciomarine: refers to sediments and processes related to the environment where marine water and glacial ice are in contact.

Holocene: term for the time period from 10,000 years ago to the present. It is often used synonymously with “postglacial” because most of New England has been free of glacial ice since that time.

Ice-contact: refers to any sedimentary deposit or other feature that formed adjacent to glacial ice. Many such deposits show irregular topography due to melting of the ice against which they were laid down, and resulting collapse.

Kettle: a depression on the ground surface, ranging in outline from circular to very irregular, left by the melting of a mass of glacial ice that had been surrounded by glacial sediments. Many kettles now contain ponds or wetlands.

Lacustrine: pertaining to a lake.

Late glacial: refers to the time when the most recent glacial ice sheet was receding from Maine, approximately 15,000-10,000 years ago.

Late Wisconsinan: the most recent part of Pleistocene time, during which the latest continental sheet covered all or portions of New England (approx. 25,000-10,000 years ago).

Lodgment till: very dense variety of till, deposited beneath flowing glacial ice. May be known locally as "hardpan."

Matrix: the fine-grained material, generally silt and sand, which comprises the bulk of many sediments and may contain clasts (q.v.).

Matrix-supported: refers to any sediment that consists mostly or entirely of a fine-grained component such as silt or sand. Generally contains less than 20-30% clasts, which are not in contact with one another. For example, a fine sand with scattered pebbles.

Moraine: General term for glacially deposited sediment, but often used as short form of "end moraine" (q.v.).

Morphosequence: a group of water-laid glacial deposits (often consisting of sand and gravel) that were deposited more-or-less at the same time by meltwater streams issuing from a particular position of a glacier margin. The depositional pattern of each morphosequence was usually controlled by a local base level, such as a lake level, to which the sediments were transported.

Outwash: sediment derived from melting glacial ice, and deposited by meltwater streams in front of a glacier.

Outwash head: the end of an outwash deposit that was closest to the glacier margin from which it originated. Ice-contact outwash heads typically show steep slopes, kettles (q.v.), and hummocks marking the former position of the ice margin and/or a zone of stagnating ice masses.

Pleistocene: term for the time period between 2-3 million years ago and 10,000 years ago, during which there were several glaciations. Also called the "Ice Age."

Proglacial: occurring or formed in front of a glacier.

Quaternary: term for the era between 2-3 million years ago and the present. Includes both the Pleistocene and Holocene.

Striation: a narrow scratch on bedrock or a stone, produced by the abrasive action of debris-laden glacial ice.

Subaqueous fan: a somewhat fan-shaped deposit of sand and gravel that was formed by meltwater streams entering a lake or ocean at the margin of a glacier. Similar to a delta (q.v.), but was not built up to the water surface.

Subglacial: occurring or formed beneath a glacier.

Till: a heterogeneous, usually non-stratified sediment deposited directly from glacial ice. Particle size may range from clay through silt, sand, and gravel to large boulders.

Topset/foreset contact: the more-or-less horizontal boundary between topset and foreset beds in a delta (q.v.). This boundary closely approximates the water level of the lake or ocean into which the delta was built.