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Robert G. Marvinney, State Geologist

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Author: *Woodrow B. Thompson*

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Surficial Geology of the Lake Auburn West 7.5-minute Quadrangle, Androscoggin and Oxford Counties, Maine

Woodrow B. Thompson
Maine Geological Survey
State House Station 22
Augusta, ME 04333-0022

INTRODUCTION

This report describes the surficial geology and Quaternary history of the Lake Auburn West 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 2000 for the STATEMAP cooperative between the Maine Geological Survey and the U. S. Geological Survey (USGS). Two maps are associated with this report. The *geologic map* (Thompson, 2001) 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, 2001) 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, 1967, 1968).

Geographic setting

The Lake Auburn West 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°15'00" to 70°22'30" W. It encompasses parts of the towns of Auburn, Minot, and Turner in Androscoggin County, and Hebron and Buckfield in Oxford County. The cities of Auburn and Lewiston are major population centers located just east of the quadrangle.

The principal streams are Bog Brook in the western part of the Lake Auburn West quadrangle, Lapham Brook in the southeast part, Meadow Brook in the northeast, and a very short segment of the Nezinscot River along the northern border. The western portion of Lake Auburn is by far the largest water body in the quadrangle, and there are several small ponds. The topography is hilly across much of the quadrangle. Elevations range from about 245 ft (75 m) above sea level (where Lapham Brook crosses the southern border) to 925 ft (282 m) on the summit of Mt. Prospect in Minot. The southern part of Lake Auburn has a deep basin where water depths reach a maximum of 120 ft (37 m) (Northrop, 1995).

Bedrock geology

Bedrock outcrops are common in the hilly terrain, especially in the central to southern parts of the Lake Auburn West quadrangle. Much of the quadrangle is underlain by Silurian metasediments comprised of various members of the Sangerville Formation. The Patch Mountain Member of the Sangerville Formation shows thin interbeds of calc-silicate assemblages and biotite granofels (Creasy, 1979). Outcrops and detached fragments of this rock unit weather unevenly, producing a distinctive ribbed surface ("ribbon rock").

Several small intrusions of Devonian granite also occur in the map area (Creasy, 1979; Osberg and others, 1985). Inclusions of metamorphic rock are locally abundant in these granites.

Granite pegmatite crops out in many places, and several feldspar quarries were formerly worked in pegmatites in the eastern part of Minot.

PREVIOUS WORK

Stone (1899) made some observations on the glacial geology of the Auburn-Minot area. He found marine clay on the east side of Lake Auburn, and proposed that glacial ice occupied the lake basin long enough to prevent clay deposition on the west side. (The present study shows that marine clay actually occurs along much of the western side of the lake basin, too.) Leavitt and Perkins (1935) briefly described the glacial geology of the Bog Brook valley.

Prescott (1967, 1968) compiled well and test hole data, and carried out preliminary surficial and gravel aquifer mapping in the study area. Reconnaissance-level mapping of surficial deposits in the Poland 15-minute quadrangle (including the present Lake Auburn West quad) was conducted by Hanley (1959) and Smith and Thompson (1980). Bromely and Robinson (1994) prepared a bathymetric map of Lake Auburn; and Northrop (1995) carried out a detailed study of the Quaternary geology and history of this lake, including sediment coring and sub-bottom acoustic profiling.

Neil and Locke (1998) compiled a detailed aquifer map of the Lake Auburn West quadrangle as part of the Maine Geological Survey's Significant Sand and Gravel Aquifer Project. The U. S. Department of Agriculture's soil surveys of Androscoggin County (McEwen, 1970) and Oxford County (Wilkinson, 1995) supplied useful materials information for 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 "gi" for glacial ice-contact deposits. Surficial map units in the Lake Auburn West 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 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.

Surface exposures in the Lake Auburn West quadrangle have revealed up to 20 ft (6 m) of till, and well logs indicate the thickness locally is as much as 144 ft (44 m) (Locke and Thompson, 2001). 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 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 Lake Auburn West 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. Within the areas mapped as till, there may also be some minor deposits of glacial sand and gravel that are too small or poorly defined to show on the surficial geology map.

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, though granite boulders may preserve nicely polished and striated surfaces.

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 and has not been recognized in the quadrangle. It would be expected to show 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.

Glacial erosion and comminution of coarse-grained bedrock from the Sangerville Formation (especially the Anasagunticook and Patch Mountain members) favored the development of

sandy till with many stones. Figure 1 on the geologic map shows an example on York Road in Minot. Some of the sandy tills in the Lake Auburn West quadrangle have been oxidized to a rusty color.

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. In many cases it is not weathered (except in the near-surface zone of modern soil formation) and light olive-gray in color.

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-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 have been deposited during the Illinoian glaciation, prior to 130,000 years ago (Weddle and others, 1989).

The author has not seen any definite exposures of lower till in the Lake Auburn West quadrangle, perhaps because borrow pits are rare in the hard-to-excavate lodgement tills. A possible equivalent of the lower till is the dense, dark olive-gray till seen in cut banks along Millett Road, near the west edge of the quadrangle and in the adjacent Oxford quad. The considerable till thickness in some of the streamlined hills in the quadrangle suggests that the lower till may be present at depth.

End moraines. End moraines 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. Several low east-west ridges that may be end moraines occur in the south-central part of the Lake Auburn West quadrangle.

Esker deposits (unit Pge)

Two major esker systems (Pge) are present in the Lake Auburn West quadrangle. One is located in the Bog Brook valley; the other passes through the Turner area in the northeast part of the quadrangle. These segmented ridges of sand and gravel were deposited by meltwater streams flowing south in tunnels at the bottom of the last glacial ice sheet. The Turner system is the more significant in terms of size and regional extent. It can be traced at least from Sumner to south of Lewiston in the Androscoggin River valley.

Much of the sediment carried along the ice tunnels was deposited into the ocean, with the coarse material forming deltas and subaqueous fans at the glacier margin, while the fine muddy sediments dispersed across the sea floor and became part of the Presumpscot Formation. Prominent series of glaciomarine deltas occur along both esker systems in the Lake Auburn West quadrangle. It is uncertain whether meltwater flowed simultaneously through the entire tunnel networks of the esker systems, but the esker segments probably formed progressively from south to north as the tunnels became clogged with sediment during deglaciation. The esker system in Turner is bordered by depressions (kettles) left when masses of glacial ice melted. Black Pond, Mud Pond, and Sandy Bottom Pond occupy some of these kettles.

In the Lake Auburn West quadrangle, exposed sections in the eskers are up to 40 ft (12 m) high. Pits in the eskers show material mostly ranging from sand to pebble-cobble gravel, with boulder-size gravel in places. The eskers are important both as potential aquifers and sources of sand and gravel. The materials map (Locke and Thompson, 2001) shows numerous borrow pits along them. Parts of the eskers have been mined out, resulting in leveling of the original ridge topography.

Ice-contact deposits (unit Pgi)

Several areas of glacial sand and gravel (Pgi) with irregular knobby topography have been mapped in the Lake Auburn West quadrangle. They are located adjacent to eskers and glaciomarine deltas in the northeastern part of the quadrangle. The internal structure of these sediments is generally not exposed, so their origin is unclear. The Pgi deposits are within the zone of late-glacial marine submergence, so probably they are deltas or submarine fans.

Glaciomarine ice-contact deltas (unit Pmdi)

The ocean submerged the lowlands of southern Maine during retreat of the last glacial ice sheet. Glacial meltwater washed sediments into the sea, forming flat-topped deposits of sand and gravel called deltas. The upper limit of marine submergence has been determined by measuring the elevations of contacts between topset and foreset beds in the deltas (Thompson and others, 1989). One such measurement was obtained at a gravel pit in the Auburn Plains delta, located just north of Lake Auburn in the Lake Auburn East quadrangle. The survey of this delta indicated a late-glacial sea level of 351 ft (107 m).

The Bog Brook valley in the western part of the quadrangle, and the valley containing Labrador Brook and Meadow Brook in Turner, both contain marine deltas (Pmdi) consisting of sand and gravel deposited in contact with glacial ice. These deltas formed at the mouths of ice tunnels, in association with the local esker systems. They were deposited at the margin of the retreating ice sheet and are younger from south to north. Some of the deltas have steep-sided topography resulting from deposition next to the ice margin, and gravel pits may show slump structures formed adjacent to melting ice remnants.

Exposures up to 30 ft (9 m) thick were seen in several pits in the Turner deltas. Only the foreset beds were exposed at these localities. The foresets mostly consist of large-scale inclined beds of sand and gravelly sand. One pit showed eolian sand overlying the foresets (Figure 5 on geologic map).

Ice-contact deltas in the Bog Brook valley range from very small deposits to the large delta in Buckfield at the north edge of the quadrangle. The Buckfield delta is relatively fine-grained, with exposures showing sand or pebbly sand. Coarser gravel was noted in some of the other glaciomarine deltas to the south. A pit on the east side of Route 124, just north of the village of West Minot, showed an excellent exposure of the contact between the deltaic topset and foreset beds. The elevation of this contact is about 355 ft (108 m), which approximates late-glacial sea level in the west-central part of the quadrangle. (Present-day elevations of the marine limit are higher toward the northwest because of the crustal uplift and tilt that occurred following deglaciation.)

Glaciomarine fan deposits (unit Pmf)

Small deposits of sand and gravel occur just west of The Basin (pond), and adjacent to the northwest shore of Lake Auburn. These two deposits are within the zone of late-glacial marine submergence. Their highest parts reach the upper marine limit, but most of the sediment was deposited at lower elevations. Inactive pits near The Basin show what appears to be foreset beds deposited in a subaqueous environment. These deposits are inferred to be submarine fans (Pmf). They formed where glacial meltwater streams dumped sand and gravel into the ocean, but sediment accumulation did not continue long enough to build deltas with flat tops graded to sea level.

Glaciomarine sediments, undifferentiated (unit Pm)

The Labrador Brook - Meadow Brook valley contains water-laid sediments (Pm) at elevations up to about 330-340 ft (101-104 m). They are below the marine limit and adjacent or close to the eskers and glaciomarine deltas in Turner. The original surface topography of this unit was generally horizontal to gently sloping, but in places it has been dissected by modern streams. Textures may range from clay to gravel. Unit Pm is thought to have been deposited on the late-glacial sea floor, but it is poorly exposed and may include sediments formed in other environments.

Presumpscot Formation (unit Pp)

Fine-grained clay-silt deposits accumulated on the ocean floor during the late-glacial marine submergence of the Bog Brook and Little Androscoggin valleys. These sediments are part of the Presumpscot Formation (Pp), which is very widespread across Maine's coastal lowland (Bloom, 1960). They are massive to well stratified and range in color from gray to bluish-gray or brownish-gray, depending on oxidation state. The Presumpscot Formation mostly consists of silt and clay in varying proportions and is often called "clay." Sand is locally interbedded with the fine-grained sediments, especially where they were deposited in higher-energy environments near the glacier margin or in shallow waters. Recent erosion of unvegetated surfaces in the Presumpscot Formation produces a distinctive pattern of many closely spaced rills (Figure 4 on geologic map).

Exposures of Presumpscot clay-silt were seen in many places around Lake Auburn. They occur in wave-cut banks along the lake shore and on roadsides next to the lake (Figure 3 on geologic map). The widespread distribution of these sediments suggests that the entire lake basin was flooded by the sea when glacial ice retreated from the area. Coring and sub-bottom profiling studies by Northrop (1995) confirmed this hypothesis. She found that glaciomarine sediments continue across the floor of Lake Auburn, where they underlie the postglacial lake deposits. These findings show that a large remnant ice mass did not exist in the lake basin during the period of marine submergence.

Fossil shells and other organic material occur locally in the Presumpscot Formation. No actual remains were found in the Lake Auburn West quadrangle, but there is an interesting fossil locality in a small borrow pit on the hillside just south of Lost Valley ski area. The pit exposed glaciomarine clay containing abundant imprints of mussel shells (*Mytilus edulis*), many of which were still articulated. This clay unit also included an unusual abundance of pebbles, which may have been mixed into the sediment by a submarine landslide. The clay is overlain by planar-bedded, eastward-dipping sand and gravel that forms a terrace along the hillside. The latter unit is interpreted as a beach terrace constructed during the regression of the sea.

Marine regressive deposits (unit Pmrs)

Sand deposits (Pmrs) occur at elevations of ~ 350-365 ft (107-111 m) on the west side of the Bog Brook valley in the Hebron Station area. These deposits are slightly lower than the local marine limit, and exposures in the pit complex north of Hebron Station show fluvial sedimentary structures indicating southward current flow. Based on this information, unit Pmrs is believed to have been deposited in shallow marine waters by the ancestral Bicknell Brook and Bog Brook as sea level regressed in late-glacial time.

Glaciolacustrine delta (unit Pld)

A pit on the north side of the Bicknell Brook valley exposes up to about 30 ft (9 m) of deltaic sand and gravel. This pit shows gravel topset beds formed by glacial streams flowing across the delta top, and sandy inclined foreset beds deposited on the prograding delta front (Figure 2 on geologic map). The contact between the topset and foreset units indicates a former water level at about 450 ft (137 m). This elevation is higher than the marine limit, so the water body is presumed to have been a glacial lake that was dammed by remant ice in the lower Bicknell Brook valley. The dip direction of the foreset beds ranges from east-southwest through south to west, so the delta was built in a generally southward direction. Meltwater channels on the hillside just north of the delta provide further evidence of southward glacial stream flow.

Eolian deposits (unit Qe)

A small area of eolian (windblown) sand was mapped on the west side of the Labrador Brook valley, just north of Fern Street in Turner. This deposit (Qe) resulted from wind erosion of glacial sediments. Eolian sand probably is more extensive than shown on the map. Thin patchy deposits are easily overlooked in wooded areas. For example, scattered sand dunes overlie till on a small unnamed hill just east of the area of Presumpscot Formation at the north edge of the quadrangle. In other cases, the eolian sand forms a thin discontinuous cover on waterlaid sand and gravel (Figure 5 on geologic map).

Wetland deposits (unit Hw)

Unit Hw consists of fine-grained and organic-rich sediments deposited in poorly drained areas. In the Lake Auburn West quadrangle this unit occurs both in valleys and upland basins. There is a very large wetland in the upper Bog Brook valley in Hebron (Figure 6 on geologic map). Many other wetlands - some of them quite large - are present along Labrador Brook, Meadow Brook, and other streams, as well as on lake shores and in low areas between till-mantled hills.

The boundaries of unit Hw were mapped primarily from aerial photographs. These boundaries are approximately located and should not be used as the basis 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.

Modern beach deposits (unit Hls)

Beach deposits (Hls) occur in several places around Lake Auburn. These shoreline deposits are mostly sand and gravel, but may also include some finer silty sediments. They were derived from recent wave erosion of glacial sediments and transported along the lake shore.

Stream alluvium (unit Ha)

Unit Ha consists of alluvial sand, gravel, silt, and organic material deposited by modern streams. In the Lake Auburn West quadrangle, these deposits occur principally along Bog Brook, Bicknell Brook, and the Nezinscot River. Narrow strips of unmapped alluvium probably occur along many other streams in the quadrangle.

GLACIAL AND POSTGLACIAL GEOLOGIC HISTORY

The following reconstruction of the Quaternary history of the Lake Auburn West 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 at a few sites in Maine (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 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. These streamlined till-covered hills are labeled on the geologic map. Glacial plucking on the sides of some hills created steep bedrock slopes. An example is Goff Ledge in Minot (Figure 8 on geologic map).

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 Lake Auburn West 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. Many of these are very narrow scratches on granite pegmatite ledges. They were revealed by rubbing a pencil across the polished rock surfaces. The striations indicate glacial flow toward the south-southeast, between 150° and 170°. This flow presumably occurred during the maximum phase of late Wisconsinan glaciation, when the glacially streamlined hills were sculpted with similar orientations.

The minimum age of glacial retreat from the Lake Auburn West 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 west of the quadrangle, so the study area probably was deglaciated by this time. However, isolated masses of stagnant ice may have lingered in valleys.

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 Lake Auburn West quadrangle, making it more difficult to reconstruct the pattern of deglaciation. The following lines of evidence show that the ice margin receded in a generally northward direction: (1) ice-contact heads on the north sides of glaciomarine deltas, some of which have esker feeders; (2) sedimentary structures in eskers and other glacial sand and gravel deposits, indicating generally southward meltwater flow, and (3) the slope of glacial meltwater channels in the uplands.

Much of the rock debris in the melting ice sheet was released directly from the glacier as deposits of till (unit Pt). A meltwater stream system within the glacier deposited sand and gravel in subglacial ice tunnels, forming the two esker systems (unit Pge) in the Bog Brook and Meadow Brook - Labrador Brook valleys. Meltwater issuing from the glacier margin deposited sediments in front of the ice during deglaciation. As the western part of the quadrangle was uncovered, a series of ice-contact deltas were built into the sea in what is now the Bog Brook valley. Another series of deltas was deposited west of Route 4 in Turner.

Several small submarine fans (unit Pmf) and ice-contact deltas (Pmdi) were deposited during deglaciation of the valleys north and west of Lake Auburn. They formed as glacial meltwater drained southeast into an arm of the sea that extended into the lake basin and its tributaries. Fine-grained marine mud (Presumpscot Formation - Pp) settled on the ocean floor in these areas, and also in parts of the Bog Brook valley and a very small valley at the north edge of the quadrangle. Northrop (1995) found that the glaciomarine mud also extends beneath the floor of Lake Auburn.

Glacial lakes were generally absent in the Lake Auburn West quadrangle, except in the lower Bicknell Brook valley. Meltwater was impounded in this area, probably by remnant ice west of Hebron Station. Sediment washed into the lake from the north and built a delta on the north side of the Bicknell valley. The delta indicates that the lake surface was at an elevation of about 450 ft (137 m). After the glacial lake drained, and the sea started to withdraw from the Bog Brook valley, sandy sediments (Pmrs) were deposited in the Hebron Station area by streams graded to a sea level slightly lower than the local marine limit.

Eolian sand dunes (unit Qe) were deposited in the Labrador Brook valley in late-glacial to postglacial time. There are other small areas of windblown sand in the quadrangle, but tree cover and lack of exposure make them difficult to distinguish from the water-laid glacial sand deposits. Wetlands (unit Hw) and flood plains (unit Ha) began to develop soon after deglaciation, and continue to accumulate sediments to the present day. Wave action on the shore of Lake Auburn has formed beach deposits at the south end of the lake.

ECONOMIC GEOLOGY

Sand and gravel supplies in the Lake Auburn West quadrangle occur mainly in the Bog Brook and Labrador Brook - Meadow Brook valleys. Numerous pits have been opened in these areas. The marine deltas (Pmdo) are predominantly sand, while gravel is most likely to be found in the eskers (Pge). Other sand and gravel deposits are contained in the glaciolacustrine delta in Bicknell Brook valley (Pld), and scattered ice-contact deposits (Pgi) shown on the geologic map. The glacial sand and gravel deposits have added importance as aquifers.

Small borrow pits have been opened in glacial till deposits. The sandy till in this area packs well and is often well-suited for fill. Many logging roads in the uplands incorporate till for this purpose. Sandy till 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
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.