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INTRODUCTION

This report describes the surficial geology and Quaternary history of the Waterford Flat 7.5-minute quadrangle in southwestern Maine. Surficial earth materials include unconsolidated sediments (sand, gravel, etc.) 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 most 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 field work for this study was carried out in 1999 for the STATEMAP cooperative between the Maine Geological Survey (MGS) and the U. S. Geological Survey (USGS). Two maps are associated with this report. The *geologic map* (Thompson, 2000) shows the distribution of sedimentary units, and indicates their age, composition, and known or inferred origin. It also includes information on the geologic history of the quadrangle, such as features indicating the flow direction of glacial ice. This map provides the basis for the discussion of glacial and postglacial history presented here.

The *materials map* (Locke and Thompson, 2000) shows specific data used to help construct the geologic map. These data include observations from gravel pits, shovel and auger holes, construction sites, and natural exposures along stream banks. The materials map also shows boring logs. Sand and gravel aquifer studies by the USGS provided additional data on the type and thickness of surficial sediments in the quadrangle (Prescott, 1979, 1980).

Geographic setting. The Waterford Flat quadrangle is located on the approximate border between the White Mountain foothills (a.k.a. Oxford Hills) and the coastal lowland of southwestern Maine. The map area extends in latitude from 44°07'30" to 44°15'00" N, and in longitude from 70°37'30" to 70°45'00" W. It encompasses parts of the towns of Waterford, Norway, and Sweden in Oxford County, and Harrison and Bridgton in Cumberland County. The neighboring villages of Waterford Flat and South Waterford are the only population centers in the quadrangle.

The Crooked River is by far the largest stream in the Waterford Flat quadrangle. The Bear River is also significant, and several brooks drain the remainder of the map area. Lakes and ponds in the quadrangle provide attractive scenery and recreation for summer camps and tourists. The topography is hilly across much of the area. Elevations range from about 310 ft (94 m) above sea level on Crystal Lake to 1328 ft (405 m) on the summit of Rice Hill.

Bedrock geology. Quaternary sediments cover the bedrock over much of the Waterford Flat quadrangle, but bedrock outcrops are common on the hills. The map area is underlain by granite of Carboniferous age, which is part of an extensive granite body called the Sebago pluton (Osberg and others, 1985). Veins of granite pegmatite occur locally.

PREVIOUS WORK

Stone (1899) conducted a reconnaissance of southwestern Maine during his USGS study of Maine's glacial gravels. He was intrigued by the divergence of glacial drainage routes just west of the study area, in North Waterford. At this location a major esker system leaves the Crooked River valley and continues southwest into the Kezar River basin, while a second series of glacial sand and gravel deposits extends eastward along the Crooked Valley and into the Waterford Flat quadrangle. Stone's discussion of these deposits (p. 252-254) includes the memorable remark that "I have long since learned that glacial rivers bear careful watching. Their deceitfulness is well exhibited at North Waterford."

Thompson (1977a) conducted reconnaissance-level surficial geologic mapping of part of the study area for the Maine

Geological Survey and Greater Portland Council of Governments. Prescott (1979, 1980) compiled well and test hole data, and carried out preliminary surficial and gravel aquifer mapping. Thompson compiled an aquifer map that included the Waterford Flat quadrangle as part of the Significant Sand and Gravel Aquifer Project sponsored by the MGS, USGS, and Maine Department of Environmental Protection (Williams and others, 1987). Neil and Locke (1998) compiled a more detailed aquifer map of the quadrangle for the Maine Geological Survey's Significant Sand and Gravel Aquifer Project. The U. S. Department of Agriculture's soil survey of Oxford County (Wilkinson, 1995) provided useful materials information for several sites that the present author did not visit in the field. Thompson (in press) summarizes the late-glacial history of western Maine.

DESCRIPTION OF GEOLOGIC MAP UNITS

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

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

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 "goc" for glacial outwash deposited in the Crooked River valley. Surficial map units in the Waterford Flat quadrangle are described below, starting with the older deposits that formed in contact with glacial ice.

Till (unit Pt)

Till (Pt) is a glacially deposited sediment consisting of a more-or-less random mixture of sand, silt, and gravel-size rock debris. In southern Maine it typically includes numerous boulders. Till blankets much of the upland portions of the quadrangle, where it is the principal surficial material; and it commonly underlies younger deposits in the valleys. Some of the till in Maine probably was derived from glacial erosion of older surficial sediments (either glacial or non-glacial), while the remainder was freshly eroded from nearby bedrock sources during the latest glaciation.

Exposures in the Waterford Flat quadrangle show up to at least 20 ft (6 m) of till, and well logs indicate the thickness locally is as much as 88 ft (27 m) (Locke and Thompson, 2000). The till cover is thin on the tops of many hills, where bedrock is likely to be exposed. A ruled line pattern on the geologic map shows areas where bedrock outcrops are common and/or the till thickness is inferred to be less than 10 ft (3 m).

Till deposits probably rest directly upon bedrock over most of the quadrangle. However, pits on the south sides of Deer Hill and Rice Hill show till overlying gravel and sand (see photos on geologic map). A similar relationship has been noted at several other localities in the uplands of southwestern Maine. In all known examples the buried gravel occurs on the south (downglacier) sides of bedrock-cored hills. The stratigraphic relationships and high degree of compaction of these gravels suggest they were deposited in front of the advancing late Wisconsinan ice sheet and then overridden by the glacier (Thompson, 1994).

The texture and structure of till deposits vary depending on their source and how they were formed. In the Waterford Flat quadrangle, till may include a small percentage of clay, but it has a dominantly 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 deposition.

Stones are abundant in this unit, and boulders scattered across the ground surface often indicate the presence of till. Till stones in the quadrangle chiefly consist of coarse-grained igneous and metamorphic rocks, especially granitic rocks derived from local bedrock sources. Most 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 (basalt occurs as dikes cutting other rock types in southwestern Maine).

Varieties of till formed beneath a glacial ice sheet include lodgement and basal melt-out tills. Lodgement till was deposited under great pressure beneath the ice sheet. It may be very compact and difficult to excavate ("hardpan"), with a platy structure (fissility) evident in the upper, weathered zone (see photo on geologic map). Basal melt-out till is difficult to identify with certainty, but typically shows a crude stratification inherited from debris bands in the lower part of the glacier. Ablation till formed during the melting of the ice and tends to be loose-textured and stony, with numerous lenses of washed sediment. More than one of these till varieties may occur at a single locality. For example, a thin veneer of stony ablation till commonly overlies lodgement till.

Field evidence in southern Maine and elsewhere in New England (e.g. Koteff and Pessl, 1985; Thompson and Borns, 1985; Weddle and others, 1989), suggests that till deposits of two glaciations are present in the region. The "upper till" is clearly the product of the most recent, late Wisconsinan glaciation, which covered southern Maine between about 25,000 and 13,000 years ago. Exposures of upper till can be seen in many shallow pits, road cuts, and temporary excavations. It is not

weathered (except in the near-surface zone of modern soil formation) and is usually light olive-gray in color. Lodgement and ablation facies of the upper till have been recognized in the Waterford Flat quadrangle (see materials map by Locke and Thompson, 2000).

The "lower till" consists of compact, silty-sandy lodgement deposits. In southwestern Maine, as in other parts of New England, it is likely to be found in drumlins and other smooth, glacially streamlined hills where a considerable thickness of till has accumulated. These thick deposits often occur as "ramps" on the gentle northwest slopes of hills, while bedrock is exposed on the steeper, glacially plucked southeast slopes. The lower till is distinguished by its thick weathering profile, which may extend to a depth of 10 ft (3 m) or more. Within this weathered zone, the till is oxidized and has an olive-gray to dark olive-gray or dark grayish-brown color. Dark-brown iron/manganese oxide staining coats the surfaces of stones and joints (Thompson, 1986). This till is believed to have been deposited during an earlier glaciation in Illinoian time, prior to 130,000 years ago (Weddle and others, 1989).

The author has not seen any exposures of lower till in the Waterford Flat quadrangle, perhaps because borrow pits are rare in this hard-to-excavate sediment. The considerable till thickness in some of the streamlined hills in the quadrangle suggests that the lower till may be present at depth. An extremely dense lodgement till occurs beneath glacial fan gravel and a late Wisconinsan lodgement till in the Norway town pit, located in the nearby West Paris quadrangle (Thompson and others, 2000). The stratigraphic position and presence of rotten stones in this buried unit suggest that it is probably equivalent to the lower till seen elsewhere.

End Moraines (unit Pem)

End moraines (Pem) are ridges of sediment deposited at the margins of glaciers. They may form in many different ways, but generally are sediment accumulations derived from the adjacent glacial ice (or shaped by glacial processes at the ice margin). Moraine ridges located 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 shallow 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.), which also occur in the Waterford Flat quadrangle. Till ridges that are thought to be end moraines occur in the Crooked River valley in the eastern part of the quadrangle. The ridge close to the river is littered with many large boulders. These moraines are located in a topographically low area. This is probably the result of meltwater and debris-flow processes focusing the deposition of glacial sediments in front of an ice tongue as it retreated northwestward up the Crooked Valley.

Hummocky Moraine (unit Phm)

An area of hummocky moraine (Phm) was mapped in the Crooked River valley, adjacent to the end moraines described above. These deposits are distinguished in the field by their knobby topography (see photo on geologic map), and large boulders are very abundant. The lack of bedrock outcrops, together with the topographic relief, suggests that the thickness of this unit may be tens of feet. Sections exposed during pipeline construction in 1998 revealed diamicton (till) with lenses of gravel.

In southwestern Maine, hummocky moraine usually is concentrated in lowlands, but it occurs at higher elevations than nearby waterlaid glacial deposits consisting of sand and gravel (e.g. unit Pgoc in present study area). Holland (1986) observed that 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. The association with end moraines in the Crooked River valley implies deposition during retreat of a valley ice tongue.

Esker Deposits (unit Pge)

A short ridge in the area of sand and gravel northwest of Papoose Pond may be an esker. It was noted on aerial photographs, but has not been field-checked. If the ridge is an esker, it would have been deposited in a subglacial ice tunnel. Alternatively, it may be some other type of ice-channel filling or part of the Crooked River outwash system (unit Pgoc).

Glacial Lake Sebago Deposits (unit Pls)

The Bear River and Crystal Lake basins contain deposits of sand, silt, and gravel (Pls). There are few diagnostic exposures from which to determine the origin of these sediments. However, the fine-grained sand observed in many places suggests that much of unit Pls formed in a quiet-water glacial-lake environment. Varved clay-silt was formerly exposed in a borrow pit on the east side of the Bear River, near the south edge of the quadrangle (W. B. Thompson, 1976 field notes). Flat-topped deposits of sand and gravel in the highest portions of the unit, at elevations of about 400 ft, probably are at least partly deltaic.

Mapping by C. T. Hildreth (1997a,b; 2000) and Thompson (1977b) in quadrangles to the south has shown that a discontinuous series of similar glaciolacustrine deposits can be traced from the Crystal Lake-Bear River area southward down the Long Lake valley to Sebago Lake. All of these deposits are attributed to a former lake (glacial Lake Sebago) that included and extended north from the Sebago Lake basin. The present eleva-

tions of Pls deposits rise to the north due to postglacial crustal uplift and tilt.

Glacial Lake Keoka Deposits (unit Plkd)

Much of the village of Waterford Flat is located on a flat deposit of sand and gravel (Plkd) at the mouth of the Kedar Brook valley, on the west side of Keoka Lake. This feature is a delta that was built into the lake when it stood at a slightly higher level than today. The materials map (Locke and Thompson, 2000) shows that 33 ft (10 m) of gravelly sand and silt overlying bedrock were encountered in a test boring through the delta.

The sediment comprising the delta probably came from glacial streams, rather than the small brooks that presently enter the lake basin. Meltwater channels southwest of Rice Hill indicate the former course of glacial drainage, which flowed from the ice margin down the Kedar Brook valley and into the lake (see geologic map). Glacial Lake Keoka was dammed at an elevation of about 500 ft by the till deposits at the outlet of the lake (head of Mill Brook). Postglacial erosion of this outlet eventually lowered Lake Keoka to its present level.

Ice-contact Deposits (unit Pgi)

A very small deposit of gravelly sand (Pgi) was mapped on the southwest side of the Crooked River valley in Waterford, at an elevation slightly higher than the adjacent glacial outwash plain (Pgoc). Unit Pgi is presumed to have formed in contact with melting glacial ice as this part of the valley was deglaciated.

Crooked River Outwash (unit Pgoc)

The Crooked River valley contains extensive deposits of sand and gravel emplaced by glacial meltwater streams (Pgoc). These outwash deposits underlie a discontinuous flat surface at elevations higher than the modern river flood plain. Sediments comprising unit Pgoc are usually well-rounded gravel or gravelly sand at the surface. The thickness of the outwash exceeds 25 ft (8 m) in places, but its maximum thickness is not known. A well log indicates 105 ft (32 m) of sand overlying 7 ft (2 m) of till southeast of Papoose Pond (Locke and Thompson, 2000). The upper part of this sand is probably outwash, but its great thickness suggests that the deeper sand is a glaciolacustrine deltaic deposit. A glacial lake may have been dammed by the bedrock threshold and end-moraine where the valley narrows in the eastern part of the quadrangle. If so, it was later filled by deltaic sediments that were in turned capped by the outwash.

Exposures of unit Pgoc were seen in numerous borrow pits (many of them inactive) along the Crooked River valley. Cross-bedding at these localities clearly indicates glacial stream flow down the valley. Trenches excavated for pipeline construction in 1998 showed many fine exposures of the outwash, in some cases including the contact between the sand and gravel and underlying till.

Talus Deposits (unit Qta)

Large boulders have fallen from the cliff on the west side of Bear Mountain, forming a prominent talus pile (Qta) along the northeast shore of Bear Pond. Similar talus accumulations may be found at the base of steep bedrock slopes elsewhere in the quadrangle. They could have been initiated by glacial plucking of the cliff faces, but the talus piles probably have grown during postglacial time as frost action causes blocks of bedrock to break loose along fracture surfaces and fall to the bottom of the slopes.

Eolian Deposits (unit Qe)

Small areas of eolian (windblown) sand were mapped in three places along the side of the Crooked River valley. These deposits (Qe) resulted from wind erosion of outwash sand in the valley. They probably formed in late-glacial time, when vegetation cover was sparse (McKeon, 1989). Eolian sand is almost certainly more extensive than shown on the geologic map. Thin patchy deposits are easily overlooked in wooded areas, and may not be obvious where they rest upon water-laid sand. For example, a small eolian deposit that had drifted up against the till slope at the east edge of the Crooked River outwash plain was recognized only because a borrow pit had been opened in it.

Shoreline Deposits (unit Hls)

Beach deposits (Hls) have formed at the south end of McWain Pond and at the north end of Bear Pond. They resulted from the erosion and transport of glacial sediments by wave and current action. Other beach deposits likely occur in the quadrangle, especially where easily eroded sand and gravel deposits form the shorelines of modern lakes.

Wetland Deposits (unit Hw)

Unit Hw consists of fine-grained and organic-rich sediments deposited in low, flat, poorly drained areas. In the Waterford Flat quadrangle this unit occurs mostly in valleys and 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. There is little information on the thickness of wetland deposits in the quadrangle. A report by Cameron and others (1984) describing peat deposits in southwestern Maine notes that they usually average less than 20 ft (6 m) thick.

Stream Alluvium (unit Ha)

Unit Ha consists of alluvial sand, gravel, silt, and organic material deposited by modern streams. In the Waterford Flat quadrangle, significant alluvial deposits occur mostly along the Crooked River and a few smaller streams. There is no informa-

tion on the thickness of this unit, but it probably is less than 10 ft (3 m) in most places.

GLACIAL AND POSTGLACIAL GEOLOGIC HISTORY

The following reconstruction of the Quaternary history of the Waterford Flat quadrangle and surrounding area is based on the interpretations of surficial earth materials described in this report, together with published information from surrounding areas of New England. It is uncertain how many episodes of glaciation have affected the study area during the Pleistocene Ice Age. Till deposits in western Maine clearly record the most recent (late Wisconsinan) glaciation, and probably one earlier event. The deeply weathered lower till found elsewhere in central and southern New England has also been recognized in this part of the state (Thompson and Borns, 1985; Weddle and others, 1989). Although it is not well-dated, the lower till was deposited during the penultimate glaciation, of probable Illinoian age.

Data published by Stone and Borns (1986) indicate that the late Wisconsinan Laurentide Ice Sheet expanded out of Canada and spread into Maine approximately 25,000 radiocarbon years ago. As the glacier flowed across the state for thousands of years, it shaped 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, with their long axes parallel to the south-southeastward flow of the ice. Prominent streamlining is seen on many till-covered hills in the Waterford Flat quadrangle, such as in the area east and south of Keoka Lake. Glacial plucking on the lee sides of some hills created steep south-facing bedrock slopes. A good example is on Hawk Mountain in Waterford (see photo on geologic map).

Abrasion by rock debris dragged at the base of the glacier polished and striated the bedrock surface. Striations are not easy to find in the Waterford Flat quadrangle because in many places they are either concealed beneath surficial sediments or have been destroyed by weathering at the ground surface. The geologic map shows sites where striation trends have been recorded. Good examples of striations and glacially polished ledges are exposed along the jeep trail that climbs the north side of Hawk Mountain. All known striation localities indicate glacial flow toward the southeast or south-southeast. This flow presumably occurred during the maximum phase of late Wisconsinan glaciation, when the glacially streamlined hills were sculpted with the same orientation.

The minimum age of glacial retreat from the Waterford Flat quadrangle can be estimated from radiocarbon dating of organic material in lake-bottom sediments deposited soon after deglaciation. Thompson and others (1996) obtained an age of 13,200 radiocarbon years from Cushman Pond in Lovell, located in the adjacent North Waterford quadrangle, so the study area probably was deglaciated by this time. However, isolated masses of stagnant ice may have lingered in valleys. The nearby Saco Valley was certainly ice-free by 12,000 years ago, judging from dated plant remains in Fryeburg (Thompson, 1999).

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 rare in the Waterford Flat quadrangle, making it more difficult to reconstruct the pattern of deglaciation. However, the orientations of meltwater channels show that ice recession proceeded in a generally north to northwestward direction.

Some of the rock debris in the ice sheet was deposited directly from the glacier as various types of till, including end moraines and hummocky moraine (units Pt, Pem, and Phm). The remainder was washed out of the ice by meltwater streams issuing from the glacier margin and deposited in valleys during deglaciation of the Waterford Flat quadrangle. The oldest meltwater deposits in the quadrangle (unit Pls) are deltaic and lake-bottom sediments deposited in glacial Lake Sebago (Crystal Lake and Bear Pond areas). This lake formed when a glaciomarine delta complex at the south end of Sebago Lake impounded a large body of fresh water that extended from the Sebago basin northward up the Long Lake valley (Hildreth, 1997a,b,c,d) and into the present study area.

As the glacier margin retreated northward from the quadrangle, a small delta (unit Plkd) was deposited in glacial Lake Keoka, and a cluster of end moraines and hummocky moraine formed in the Crooked River valley. The youngest glacial meltwater deposit in the quadrangle is the outwash (unit Pgoc) in the Crooked River valley. These sediments continued to wash down the valley from the ice margin when the glacier had receded northwest from the map area. The prolonged influx of sand and gravel probably filled in a glacial lake dammed behind the constriction of the valley in the eastern part of the quadrangle.

Minor deposits of eolian sand (unit Qe) formed on the sides of the Crooked River valley in late-glacial to postglacial time. Wetlands (Hw) and flood plains (Ha) began to develop soon after deglaciation, and continue to accumulate sediments to the present day.

ECONOMIC GEOLOGY

Sand and gravel supplies are plentiful in several valleys in the Waterford Flat quadrangle, especially along the Crooked River valley (Pgoc) and in the vicinity of Bear Pond and Crystal Lake (Pls). Numerous borrow pits have already been opened in these deposits. Gravel is most abundant in the upper part of the Crooked River outwash plain, while sand or gravelly sand may occur at depth. The outwash is generally coarsest (more gravelly, with larger stones) in the western part of the quadrangle, which was closer to the ice margin during the final period of deposition.

Small pits have been opened in glacial till deposits. The sandy till in this area packs well and is often well-suited for fill. It may also provide favorable sites for septic tank absorption fields.

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APPENDIX A

GLOSSARY OF TERMS USED ON MAINE GEOLOGICAL SURVEY SURFICIAL GEOLOGIC MAPS

compiled by
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Note: Terms shown in italics are defined elsewhere in the glossary.

Ablation till: *till* formed by release of sedimentary 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* 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*. Often refers to stones in glacial till or gravel.

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, e.g. glacial *till*.

Drumlin: an elongate 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 at least partly by meltwater flowing in a tunnel within or beneath glacial ice. Many ridges mapped as eskers include variable amounts of sediment deposited in narrow open channels or at the mouths of ice tunnels.

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 environments where marine water and glacial ice were in contact.

Head of outwash: same as *outwash head*.

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 age: see *Pleistocene*.

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.

Kettle hole: same as *kettle*.

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 ice sheet covered all or portions of New England (approx. 25,000-10,000 years ago).

Lodgement 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*.

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*."

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* and hummocks, and/or boulders dumped off the ice. These features help define former positions of a retreating glacier margin, especially where *end moraines* are absent.

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. Plural form sometimes given as "striae."

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*, 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*. This boundary closely approximates the water level of the lake or ocean into which the delta was built.