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INTRODUCTION

This report describes the surficial geology and Quaternary history of the East Stoneham 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 stages, first to gather data for the Maine Geological Survey's (MGS) sand-and-gravel aquifer mapping program (Williams and others, 1987) and later to complete the surficial geologic mapping of the East Stoneham quadrangle. Field work to update earlier observations, and preparation of the present report, were done in 2001-02 for the STATEMAP cooperative between the MGS and the U. S. Geological Survey (USGS).

Two maps are associated with this report. The *geologic map* (Thompson, 2003) 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, along with mapping done by the author in adjacent quadrangles, provides the basis for the discussion of glacial and postglacial history presented here. The *materials map* (Thompson and Locke, 2003) 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. Sand and gravel aquifer studies by the MGS provided subsurface data, including seismic and well logs for parts of the quadrangle (Williams and others, 1987).

Geographic setting

The East Stoneham quadrangle is located in the White Mountain foothills (a.k.a. Oxford Hills region) of southwestern Maine. The map area extends in latitude from 44°15'00" to 44°22'30" N, and in longitude from 70°45'00" to 70°52'30" W. It encompasses parts of the towns of Albany, Stoneham, Mason, Bethel, Lovell, and Greenwood, but the only population center is the village of East Stoneham. The principal stream in the map area is the Crooked River. Numerous brooks in the quadrangle are tributary to this south-flowing river. Other streams - notably Mill Brook and the East and West Branches of the Pleasant River - drain north to the Androscoggin River. The topography across the quadrangle is generally hilly to mountainous. Elevations range from about 550 ft (168 m) above sea level (where the Crooked River crosses its southern border) to about 1960 ft (597 m) on Peter Mountain near the west edge of the quadrangle.

Part of the White Mountain National Forest is located in the East Stoneham quadrangle. These Forest lands, together with ponds, lakes, and streams, are important for outdoor recreation in this part of Maine. Other natural resources that have been utilized in the study area include timber, sand and gravel, crushed stone, and a variety of industrial and gem minerals such as feldspar and beryl.

Bedrock geology

Quaternary sediments cover the bedrock over much of the East Stoneham quadrangle, but outcrops are very common on hills and mountains. Most of the map area is underlain by a large granite body of Devonian age, called the Songo Pluton (Osberg and others, 1985). Veins of granite pegmatite are found throughout the area.

PREVIOUS WORK

Stone (1899) conducted a reconnaissance of southwestern Maine during his statewide USGS study of Maine's glacial gravels. He briefly discussed the esker system and related glacial meltwater deposits in the Crooked River valley in the East Stoneham quadrangle and adjacent areas (Stone, 1899, p. 248-250). Stone included the esker deposits with the "Albany-Saco River Series," which he traced from Albany south to East Brownfield in the Saco Valley. He further noted that in some places in southern Albany and northern Waterford, this esker system consists of two adjacent ridges. Stone also proposed that a lake formerly existed in the vicinity of Bethel in the Androscoggin Valley (just north of the present study area), and that the early postglacial drainage of the Androscoggin River may have "overflowed" across the low divide into the Crooked River valley.

Prescott (1979) compiled well and test hole data in the area of the East Stoneham quadrangle, and also carried out preliminary surficial and gravel aquifer mapping (Prescott, 1980; Prescott and Dickerman, 1981). Thompson compiled a more detailed aquifer map that included the East Stoneham 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). 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.

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 "lw" for sediments deposited in glacial Lake Waterford. Surficial map units in the East Stoneham quadrangle are described below, starting with the older deposits that formed in contact with glacial ice.

Till (unit Pt)

Till 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 presumably 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.

Pit exposures in the East Stoneham quadrangle have revealed up to 40 ft (12 m) of till, and well logs indicate the thickness locally reaches 50 ft (15 m) or more (Thompson and Locke, 2003). Till 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 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 East Stoneham 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 mainly 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.

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. 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 the Oxford Hills region, coupled with studies 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 small 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. Ablation facies of the upper till have been recognized in the East Stoneham quadrangle.

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 smooth, glacially streamlined hills where a considerable thickness of till has accumulated. These thick deposits often occur as "ramps" on the gentle northwest-facing 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). Probable equivalents of this till in southern New England are believed to be have been deposited during an earlier glaciation in Illinoian time, prior to 130,000 years ago (Weddle and others, 1989).

A thick deposit of lodgement till was seen in a small abandoned pit on the hillside just south of the southwest corner of Keewaydin Lake, adjacent to Route 5. This section is approximately 45 ft (14 m) high. It was less overgrown with vegetation when described by Thompson (1986). Digging in the pit face revealed ~ 3 ft (1 m) of sandy, stony late Wisconsinan till overlying at least ~ 40 ft (12 m) of what is probably the lower till. The latter till is compact, olive-gray, silty, and less stony than the upper till. The upper part of this unit has iron or manganese oxides coating joint surfaces. Between the two tills is a 3-ft (1 m) unit in which fragments of the lower till are mixed with deformed sand lenses. This unit probably resulted from erosion of the lower till by the late Wisconsinan ice sheet, producing a mixed zone in which sheared clasts of lower till were mingled with sandy sediments from the overriding glacier.

End moraine (unit Pem)

On the south side of Keewaydin Lake, between the lake shore and Route 5, there is a bouldery till ridge that trends east-west. This feature probably is an end moraine, which was deposited along the margin of the last glacial ice sheet as it retreated northward from the lake basin. Several other till ridges between Keewaydin Lake and East Stoneham village are inferred to be end moraines. Their orientation suggests a tongue of glacial ice retreating northwestward up the Mill Brook valley. The crests of these ridges are shown on the geologic map.

Esker deposits (unit Pge)

A discontinuous esker system (Pge) extends from the south edge of the quadrangle northward along the Crooked River for a short distance and thence to Kneeland Pond and the valley occupied by a chain of ponds in the White Mountain National Forest. This map unit consists of ridges of gravel and sand deposited by meltwater streams flowing south in tunnels at the bottom of the last glacial ice sheet. It is part of a segmented esker system that can be traced from the East Stoneham quadrangle southward for many miles to a large glaciomarine delta in the Dayton area (York County). This delta contains sediments that washed into the sea at the terminus of the ice-tunnel network. Whether meltwater flowed simultaneously through the entire tunnel network is debatable, but it is likely that the esker segments formed progressively from south to north as the tunnel became clogged with sediment during deglaciation.

The ridges comprising the esker system are typically 20-60 ft (6-18 m) high and about 200-300 ft (60-90 m) wide. Between Little Papoose and Kneeland Ponds, the esker consists of two parallel and closely spaced ridges. This indicates the former presence of two ice tunnels, though it is not known whether both of them carried meltwater at the same time. A long gap in the esker exists northwest of Kneeland Pond, in the Albany Brook valley. The valley is very narrow and confined between bedrock hills in this area. The subglacial stream carved a gorge at least 80 ft (24 m) deep in the east-west portion of the valley. Large potholes occur in the walls of this gorge. Many years ago, the site was a tourist attraction called "Albany Basin," but it is now on private property and off-limits to visitors.

Glacial Lake Waterford deposits (unit Plw)

Glacial Lake Waterford formerly occupied a part of the Crooked River valley from East Stoneham to North Waterford, and extended southwest to the Kezar Falls gorge in the North Waterford quadrangle (where its outlet was located). It was dammed by remnant ice in the North Waterford area, which prevented the lake waters from escaping eastward down the Crooked River valley (Thompson, 1999a,b). The sediments that record the existence of this lake (Plw) are thought to be largely of deltaic origin. They were deposited where glacial meltwater streams entered the lake and dropped their load. Elevations of the flat, graded tops of deltas in the North Waterford quadrangle indicate that the lake surface stood at approximately 600-620 ft (183-189 m). The upper surface of the Plw deposit in the southern part of the East Stoneham quadrangle has the same elevation and likewise may be deltaic. There is little information on the maximum thickness of the unit, but pit exposures in the East Stoneham quadrangle reach depths of at least 20 ft (6 m).

Crooked River ice-contact deposits (unit Pgic)

Ice-contact sand and gravel deposits (Pgic) occur along the Crooked River valley between Town House and the south edge of the quadrangle. They have flat to hummocky topography on their upper surfaces. In some areas unit Pgic forms valley-side terraces bordered by till-covered slopes on the uphill side and outwash (Pgoc) or postglacial alluvial sediments (Ha) at lower elevations toward the valley center. Good examples of these terraces occur on both sides of the Crooked River valley in the area east of Square Dock Mountain. Elevations of the tops of Pgic deposits decrease southward from about 660 ft (201 m) in the Ingham Hill area to 610 ft (186 m) at the south edge of the quadrangle. Kettles and kames are present locally. Together with faults and slump structures exposed in gravel pits, these features show that unit Pgic was deposited adjacent to remnants of decaying glacial ice.

Textures in unit Pgic vary widely from sand to boulder gravel. The exposed thickness of the unit reaches at least 40 ft (12 m) in some gravel pits, but the total thickness can be substantially greater. Observation well 14-6, located at the Albany/Waterford waste disposal facility on the east side of Route 5, is probably within unit Pgic. This well penetrated 87 ft (26.5 m) of sand and gravelly sand (Williams and others, 1987). Pit exposures adjacent to the waste facility have shown a variety of sedimentary structures in sandy outwash, including excellent examples of trough and tabular cross-beds, dunes, and current ripples. Sections observed in 1990 showed 20 ft (6 m) of this material, overlain by 6 ft (2 m) of coarser outwash consisting of poorly sorted pebble-cobble gravel.

A coarse upper gravel was also noted in the Hatstat pits, located 0.8 mile north of Flints Brook on the east side of the Crooked River valley. In this pit complex, unit Pgic includes thick deposits (up to 40 ft or more) of glaciolacustrine sand. The well-stratified sand exhibits current ripples, water-escape structures, and other sedimentary features typical of sandy deltaic and lake-bottom deposits. These fine-grained sediments are locally underlain by mixed sand and gravel, and overlain by several feet of glaciofluvial gravel. Another sandy lacustrine component of unit Pgic occurs on the west side of the Crooked River valley, along a logging road leading to the north flank of Square Dock Mountain.

Crooked River outwash deposits (unit Pgoc)

The youngest glacial deposits in the Crooked River valley are outwash sand and gravel (Pgoc). These deposits underlie a discontinuous flat surface at elevations intermediate between unit Pgic and the modern river flood plain. Elevations of the outwash plain range from 665 ft (203 m) in the north to about 610 ft (186 m) in the south.

Pit exposures in unit Pgoc are generally shallow (10 ft or less) and expose materials ranging from sand to boulder gravel. Bedrock outcrops protruding from the floors of some pits show that the outwash is locally thin. The coarsest gravel in this unit was seen in a pit on the west side of Route 5, ESE of Square Dock Mountain. Here there are many boulders with diameters to 3 ft (1m). The local occurrence of coarse gravel within unit Pgoc suggests that the outwash may have been deposited from several ice-margin positions in the Crooked River valley and its tributaries. Meltwater drainage from ice in the main valley was supplemented by glacial tributary streams carrying sand and gravel from the Barkers Brook and Walker Brook valleys, and from the same drainage that formed the ice-contact deposits south of Ingham Hill (the contact between Pgic and Pgoc in the latter area is gradational and has been drawn somewhat arbitrarily).

Glacial Lake Mill Brook deposits (unit Plm)

Sand and gravel deposits (unit Plm) are common in the Mill Brook valley in the northeast part of the quadrangle. These deposits form flat to gently sloping surfaces at elevations up to about 720 ft (219 m), and presumably underlie the wetland and flood plain areas along Mill Brook. Much of unit Plm is sand or gravelly sand. Exposures are few in number and usually shallow, and the maximum thickness of the unit is unknown. The low, flat areas on the floor of Mill Brook valley are mostly underlain by sand, while gravel is common in the southern and northeast extremities of unit Plm (east of Ingham Hill and east of Grover Hill). The coarse gravelly sediments probably were deposited close to the glacier margin when it stood in the latter areas.

The Plm deposits are interpreted as having formed in a glacial lake, which is here called “glacial Lake Mill Brook.” The Mill Brook valley drains to the north and would likely have been dammed by the the northward-receding ice margin during deglaciation of the study area. There are two probable spillways for Lake Mill Brook. The first is the gap southeast of Ingham Hill, which has an elevation of about 710 ft (216 m). The lake would have drained through here until the ice margin withdrew to the north end of Songo Pond. At this point a lower spillway became available at an elevation of about 690 ft (210 m).

Ice-contact deposits (unit Pgi)

Unit Pgi comprises miscellaneous bodies of sand and gravel deposited adjacent to decaying remnants of ice in valleys other than that of the Crooked River. These deposits formed during recession of the late Wisconsinan glacier. The ice-contact environment is often indicated by morphologic features such as kettle holes, steep-sided mounds and ridges, and terraces bordered by ice-contact slopes. Where exposed in gravel pits, the Pgi sediments commonly are coarse-grained (abundant pebble to boulder gravel), poorly sorted, and may exhibit folds and faults resulting from slumping when the supporting ice melted.

Some of the best-developed Pgi deposits occur in the vicinity of Crocker Pond Campground in the White Mountain National Forest. The ponds in this area occupy kettles left by the melting of stagnant ice masses. The Pgi terrace just south of Patte Hill may actually be a small ice-contact delta that was deposited in a glacial lake between the valley side and remnant ice in the center of the valley.

Glacial outwash - Keewaydin Lake area (unit Pgo)

A small flat area of sandy sediments occurs on the north side of Keewaydin Lake. This map unit is interpreted as outwash deposited by a glacial meltwater stream issuing from the valley to the north. Alternatively, it may be a postglacial alluvial fan deposit.

Glacial Lake Pleasant deposits (unit Plp)

The Pleasant River and its two principal tributaries (East Branch and West Branch) are located in the northwestern part of the quadrangle. The river system drains to the north and empties into the Androscoggin River in the adjacent Bethel quadrangle. As the last glacial ice sheet withdrew northward from the East Branch valley, the ice margin blocked the drainage of this valley and impounded a glacial lake (Lake Pleasant). Evidence of the lake is provided by abundant sand deposits (unit Plp). These deposits formerly occupied the full width of the East Branch valley, but they have been partly eroded by the river.

The Plp sediments washed out of the ice sheet and directly into glacial Lake Pleasant. The first spillway for the lake was the bedrock-floored channel at the southeast end of the map unit (along the National Forest road south of Browns Ledge). This outlet has an elevation of about 830 ft (253 m). Plp deposits at similar or slightly higher elevations just north of the spillway probably formed as a delta graded to the lake surface.

A lower and younger spillway for Lake Pleasant is located along the pipeline route between Browns Hill and Cummings Hill, at about 770 ft (235 m). This outlet would have been available as soon as the glacier margin retreated far enough to uncover it. The northernmost Plp deposits formed when the glacial lake stood at the 770-ft level.

Most exposures of unit Plp are shallow excavations (road cuts, stream banks, and temporary excavations) that show well-stratified sand, pebbly sand, and/or silt. The finer-grained materials probably were deposited on the lake floor in a quiet-water environment, while the coarser (gravelly) sediments were deposited close to the ice margin as deltas and subaqueous fans. Contours on the topographic map suggest that unit Plp has a thickness of up to 100 ft (30 m) or more.

Glacial Lake Bethel deposits (unit Plbe)

The northern portion of the Pleasant River valley contains fine-grained glacial-lake sediments underlying flat to gently sloping surfaces at elevations to about 710 ft (216 m). These sediments (unit Plbe) were deposited in glacial Lake Bethel, which developed as the late Wisconsinan ice sheet receded from the Androscoggin Valley in the Bethel quadrangle, just north of the present study area. Deltaic sand and gravel that was deposited in glacial Lake Bethel underlies a surface at ~ 700-710 ft in the vicinity of West Bethel village. The stratigraphy of this delta was exposed in the eroded bank of the Androscoggin River at the western edge of the Bethel quadrangle, following the major spring flood of 1987. This riverbank section, together with nearby delta exposures resulting from pipeline construction in 1998, showed that the surface elevation of glacial Lake Bethel was approximately 690-700 ft (210-213 m). The spillway for the lake was located in the Androscoggin valley just south of Newry, in the northeast part of the Bethel quadrangle. Here the valley is very narrow, and the Androscoggin cuts through till deposits that formerly could have dammed the river and thus impounded Lake Bethel.

In the East Stoneham quadrangle, exposures of unit Plbe are usually limited to shallow road cuts and temporary excavations along the pipelines in the Pleasant River valley. Additional information was gathered by augering to depths up to 6 ft (2 m). The materials comprising unit Plbe typically include fine sand and/or silt, which in many places is overlain by a thin cover of gravel or gravelly sand. These coarser sediments are interpreted as a veneer of alluvium deposited by the East and West Branches of the Pleasant River after the glacial lake had drained.

Some of the silt and sand included in this map unit likewise may be alluvial. It is often difficult to determine the depositional environment of the fine-grained materials, i.e. whether they are glaciolacustrine sediments or postglacial alluvium. At a few localities in the Pleasant River valley, this distinction was made on the basis of sedimentary structures such as current ripples that indicate paleoflow directions. Glacial meltwater currents generally flowed to the south, while the postglacial Pleasant River transported sediments to the north.

Well data on the surficial materials map show depths to bedrock locally exceeding 100 ft (30 m) beneath the floor of the Pleasant River. Some of the overburden material at these sites is likely to be alluvium (in the uppermost part) and/or till (usually the lowest and oldest surficial unit), but much of the sediment thickness recorded in the wells probably consists of glacial lake sediments belonging to unit Plbe.

Eolian deposit (unit Qe)

A small deposit of eolian (windblown) sand (unit Qe) was mapped on the west side of the Crooked River valley, north of Songo Pond. Other patchy eolian deposits occur in the quadrangle, but generally are too small or irregular to distinguish on the map. These deposits resulted from wind erosion of glacial lake sediments in the adjacent valleys. They probably formed in late-glacial time, when vegetation cover was sparse. The prevailing winds blew from the west, as they do today (McKeon, 1989).

The texture of the windblown sand may range from very fine to very coarse. Coarse sand is common in the eolian deposits of western Maine, and even lenses of granules are occasionally found. Thus, the winds that carried the sand are inferred to have been strong at times.

Fan deposits (unit Qf)

Alluvial fans of late-glacial to postglacial age have been mapped in two places. There is a small example at the mouth of an unnamed brook on the east side of Keewaydin Lake, and a larger fan occurs along Wild Brook in the northeastern part of the quadrangle. A borrow pit in the Wild Brook fan exposes very coarse pebble-boulder gravel which may have been deposited by a glacial meltwater stream.

Stream terrace deposits (unit Qst)

Stream terraces are flat-topped benches along streams. They are remnants of flood plains which have been dissected by stream erosion, with the result that the terraces now stand higher than the adjacent modern flood plains and may no longer be subject to flooding. One example of a stream terrace was mapped in the East Stoneham quadrangle. It is located along the West Branch of the Pleasant River in Mason township. A road cut in this terrace exposed about 8 ft (2.4 m) of poorly sorted, somewhat angular, pebble to boulder gravel. The coarse sediment in the terrace most likely was derived from erosion of till deposits by the early postglacial West Branch.

Late-glacial or postglacial stream alluvium (unit Qa)

The unnamed stream valley southeast of Bad Mountain contains alluvial gravel (unit Qa) of uncertain age. Unit Qa underlies the National Forest road where it crosses the broad lower part of the valley. In this area, the upper surface of the gravel is sufficiently high above the stream that it appears unlikely to be affected by modern flooding. Much of the alluvium probably was deposited soon after deglaciation of the valley or in early Holocene time. Coarse gravel of more recent age occurs right along the modern stream, but is not differentiated at the scale of the map.

Wetland deposits (unit Hw)

Unit Hw consists of fine-grained and organic-rich sediments deposited in low, flat, poorly drained areas. In the East Stoneham quadrangle this unit occurs 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 found that they usually average less than 20 ft (6 m) thick.

Lake shoreline deposit (unit Hls)

A modern sand beach (unit Hls) is located at the south end of Virginia Lake in Stoneham. The sand in this deposit most likely was derived from erosion of adjacent till deposits along the east and west sides of the lake. A small wetland has developed behind (south of) the beach. Similar beaches probably occur along parts of other lake shores in the East Stoneham quadrangle.

Stream alluvium (unit Ha)

Unit Ha consists of alluvial sand, gravel, silt, and organic material deposited by modern streams on present or former flood plains. In the East Stoneham quadrangle these deposits occur along parts of the Crooked River, Pleasant River, Mill Brook, and other streams. They may be closely associated with wetlands, and some wetlands probably have formed on the surfaces of poorly drained alluvial deposits. For this reason, the mapped contacts between wetlands (Hw) and alluvium (Ha) are approximately located.

GLACIAL AND POSTGLACIAL GEOLOGIC HISTORY

The following reconstruction of the Quaternary history of the East Stoneham 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 been recognized at a few localities 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 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 radiocarbon years ago. As the glacier continued to flow across the state for thousands of 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. Their long axes are parallel to the south-southeastward flow of the ice. A moderate degree of streamlining is seen on the till-covered hills in the northeastern part of the East Stoneham quadrangle, particularly east of Songo Pond and north of Ingham Hill.

Late Wisconsinan glaciation produced a large portion of the stony till deposits that blanket the upland areas of the quadrangle. Glacial plucking on the lee sides of bedrock hills eroded steep southeast-facing slopes and cliffs. Many dramatic examples of these cliffs can be seen in the East Stoneham quadrangle, such as those on Albany Mountain, Rattlesnake Mountain, and Square Dock Mountain. Rocks torn from the hills were scattered in the direction of glacial transport.

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 East Stoneham quadrangle because in most places they are either concealed beneath surficial sediments or have been destroyed by weathering at the ground surface. The geologic map shows sites in the quadrangle where striation trends have been recorded. Some of the best examples of striations and glacially polished ledges are exposed on granite pegmatite veins.

Most striations observed in the quadrangle indicate glacial flow toward the south-southeast. This flow probably occurred during the maximum phase of late Wisconsinan glaciation, when the glacially streamlined hills were sculpted with the same orientation. Striations in a few places indicate a more southward ice flow (170-183^o). The latter flow trend is generally younger, based on evidence from multiple striation sets in the Fryeburg quadrangle (Thompson, 1999c) and elsewhere in southwestern Maine. The southward movement is believed to have resulted from reorganization of ice flow as the glacier thinned over the Mahoosuc Range to the north (Thompson and Koteff, 1995; Thompson, 2001).

In the East Stoneham quadrangle, numerous striation measurements were obtained on pegmatite ledges adjacent to the quarry southeast of Songo Pond, including an older 161^o set preserved on a sheltered surface adjacent to a younger set trending 177^o. A very strong set of glacial grooves trending 180^o was seen on the summit of a small unnamed hill east of Route 5, on the extreme southwest spur of Parsonage Hill.

The minimum age of glacial retreat from the East Stoneham 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, 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, 1999c).

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 East Stoneham quadrangle, making it more difficult to reconstruct the pattern of deglaciation. However, meltwater channels and sand and gravel deposits provide clues to the history of ice recession in the area. The locations and slopes of channels carved on hillsides by glacial streams generally support a northward recession of the ice margin. Additional evidence of northward retreat is provided by the topography and sedimentary structures of glaciofluvial deposits, and by the distribution of deposits formed in ice-dammed glacial lakes. South-draining stream basins typically contain series of glaciofluvial deposits such as the Crooked River outwash (Pgoc), in which the stream-graded tops of the deposits are lower from north to south, and structures such as current ripples and large-scale cross-bedding indicate southward meltwater flow. On the other hand, north-draining valleys such as the Pleasant River and Mill Brook basins were temporarily dammed by the receding ice margin and hosted glacial lakes that spilled through the lowest available gaps in the surrounding hills.

The history of glacial retreat from the East Stoneham quadrangle will be discussed in relation to two major series of sand and gravel deposits that washed out of the melting ice: (1) the deposits of the Crooked River and adjacent Mill Brook valleys (units Pge, Plw, Pgic, Pgoc, Pgi, and Plm); and (2) the series extending from the central to northwestern parts of the quadrangle (Pge, Pgi, Plp, and Plbe).

The earliest glacial meltwater deposits in the Crooked River valley are the esker ridges (Pge). These deposits were emplaced in subglacial ice tunnels, so their relation to the glacier margin is unknown. Two parallel ridges formed in some places, as adjacent tunnels became clogged with sand and gravel and the surrounding ice eventually melted. The twin ridges are best seen along the Albany Basin Road leading toward Kneeland Pond. The same esker system can be traced to the northwest, where it passes through the Crocker Pond Campground in the White Mountain National Forest. Some of the gaps in the system occur where the subglacial stream scoured down to bedrock and no esker gravel was deposited. The best example of this erosion is the deep gorge northwest of Kneeland Pond (described above).

As the ice margin started to recede northward from the southern edge of the quadrangle, sand and gravel washed from the edge of the glacier into glacial Lake Waterford. Unit Plw is the resulting lake deposit. The head of this map unit is just southwest of Little Papoose Pond, which is where the edge of the glacier presumably stood when the final part of the lake delta was deposited.

As melting of ice started to uncover the Crooked River valley, glacial meltwater streams deposited large volumes of ice-contact sand and gravel (unit Pgic). These deposits choke the valley in the vicinity of Little Papoose Pond and are common along the sides of the valley to the north. They formed both along the glacial streams and where meltwater was locally ponded against remnants of stagnant ice. Unit Pgic has been traced north to the Town House area in Albany, where it may have been built from an ice margin position east of Ingham Hill. Slightly younger ice-contact sand and gravel deposits (Pgi) formed close to the glacier margin in the lower Patte Brook valley and in the headwaters of Mill Brook (both in Albany).

As ice remnants continued to disappear from the Crooked River valley, glacial streams deposited outwash sand and gravel (unit Pgoc) at lower elevations than the earlier ice-contact deposits. These younger glacial deposits filled the central portion of the valley across much of the quadrangle, forming a flat surface seen along Route 5. Some of the outwash gravel is extremely coarse, suggesting that the ice remained nearby when it was deposited. Unit Pgoc wraps around the western side of Songo Pond, but did not fill the pond basin. Perhaps a remnant ice mass lingered in the basin, leaving a long kettle hole now occupied by Songo Pond.

When the ice sheet receded from the northeastern part of the quadrangle, meltwater was trapped in the north-sloping Mill Brook valley, forming glacial Lake Mill Brook. The lake is believed to have first drained southward through the 710-ft gap east of Ingham Hill. This initial water level was maintained until ice recession opened the slightly lower (690 ft) spillway near the north end of Songo Pond. Sand and gravel washed into Lake Mill Brook from an ice-margin position east of Grover Hill in the northeast corner of the quadrangle.

Glacial retreat from the western part of the quadrangle resulted in a sequence of events similar to those described above. The earliest meltwater drainage was subglacial, producing a series of esker ridges (unit Pge) in the valley that extends from Waterfowl Marsh south to Round Pond. Ice-contact sand and gravel deposits (Pgi) formed during deglaciation of this valley, as meltwater streams flowed over and between remnant ice masses. Bedrock knobs and glacial deposits in the Crocker Pond area probably blocked the southward drainage, causing ponding of meltwater to an elevation of about 830 ft (253 m). The ice-contact deposits east and west of Waterfowl Marsh may be deltaic glaciolacustrine sediments that formed in these ponded waters.

Further deglaciation in the northwestern part of the quadrangle uncovered the East Branch of the Pleasant River valley. This valley slopes northward, so meltwater was trapped between the receding ice margin and the bedrock-floored 830-ft (253 m) spillway south of Browns Ledge, forming glacial Lake Pleasant. A large quantity of sand (unit Plp) accumulated in this water body. The lake level probably dropped to about 770 ft (235 m) when continued ice retreat opened the gap south of Cummings Hill. Lake Pleasant persisted until the Bethel area was deglaciated (north of the quadrangle), and glacial Lake Bethel formed in the Androscoggin Valley. Silty to sandy Lake Bethel deposits (unit Plbe) underlie low flat areas to about 710 ft (216 m) in the Pleasant River valley.

During and after deglaciation of the East Stoneham quadrangle, nonglacial streams began to establish their modern drainage patterns. Water emptied from the glacial lakes upon removal of their ice or sediment dams, and the fine-grained lake deposits in the East Branch valley were deeply eroded. As soon as the ice retreated from the sides of hills and mountains, the freshly deposited glacial sediments were very susceptible to erosion until a vegetation cover was established. For example, alluvial gravel washed down the East and West Branches of the Pleasant River and in many places forms a thin deposit on top of the fine-grained glacial lake sands. Some of the older alluvium now occurs as a stream terrace (unit Qst) that stands higher than the present-day flood plain along the West Branch of the Pleasant River.

Deposits of recent flood-plain alluvium (unit Ha) continue to accumulate along modern streams, and organic-rich sediments (unit Hw) are being deposited in wetland swamps, marshes, and heaths.

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Sand and gravel deposits are a very abundant and economically important resource in the East Stoneham quadrangle. Gravel is likely to be found in many places along the esker system (unit Pge) that extends through the central part of the quadrangle, and in the ice-contact and outwash deposits of the Crooked River valley (units Pgic and Pgoc). Numerous pits have been opened in these deposits, and many of them were still active at the time of this study.

Other sand and gravel resources occur in the ice-contact deposits (unit Pgi) at various locations in the quadrangle, and in the abundant glacial lake deposits. However, many of the lake sediments are dominantly sand, and gravel may occur only as a relatively thin surface layer.

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APPENDIX A
GLOSSARY OF TERMS USED ON MAINE GEOLOGICAL SURVEY SURFICIAL GEOLOGIC MAPS

compiled by
John Gosse and Woodrow Thompson

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.