**DEPARTMENT OF CONSERVATION**
**Maine Geological Survey**
Robert G. Marvinney, State Geologist

# OPEN-FILE NO. 99-121

**Title:** *Surficial Geology of the Limington 7.5-minute Quadrangle, York and Cumberland Counties, Maine*

**Author:** *Andres Meglioli and Woodrow B. Thompson*

**Date:** *1999*

**Financial Support:** Funding for the preparation of this report was provided in part by the U.S. Geological Survey Cooperative Geological Mapping (COGEO-MAP) Program, Cooperative Agreement No. 14-08-0001-A0793.

**Associated Maps:** Surficial geology of the Limington quadrangle, Open-File 99-90
Surficial materials of the Limington quadrangle, Open-File 98-175

**Contents:** 12 p. report

Maine Geological Survey
Open-File 99-121

# *Surficial Geology of the Limington 7.5-minute Quadrangle, York and Cumberland Counties, Maine*

***Andres Meglioli***
*Geraghty & Miller, Inc.*
*8222 South 48th St., Suite 140*
*Phoenix, Arizona 85044*

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

## INTRODUCTION

Mapping of the surficial geology of the Limington quadrangle was carried out during the summer of 1990, as part of the COGEOMAP Program of the Maine Geological Survey and the U.S. Geological Survey. Two 1:24,000-scale maps were prepared: *a surficial materials map* (Meglioli and Thompson, 1998) which shows the thickness, texture, and composition of surficial sediments at points where observations were made, and a *surficial geologic map* (Meglioli and Thompson, 1999) which shows the distribution of geologic units and features that can help to reconstruct the glacial and postglacial history of the quadrangle. The surficial deposits mapped in the Limington quadrangle are described in this report.

## PREVIOUS WORK

In the late 1970's, G. W. Smith and W. B. Thompson mapped surficial deposits in the Limington quadrangle at a scale of 1:62,500 based on reconnaissance field work and aerial photograph interpretation. Their information was used to prepare a reconnaissance surficial geologic map of the Buxton 15-minute quadrangle (Smith and Thompson, 1977) and was incorporated in the Surficial Geologic Map of Maine (Thompson and Borns, 1985a). The elevations of deltas and other indicators of the late-glacial marine submergence were measured and reported by Thompson and others (1989).

## INVESTIGATION PROCEDURES

Several types of field exposures provided data on surficial sediments in the study area. Observations were made in numerous active and inactive gravel pits, building excavations, and road cuts throughout the quadrangle. In addition to stratigraphic information from these sites, the authors recorded locations of bedrock outcrops and the morphology and other characteristics of the surficial deposits. Subsurface information was obtained through the use of a shovel and hand auger, and from analysis of boring logs provided by the Maine Department of Transportation. Additional subsurface data came from sand and gravel aquifer mapping by Tolman and Lanctot (1985).

The analysis of aerial photographs at a scale 1:20,000 was useful in refining boundaries of wetland areas and locating terrace scarps. Glacially streamlined hills and ice-contact features, including kettles and esker ridges, were mapped in part from air photos and topographic map contours. Geologic contacts mapped in the field were plotted on a 1:24,000 topographic map of the Limington quadrangle with a contour interval of 10 feet. All colors mentioned in the description of soils and sediments were described according to the Munsell Soil Color Chart (1990 Edition).

## LOCATION AND PHYSIOGRAPHY

The study area is the Limington 7.5-minute quadrangle, located in York and Cumberland Counties in southwestern Maine (Figure 1). The Saco River separates these counties in the map area. The Limington quadrangle extends in latitude from 43°37'30"N to 43°45'N, and in longitude from 70°37'30"W to 70°45'W, and covers an area of 54 square miles (approximately 142 square kilometers).

The general physiography of the area is an undulating terrain with many hills largely concentrated in the northwest corner of the quadrangle, where the highest elevation is 1,058 ft (322 m) above sea level (asl) just west of Libby Mountain. The lowest elevation is approximately 180 ft (55 m) asl, which is the level of the Saco River in the northeast part of the quadrangle. Maximum local relief is approximately 600 ft (183 m), in the western part of the quadrangle. The topographic gradient decreases markedly from northwest to southeast. Bedrock outcrops are scattered throughout the area, particularly in the northwestern part of the quadrangle. Between the bedrock ridges are Quaternary deposits of variable thickness.

There are a few glacially sculpted northwest-southeast trending bedrock ridges in the quadrangle. In places these ridges are covered with only a thin veneer of till and reworked sediments (e.g. colluvium). An example is Isinglass Hill, in the south-central portion of the quadrangle.

Much of the southern portion of the Limington quadrangle shows a landscape characterized by ice-disintegration features resulting from deglaciation, such as kettle holes, ice-contact deltas, and esker ridges. Numerous ponds and swamps are present in the quadrangle, such as Killick, Deer, and Doles Ponds. The southwestern corner of the quadrangle is occupied by Lake Arrowhead. The whole study area has a complicated and poorly integrated drainage network. The major streams in the quadrangle are the Saco and Little Ossipee Rivers. The valleys of these rivers contain several terraces, abandoned stream channels, and steep scarps marking former courses of the rivers. As a consequence of lateral westward erosion of the Saco River, south of East Limington, a distance of only about 800 ft (244 m) separates the south-flowing Saco River from the north-flowing Little Ossipee River. The sluggish drainage of the Little Ossipee River is partially the consequence of several artificial dams built along the river upstream from the study area.

## BEDROCK GEOLOGY

The bedrock units in the Limington and neighboring quadrangles were mapped by Hussey (1985). Bedrock exposed in the study area consists almost exclusively of igneous felsic plutons and subordinate metamorphic rocks. Metamorphic lithologies include rocks of the Vassalboro and Windham Formations ranging in age from Ordovician to Devonian, and gneiss and marble of the lower member of the Rindgemere Formation, the basal formation of the Shapleigh Group. Igneous lithologies are represented by an unnamed pluton composed primarily of two-mica granites of Early Devonian age. The bedrock units and their ages are (Hussey, 1985):

**Shapleigh Group:** Represented by the lower member of the Rindgemere Formation. It is described as a thin, discontinuous, slightly migmatized, rusty-weathering muscovite-biotite-garnet-quartz schist. It has marble bands and its thickness is variable, ranging from approximately 4900 to 7900 ft (1500-2400 m).

**Vassalboro Formation:** Thin to medium-bedded, fine to medium-grained, quartz-plagioclase-biotite-hornblende granofels and slightly schistose granofels. The Vassalboro Formation is thought to be Ordovician to Lower Silurian in age.

**Windham Formation:** The Windham Formation consists of thin-bedded to massive, weathered muscovite-biotite-garnet-quartz schist with kyanite and staurolite. The approximate thickness of the Windham Formation is 2000 ft (600 m). It is placed stratigraphically above the Vassalboro Formation, and its age is estimated to be Early Silurian on the basis of fossil content (Hussey, 1985).

**Unnamed Pluton:** A small pluton in the central part of the study area is composed of fine to medium-grained, light gray, weakly to moderately foliated biotite and two-mica granite. Its estimated age is early Devonian.

Rocks of the Vassalboro Formation and Shapleigh Group have undergone several phases of deformation that resulted in folding and thrusting. Major bedrock structures in the area are chiefly oriented north-south. Several plunging folds are clearly related to the emplacement of plutonic bodies.

## SURFICIAL DEPOSITS

The Limington quadrangle is almost completely covered by a blanket of glacial, glaciofluvial, glaciomarine, and glaciolacustrine sediments, which were deposited during the most recent glacial advance and subsequent recession across the area in late Wisconsinan time (approximately 25,000 to 13,000 years ago in southwestern Maine). The composition and distribution of the mapped surficial units are briefly described in the following paragraphs.

### *Thin drift*

Many upland areas in the quadrangle, particularly in the western and central parts, have only a thin cover of glacial till overlying the bedrock. These areas are shown on the map with a horizontal ruled line pattern. Here the till cover is generally less than 10 ft (3 m) in thickness, and bedrock outcrops are locally common. Often the underlying structure of the bedrock is distinguishable on air photos. The till exposed in these thin-drift areas is generally a non-sorted, non-stratified, loose, weathered dark-yellow to dark-brown diamicton. In some areas with very thin drift cover, the till matrix is almost absent and the deposits are characterized by large angular boulders.

### *Till (Pt)*

End moraines were mapped chiefly on the basis of air photo interpretation and topographic map analysis. A cluster of moraine ridges is located in the southeast corner of the quadrangle. These end moraines were deposited at successive positions of the glacier margin during its overall recession. Most moraines in this part of Maine are small, with heights rarely exceeding 10

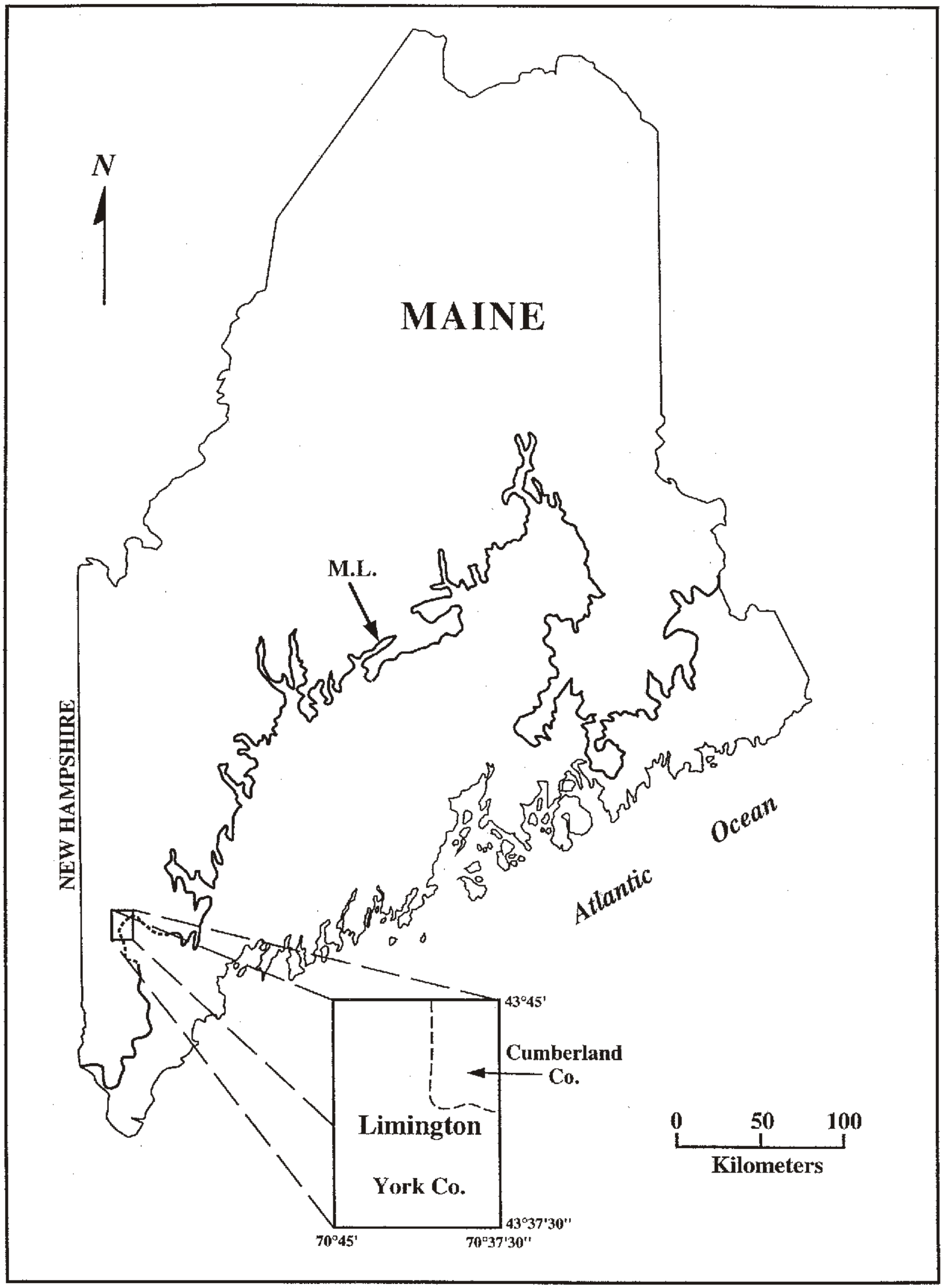


Figure 1. Location map of the Limington quadrangle, York and Cumberland Counties, Maine.
Line marked M.L. indicates the limit of marine transgression.

ft (3 m), widths on the order of 100 ft (30 m), and lengths of up to a few hundred yards. The ridges are generally oriented parallel to the former ice margin and perpendicular to the local ice flow direction. The end moraines typically are composed of till with variable amounts of ice-contact sand and gravel, which is generally located on the flanks of the moraine ridges.

### *Esker Deposits (Pge)*

Eskers are ridges of variable length, comprised of moderately to well-stratified gravel and sand. The gravel consists of waterworn cobbles, pebbles, and subordinate boulders. Eskers were deposited where meltwater flowed in tunnels beneath glacial ice. Well-defined esker ridges and associated ice-disintegration deposits were identified in the Limington quadrangle. There are two esker trends in the study area: a generally southeastward direction for some of the eskers in the vicinity of Lake Arrowhead, and a southward trend for eskers in the central to south-central part of the quadrangle.

The most prominent esker system diagonally crosses the southwestern corner of the quadrangle from northwest to southeast. Its continuation to the south can be found in the Little Ossipee Pond area of the Waterboro quadrangle (Meglioli, 1999a,b). To the west the esker extends into the Limerick quadrangle. It can be easily recognized on maps and air photos in the Lake Arrowhead area, where the ridges form long narrow islands and peninsulas in the lake. The part of this esker system in the Limington quadrangle can be traced for approximately three miles (5 km). The maximum measured ridge height is 100 ft (30 m) above the surrounding terrain at Lake Arrowhead. Shorter esker ridges have also been recognized running parallel to the main esker. This esker system will be referred to here as the Arrowhead esker system. The geomorphology of the Lake Arrowhead area is the direct consequence of the fragmentary ridges of the esker system and associated ice-contact landforms. Here the esker system consists of rather narrow, steep-sided, short and semi-rectilinear ridges. The low-lying areas now occupied by the lake and wetlands were formerly filled with melting blocks of glacial ice.

A second esker system was recognized in the central portion of the quadrangle. It starts to the north of Boyd Pond and is more discontinuous than the Lake Arrowhead esker. This series of eskers is referred to here as the Limington esker system. It can be traced in the study area for approximately four miles (6.5 km). Its continuation to the south can be found in the Waterboro quadrangle, where it joins the Lake Arrowhead esker system.

In the Isinglass Hill-North Hollis area in the central part of the quadrangle, short esker segments are associated with glaciomarine deltas. Some very good exposures found in gravel pits near the Boyd Pond area, and in the vicinity of Lake Arrowhead and Chadbournes Mills, revealed that the local esker ridges are composed of subrounded and well-bedded cobble to boulder gravel. Some of the boulders are larger than 6 ft (2 m) in diameter. The matrix is composed of fine gravel to very coarse sand. Pockets of very fine to medium, well-sorted sand are common. High-angle normal faults were often observed on the sides of the eskers (Figure 2). Deposits of unsorted gravel showing collapse with ice-disintegration features are commonly associated with esker ridges and were mapped as unit Pgi (see below). Typically, eskers occupy lowlands and valleys; the ridges are usually interrupted across knobs and highlands.

### *Undifferentiated Ice-Contact Deposits (Pgi)*

Ice-contact stratified sediments are predominantly sandy gravel and gravelly sand that was deposited against melting glacial ice. Although some of these deposits formed in contact with the margin, other ice-contact deposits formed around ice blocks separated from the main glacier. The melting of the ice blocks produced topographic depressions (kettles) now occupied in many cases by ponds and bogs. In some kettles, sand is the predominant sediment. A good example of this is Sand Pond. Ice-contact deposits were found (but not separately mapped) in narrow zones around the margins of Killick, Lily, Wales, and Deer Ponds. All these ponds are located in the glaciomarine delta complex in the southeastern part of the quadrangle. Ice-contact deposits are also associated with esker ridges in the Lake Arrowhead area, and with the Limington esker ridges.

### *Outwash deposits (Pgo)*

As glacial ice receded from the northwestern part of the quadrangle, meltwater streams deposited outwash sediments in a small unnamed valley that drains southwest into the Limerick quadrangle. These deposits consist of sand and gravel, and probably are not very thick.

### *Glaciolacustrine Deltas (Plad)*

Glaciolacustrine deltas were mapped in the southern part of the Limington quadrangle, where they were deposited in a temporary water body that is here called glacial Lake Arrowhead. Glacial Lake Arrowhead formed just north of a large ice block that remained in Little Ossipee Pond in the Waterboro quadrangle to the south. The ice dam melted gradually while the main glacier margin retreated northward into the Limington quadrangle. The deltas are usually composed of flat-topped deposits of coarse to medium sand with lesser amounts of medium to fine gravel commonly interbedded as lenses within the sand and capping the delta tops. The orientation of foreset beds in the Lake Arrowhead deltas indicates that they built generally in a southeastward direction. The Arrowhead Estates are located on the largest of these glacial lake deltas. The elevation of the delta top in the Lake Arrowhead area is 350-360 ft (107-110 m) asl.

The elevations of the glaciolacustrine deltas, such as those seen around Lake Arrowhead, provide helpful information for the reconstruction of former lake levels during deglaciation (Ko-

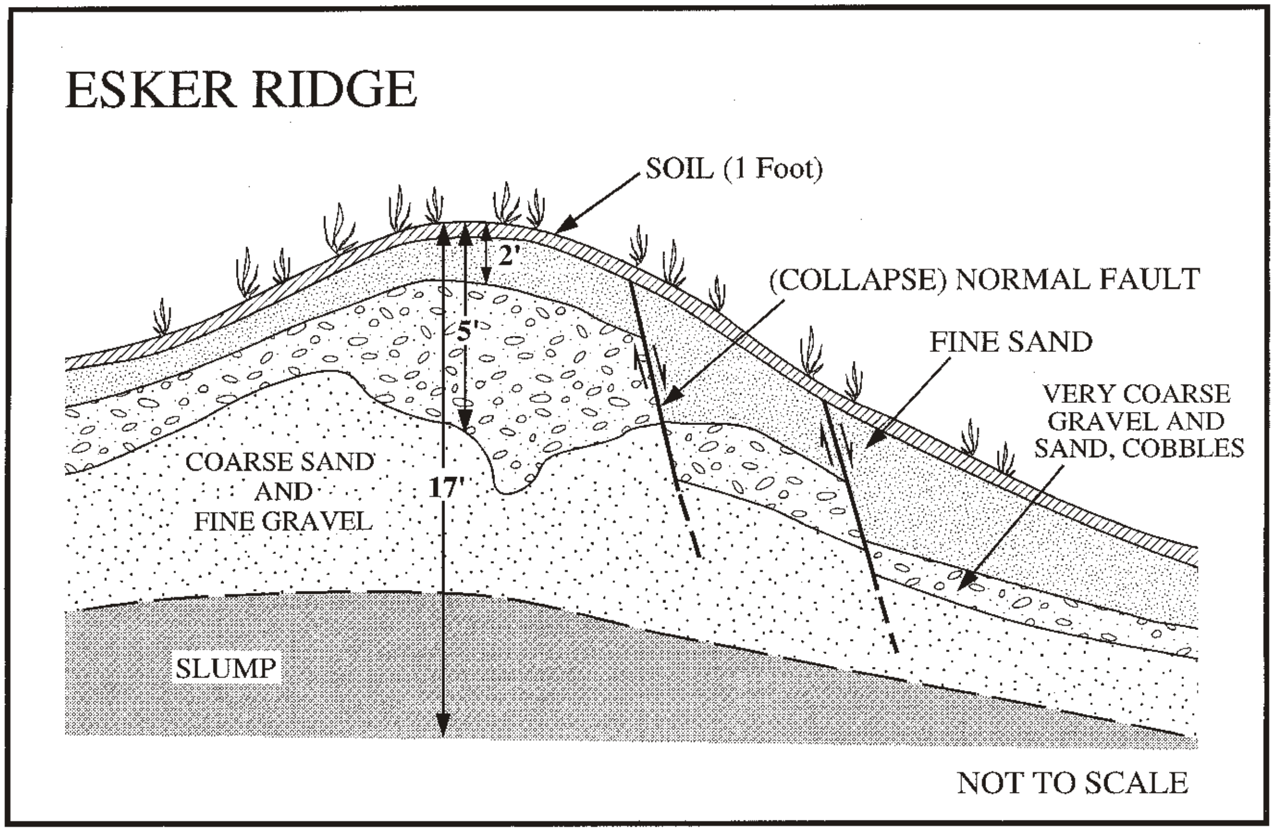


Figure 2. Cross section of an esker ridge of the Limington esker system. The features and textures are common to most esker ridges found in the area.

teff, 1974; Koteff and Pessl, 1981). Probable outlet spillways for glacial Lake Arrowhead have been identified on the basis of channel features whose elevations are compatible with the elevations of the delta tops (i.e. not higher than the former lake levels). The first and highest possible spillway for glacial Lake Arrowhead is located in the Waterboro quadrangle, where there appears to be an abandoned outlet channel east of Little Ossipee Pond. The present elevation of this channel is about 340 ft (104 m).

A second spillway for glacial Lake Arrowhead may have opened at the southern tip of Little Ossipee Pond (Waterboro quadrangle) at an elevation of approximately 320 ft (98 m), when residual ice melted from the pond basin. A third possibility is that the lake drained eastward as ice retreat opened the bedrock-floored channel at 325 ft (99 m), just south of Isinglass Hill. There is a scarp about 600 ft (183 m) south of the manmade dam, indicating what is probably the final drainage level of the glacial lake at an elevation of nearly 320 ft (98 m). This is essentially the elevation of marine submergence in the Little Ossipee valley, judging from marine deltas just east of here, so we infer that glacial Lake Arrowhead ultimately flushed into the encroaching sea. The boundary between glacial Lake Arrowhead deposits and the glaciomarine delta complex to the east is not clear in the field, so the mapped contacts were inferred from topography and relative elevations.

Sediments may have been transported to glacial Lake Arrowhead by the Arrowhead esker sytem, at least during the early part of delta formation. Field evidence in the Lake Arrowhead area indicates that the esker system predates at least some parts of the delta complex, because in places the delta deposits overlie esker ridges transgressively. This transgression is marked by an unconformity observed in a few exposures. This stratigraphic relationship was not always seen, and perhaps in other cases the esker and deltaic deposits formed synchronously. It is likely that the esker segments formed successively from south to north, such that the earlier segments were draped by deltaic sediments as the lake expanded.

### *Glacial Lake Town Farm deposits (Pltf$_1$)*

Near the northwest corner of the map area, a narrow valley (north of Libby Mtn.) drains northward into the Steep Falls quadrangle. Glacial retreat from this valley resulted in ponding of meltwater, forming glacial Lake Town Farm (Gosse and Thompson, 1999a,b). The earliest and highest (Pltf$_1$) stage of this lake drained through the channel at an elevation of about 485 ft (148 m), north of Libby Hill. A small area of water-laid sediments associated with this level of glacial Lake Town Farm has been mapped near the northern edge of the Limington quadrangle.

### *Glaciomarine Deltas (Pmdnh, Pmdbp, Pmdnl, Pmd)*

Glaciomarine deltas in the study area include three named deltas, which from south to north are: the North Hollis delta (Pmdnh), the Boyd Pond delta (Pmdbp), and the North Limington delta (Pmdnl). These map units are distinguished on the basis of subtle differences in elevations and ice-contact landforms, and in some areas their boundaries are not known with certainty. The undifferentiated Pmd unit in the Saco Valley probably is a complex of several deltas, but it is hard to identify them because postglacial erosion by the Saco and Little Ossipee Rivers has obscured the original surface topography.

The apex of the North Hollis delta (unit Pmdnh) is at 310-320 ft (94-98 m) in the area between North Hollis and Isinglass Hill. This delta appears to have built eastward into the marine embayment in the Saco Lowland. The associated glacier margin probably trended east-west along the north edge of the delta. The position of this margin is inferred from the distinct chain of kettles that extends from Isinglass Pond east to Wales and Lily Ponds. A correlative ice-margin postion has been mapped by Gosse (1999a,b) at the head of his $Pmd_4$ delta in the adjacent Standish quadrangle, only one mile east-northeast of Wales Pond. Short esker segments in the area may indicate feeder tunnels that delivered sediment to the North Hollis delta.

The head of the Boyd Pond delta (unit Pmdbp) is thought to be located in the vicinity of Boyd Pond and Doles Pond. Just south of these ponds, there are remnants of delta tops at about 310 ft (94 m) in elevation. The upper surface of the Boyd Pond delta complex slopes gently eastward to 290 ft (88 m) in the area east of North Hollis. A contact between the delta topset and foreset beds was exposed in an active gravel pit located next to Boyd Pond. The contact elevation was estimated at 308 ft (94 m) asl. In ice-contact marine deltas such as the Boyd Pond delta, the elevation of the topset-foreset contact closely approximates the elevation of sea level in the area when the delta was built.

Field work revealed that the head of the delta at Boyd Pond is connected to a short esker ridge on the shore of the pond. While this part of the Boyd Pond complex was esker-fed, it is likely that sediments also washed onto the delta from the Doles Pond and Lake Arrowhead valleys to the west. The orientations of kettles just south of the Little Ossipee River suggest at least two arcuate ice-margin positions trending east-west in the Boyd Pond delta complex. These ice margins may have been similar in age to the ice-margin positions mapped near Doles Pond and Boyd Pond.

The predominant sediments in the Boyd Pond delta are well-bedded, well-sorted, loose gravelly sand. Pebbles are well rounded, and boulders and cobbles are almost absent. To the south and east of Boyd Pond the grain size decreases towards North Hollis. In the North Hollis area, cross bedding in the delta topset beds was observed dipping gently (5 degrees) to the northeast. The flat topography of the delta plain in the North Hollis area is better preserved than in the Boyd Pond area, where the delta surface has been pervasively modified by ice-disintegration features and fluvially dissected by the Little Ossipee River.

The North Limington delta (unit Pmdnl) is located at the north edge of the quadrangle. This relatively small and well-defined delta represents a stillstand position of the retreating glacier margin. The surveyed elevation of the topset-foreset contact was 310 ft (94 m) asl in a gravel pit located approximately 0.75 miles west of North Limington. The North Limington delta was at least partly fed by an esker that extends north from Webster Millpond in the adjacent Steep Falls quadrangle (Gosse and Thompson, 1999a,b).

An extensive glaciomarine delta complex occurs on both sides of the Saco Valley in the northeastern quadrant of the map. The deltaic deposits of the South Limington area have been severely eroded by the Little Ossipee and Saco Rivers. One remnant of the original delta plain is located on Boothby Road, northeast of the village of South Limington. An exposure in an abandoned gravel pit showed a well-defined topset-foreset contact in this delta. The elevation of the contact was approximately 300 ft (91 m) asl. This elevation is consistent with other glaciomarine delta elevations measured in southwestern Maine (Thompson and others, 1989; Koteff and others, 1993). Another topset-foreset contact was measured at an elevation of 296 ft (90 m) asl by Thompson and others (1989) in a delta remnant on the east side of the Saco River. Prior to erosion by the Saco River, the latter deposit may have been part of the same delta complex that occurs between South Limington and East Limington.

### *Submarine Fans (Pmf)*

Deposits on the eastern side of the quadrangle, northeast of Wales Pond, were interpreted as submarine fans, on the basis of their probable continuity with fan deposits mapped by Gosse (1999a,b) in the adjacent Standish quadrangle. Many submarine fans are composite units including not only sand and gravel but also till, and layers of Presumpscot Formation silty clay interbedded with the sand and gravel (Figure 3). Where till is present, it usually occurs only in the proximal parts of fans, and the bulk of the deposits are made of sand and gravel. These submarine fans consist of sediments deposited at the mouths of subglacial tunnels where the glacier terminated in the ocean.

### *Regressive Marine Deposits (Pmrs)*

Fine sand, silt, and lesser amounts of clay in the area east of Wales Pond, just south of the submarine fan described above, were mapped as sandy regressive marine sediments. These deposits probably were derived partly from erosion of adjacent marine deltas as relative sea level was falling. The finer-grained Presumpscot Formation muds, which are typical of the formation as defined by Bloom (1960), were delivered to the glacier terminus by meltwater streams and then transported farther out to sea from the ice margin, where they settled out and filled topographically low areas. Clay of probable marine origin has been

reported by well drillers and residents in the Limington quadrangle. It is usually buried beneath the deltaic sands.

### *Alluvium (Ha) and Stream Terraces (Qst)*

Alluvial (flood plain) deposits in the quadrangle are found along modern streams and rivers such as the Saco and Little Ossipee. They usually consist of reworked glacial sediments composed of sand, gravel, and silt. Pebbles in gravelly alluvium are typically imbricated. Older alluvial deposits, likewise composed of sand and gravel, occur on fluvial terraces with flat topography that stand above the modern flood plains. Several well-developed terraces were mapped in the quadrangle. Some of the most prominent examples are along the Saco River, where they were cut into the older and higher deltaic deposits.

### *Wetlands (Hw, Hwh, Hwm, Hws) and Shoreline Deposits (Hls)*

Holocene wetland deposits were mapped over large areas of the Limington quadrangle. They have formed in areas of poor drainage with a high water table. Some of these wetlands hold pools of standing water only during rainy periods and after snow melt, therefore changing their apparent size over the course of the year. Wetlands covered with trees, bushes and scrub brush were classified as swamps (Hws), while marshes (Hwm) were distinguished by the dominance of grassland vegetation. A few shrub-covered wetlands were mapped as heaths (Hwh) and probably contain peat deposits. It should be noted that due to poor access and indistinct boundaries on air photos, many wetlands were mapped at a reconnaissance level. Thus, their boundaries and classification on the Limington geologic map are not definitive for regulatory purposes.

Modern beach deposits (Hls) were mapped on the shore of Lake Arrowhead. Other beach deposits were too small for mapping at the scale of the quadrangle. The lacustrine beaches are predominantly composed of coarse sand and fine gravel derived from the erosion of nearby glacial deposits.

## GLACIAL AND POSTGLACIAL HISTORY

The glacial deposits of the Limimgton quadrangle provide evidence of only the most recent (late Wisconsinan) glaciation, although it is almost certain that southern Maine was affected by more than one glaciation (Thompson and Borns, 1985b). Interglacial weathering and erosion, followed by the scouring action of the last ice sheet, are presumably responsible for the lack of deposits from an earlier glaciation in the study area.

Due to the combination of postglacial weathering and scarcity of freshly exposed bedrock outcrops, glacial flow directions in the Limington quadrangle could be determined from striated ledges in only a few places. The dominant ice flow direction in the quadrangle was deduced from the long-axis orientation of glacially streamlined hills, along with striation evidence from nearby areas and the regional trends of esker systems. This combined evidence indicates a south-southeastward glacial flow direction during the last glacial maximum. The till deposits in the quadrangle were deposited directly from this ice sheet, through a variety of processes, during its advance and retreat.

Regional studies indicate that the Laurentide Ice Sheet covered the Gulf of Maine during the late Wisconsinan glaciation and began to retreat approximately 17,000 years ago (yr BP). Although radiocarbon dates indicating the time of deglaciation are not available from the Limington quadrangle, dates from marine shells in nearby areas of southwestern Maine indicate that the study area was deglaciated at about 14,000 yr BP (Weddle and others, 1993). Most of the surficial deposits in the Limington quadrangle were formed during and after the recession of the last ice sheet. End moraines and the great quantity of sediments in the glaciomarine deltas suggest that glacier retreat was not continuous, but rather was interrupted by standstills and perhaps minor local readvances. Zones of local stagnation and residual ice masses are indicated by the distribution of kettles and other ice-contact landforms in glacial sand and gravel deposits.

The weight of the ice sheet caused subsidence of the land of several hundred feet. As the ice retreated, the Atlantic Ocean inundated the subsided land (Bloom, 1960; Stuiver and Borns, 1975; Smith, 1985). Ice-contact glaciomarine deltas indicate that in the eastern part of the quadrangle the receding glacier was in contact with the sea. The positions of the deltas in relation to higher terrain (mainly to the west) suggest that the inland limit of late-glacial marine submergence occurs along a line that generally follows the 290 to 310-ft contours (highest to the northwest due to postglacial crustal tilt). This line passes through North Limington and South Limington, swings west up the Little Ossipee Valley to the outlet of Lake Arrowhead, and then back east and south through the Isinglass Pond-North Hollis-West Hollis area. This is approximately the same marine limit shown on the Surficial Geologic Map of Maine (Thompson and Borns, 1985a). The absence of marine shorelines suggests that uplift of the land occurred rapidly following deglaciation.

During deglaciation of the Limington quadrangle, ice flow may have shifted to a more southward direction, as indicated by the few end moraines, striation trends, and by the ice-margin trends inferred from kettle alignments and heads of meltwater deposits. The distribution of these ice-contact features suggests that the position of the glacier margin was controlled by the local topography of the Saco Valley region. Topographically higher areas were free of ice before the lowlands, and the final ice flow probably was concentrated along the axes of larger valleys. Stagnation of residual ice masses (which were surrounded by sand and gravel deposits from the melting ice) formed the numerous kettles in the area, and eskers were deposited as glacial tunnels became choked with sediments.

Glacial lakes formed inland from the marine limit in southwestern Maine, usually in areas where meltwater drainage was dammed by remnant ice masses or hilly terrain in front of the glacier margin (e.g. in north-sloping valleys). In the Limington

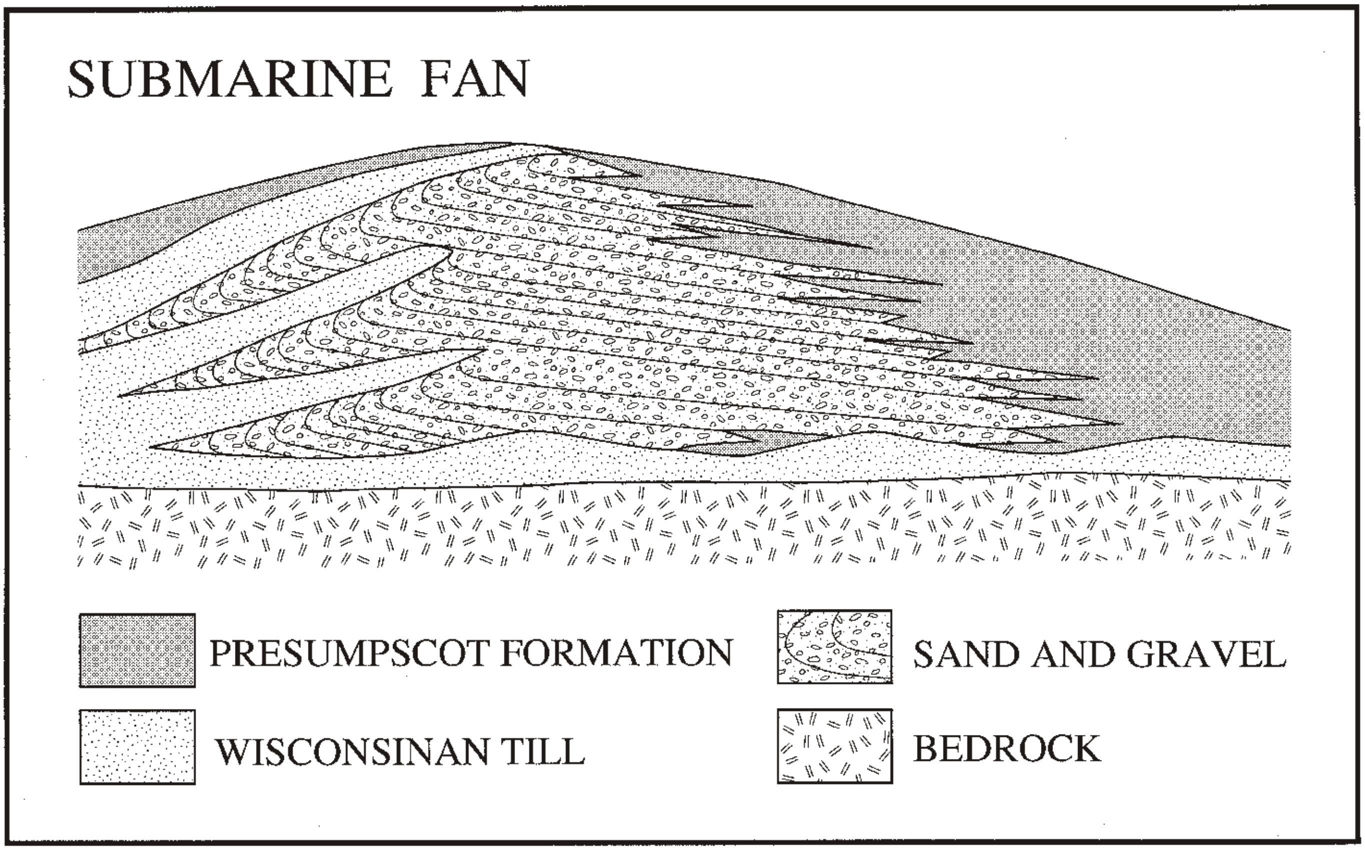


Figure 3. Idealized cross section of a submarine fan in the Limington quadrangle, based on field exposures and subsurface information.

quadrangle, prominent glaciolacustrine deltas formed in glacial Lake Arrowhead. Sand and gravel deposits west of Isinglass Hill probably formed in the same glacial lake, although these deposits are not sufficiently well exposed to identify the deltaic component. The spillway for this lake was the 325 ft (99 m) bedrock-floored channel seen just south of Isinglass Hill.

Postglacial geologic activity in the area seems to be limited to erosion caused by the incision of the local drainage network, which was probably enhanced by uplift resulting from glacio-isostatic rebound. Erosion of glacial deposits provided the sediments deposited on stream terraces and modern flood plains. Low, poorly drained areas (such as kettles) favored the formation of wetland deposits. Sedimentation continues to occur in these environments today, including the accumulation of organic debris.

One of the most puzzling geologic features in the quadrangle is the unnamed stream valley that includes Killick Pond in Hollis. This northeast-trending valley incises a large glaciomarine delta complex. Parts of the valley appear deep and wide in proportion to the small stream that occupies it, and the broad segment west of Wales Pond resembles the neighboring kettles. Perhaps the stream has reached its present configuration in part from having connected some kettles, and partly as a consequence of headward erosion aided by spring sapping of water-saturated sand in the delta complex.

## ECONOMIC GEOLOGY

Sand and gravel are by far the most economically important surficial deposits in the Limington quadrangle, and numerous borrow pits have been opened in these deposits. Sand is extremely abundant in the glaciomarine and glaciolacustrine deltas, and the supply probably far exceeds demand. Gravel is locally abundant, and its distribution is somewhat predictable from both the geologic map and the distribution of existing pits shown on the materials map.

Gravel usually forms a thin layer (3-10 ft) of “topset beds” on the tops of deltas, while the underlying “foreset beds” are more likely to consist of thick sand or gravelly sand. Gravel caps also are expected to occur on stream terraces (unit Qst) that have been cut into the deltas. Gravel pits in these delta-plain and terrace deposits are often quite shallow because they soon encounter the underlying sand. The headward (northern or western) parts of the glaciomarine deltas may have thicker gravel deposits that washed off melting glacial ice that formerly existed nearby. These areas are distinguished by ice-contact topography (kames

and kettles). Sizable gravel concentrations are especially apt to be found in eskers (unit Pge) and other ice-contact deposits (unit Pgi). Restrictions on the exploitation of these gravels may be expected in areas that border lakes and/or have been developed into residential communities.

Ground water is another very important geologic resource, including the water supplies in sand and gravel aquifers in the study area. These aquifers have been mapped by Tolman and Lanctot (1985). Finally, some of the wetlands - especially in the kettle depressions - contain peat deposits.

## ACKNOWLEDGMENTS

Support for field work was provided by the Maine Geological Survey. We express our thanks to Carl Koteff (U. S. Geological Survey) and Thomas Weddle (Maine Geological Survey) for their valuable advice and for the benefits obtained from discussions with them. We also wish to thank many landowners for their hospitality, particularly Mr. and Mrs. Getchell of Lake Arrowhead. Henry Berry (Maine Geological Survey) provided data on locations of many bedrock outcrops in the quadrangle.

## REFERENCES

Belknap, D. F., Shipp, R. C., Stuckenrath, R., Kelley, J. T., and Borns, H.W., Jr., 1989, Holocene sea-level change in coastal Maine, *in* Anderson,W. A., and Borns, H. W., Jr. (editors), Neotectonics of Maine: Studies in seismicity, crustal warping, and sea-level change: Maine Geological Survey, Bulletin 40, p. 85-105.

Bloom, A. L., 1960, Late Pleistocene changes in sea level in southwestern Maine: Maine Geological Survey, 143 p.

Borns, H. W., Jr., 1985, Changing models of deglaciation in northern New England and adjacent Canada, *in* Borns, H. W., Jr., Lasalle, P., and Thompson, W. B. (editors), Late Pleistocene history of northern New England and adjacent Quebec: Geological Society of America, Special Paper 197, p. 135-138.

Flewelling, L. R., and Lisante, R. H., 1982, Soil survey of York County, Maine: United States Department of Agriculture - Soil Conservation Service, Maine Agricultural Experiment Station, and Maine Soil and Water Conservation Commission, 143 p.

Gosse, J. C., 1999a, Surficial geology of the Standish quadrangle, Maine: Maine Geological Survey, Open-File Map 99-101.

Gosse, J. C., 1999b, Surficial geology of the Standish 7.5-minute quadrangle, York and Cumberland Counties, Maine: Maine Geological Survey, Open-File Report 99-132, 24 p.

Gosse, J. C., and Thompson, W. B., 1999a, Surficial geology of the Steep Falls quadrangle, Maine: Maine Geological Survey, Open-File Map 99-102.

Gosse, J. C., and Thompson, W. B., 1999b, Surficial geology of the Steep Falls 7.5-minute quadrangle, York and Cumberland Counties, Maine: Maine Geological Survey, Open-File Report 99-133, 23 p.

Hussey, A. M., II, 1985, The bedrock geology of the Bath and Portland 2-degree map sheets, Maine: Maine Geological Survey, Open-File Report 85-87, 82 p.

Koteff, C, 1974, The morphologic sequence concept and deglaciation of southern New England, *in* Coates, D. (ed.), Glacial geomorphology: State University of New York, Binghamton, p.121-144.

Koteff, C., and Pessl, F., Jr., 1981, Systematic ice retreat in New England: U.S Geological Survey, Professional Paper 1179, 20 p.

Koteff, C., Robinson, G. R., Goldsmith, R., and Thompson, W. B., 1993, Delayed postglacial uplift and synglacial sea levels in coastal central New England: Quaternary Research, v. 40, p. 46-54.

Meglioli, A., 1999a, Surficial geology of the Waterboro quadrangle, Maine: Maine Geological Survey, Open-File Map 99-103.

Meglioli, A., 1999b, Surficial geology of the Waterboro 7.5-minute quadrangle, York County, Maine: Maine Geological Survey, Open-File Report 99-134, 7 p.

Meglioli, A., and Thompson,W. B., 1998, Surficial materials of the Limington quadrangle, Maine: Maine Geological Survey, Open-File Map 98-175.

Meglioli, A., and Thompson,W. B., 1999, Surficial geology of the Limington quadrangle, Maine: Maine Geological Survey, Open-File Map 99-90.

Munsell Soil Color Chart, 1990.

Smith, G. W., 1980, End moraines and glaciofluvial deposits of Cumberland and York Counties, Maine: Augusta, Maine, Maine Geological Survey, Open-File No. 77-13.

Smith, G. W., 1982, End moraines and the pattern of the last ice retreat from central and southern Maine, *in* Larson, G. J., and Stone, B. D. (editors), Late Wisconsinan glaciation of New England: Kendall/Hunt, Dubuque, Iowa, p. 195-210.

Smith, G. W., 1985, Chronology of Late Wisconsinan deglaciation in coastal Maine, *in* Borns, H. W., Jr., Lasalle, P., and Thompson, W. B. (editors), Late Pleistocene history of northeastern New England and adjacent Quebec: Geological Society of America, Special Paper 197, p. 29-44.

Smith, G. W., and Thompson, W. B., 1977, Reconnaissance surficial geologic map of the Buxton quadrangle, Maine: Maine Geological Survey, Open-File Map 77-19.

Stuiver, M., and Borns, H. W., Jr., 1975, Late Quaternary marine invasion in Maine: its chronology and associated crustal movements: Geological Society of America, Bulletin, v. 86, p. 99-104.

Thompson, W. B.,1982, Recession of the late Wisconsin ice sheet in Coastal Maine, *in* Larson, G. J., and Stone, B. D. (editors), Late Wisconsinan glaciation of New England: Kendall/Hunt, Dubuque, Iowa, p. 211-228.

Thompson, W. B., and Borns, H. W., Jr., 1985a, Surficial geologic map of Maine: Maine Geological Survey, scale 1:500,000.

Thompson, W. B., and Borns, H. W., Jr., 1985b, Till stratigraphy and late Wisconsinan deglaciation of southern Maine: a review: Geographie Physique et Quaternaire, v. 39, no. 2, p. 199-214.

Thompson, W. B., Crossen, K. J., Borns, H. W., Jr., and Andersen, B. G., 1989, Glaciomarine deltas of Maine and their relation to Late Pleistocene-Holocene crustal movements, *in* Anderson,W. A., and Borns, H. W., Jr. (editors), Neotectonics of Maine: Studies in seismicity, crustal warping, and sea-level change: Maine Geological Survey, Bulletin 40, p. 43-67.

Tolman, A. L., and Lanctot, E. M., 1985, Hydrogeologic data for significant sand and gravel aquifers in parts of York and Cumberland Counties, Maine - Map 4: Maine Geological Survey, Open-File Report 85-93.

Weddle, T. K., Koteff, C., Thompson, W. B., Retelle, M. J., and Marvinney, C. L., 1993, The late-glacial marine invasion of coastal central New England (northeastern Massachusetts-southwestern Maine): Its ups and downs, *in* Cheney, J. T., and Hepburn, J. C. (editors), Field trip guidebook for the northeastern United States: 1993 Boston GSA - Volume 1: Amherst, Massachusetts, University of Massachusetts, Department of Geology and Geography, Contribution No. 67, p. I-1 - I-31.

**APPENDIX. Glossary of geologic terms that may appear in this report.**

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

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

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

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

**Colluvium:** a mantle of poorly-sorted sediments produced by mass wasting on hillsides, and commonly derived from underlying till or other glacial deposits.

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

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

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

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

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

**Englacial:** occurring or formed within glacial ice.

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

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

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

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

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

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

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

**Kame:** a mound-shaped deposit of sand and gravel formed within or adjacent to glacial ice

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

**Lacustrine:** pertaining to a lake.

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

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

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

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

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

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

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

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

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

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

**Proglacial:** occurring or formed in front of a glacier.

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

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

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

**Subglacial:** occurring or formed beneath a glacier.

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

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