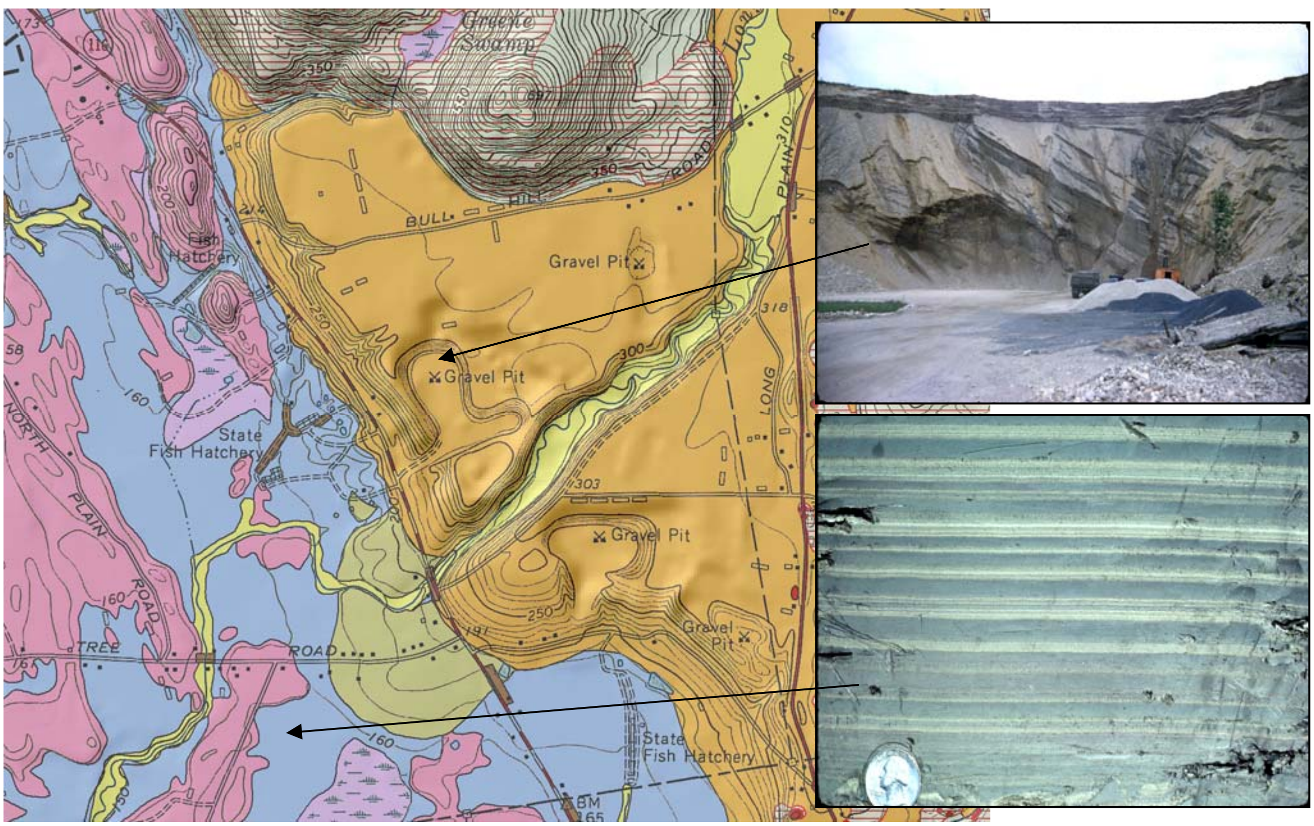
Prepared in cooperation with the Commonwealth of Massachusetts
Office of the State Geologist and Executive Office of Energy and Environmental Affairs

Surficial Geologic Map of the Heath-Northfield-Southwick-Hampden 24-Quadrangle Area in the Connecticut Valley Region, West-Central Massachusetts

Compiled by Janet R. Stone and Mary L. DiGiacomo-Cohen



Open-File Report 2006-1260-G

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Cover figure: A part of the surficial geologic map of the Mount Toby quadrangle, shown with semi-transparent shaded relief overlaid on the scanned topographic base map. Upper photograph by J.H. Hartshorn shows deltaic bedding in a gravel pit excavated into the Long Plain delta of glacial Lake Hitchcock; lower photograph by J.R. Stone shows summer silt layers (lighter) and winter clay layers (darker) in varved lake-bottom sediments of glacial Lake Hitchcock.

Contents

Figures

Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)
yard (yd)	0.9144	meter (m)
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
square kilometer (km^2)	0.3861	square mile (mi^2)

Surficial Geologic Map of the Heath-Northfield-Southwick-Hampden 24-Quadrangle Area in the Connecticut Valley Region, West-Central Massachusetts

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Introduction

The surficial geologic map layer shows the distribution of nonlithified earth materials at land surface in an area of 24 7.5-minute quadrangles (1,238 mi^2 total) in west-central Massachusetts (fig. 1). Across Massachusetts, these materials range from a few feet to more than 500 ft in thickness. They overlie bedrock, which crops out in upland hills and as resistant ledges in valley areas. The geologic map differentiates surficial materials of Quaternary age on the basis of their lithologic characteristics (such as grain size and sedimentary structures), constructional geomorphic features, stratigraphic relationships, and age. Surficial materials also are known in engineering classifications as unconsolidated soils, which include coarse-grained soils, fine-grained soils, and organic fine-grained soils. Surficial materials underlie and are the parent materials of modern pedogenic soils, which have developed in them at the land surface. Surficial earth materials significantly affect human use of the land, and an accurate description of their distribution is particularly important for assessing water resources, construction aggregate resources, and earth-surface hazards, and for making land-use decisions.

The mapped distribution of surficial materials that lie between the land surface and the bedrock surface is based on detailed geologic mapping of 7.5-minute topographic quadrangles, produced as part of an earlier (1938–1982) cooperative statewide mapping program between the U.S. Geological Survey and the Massachusetts Department of Public Works (now Massachusetts Highway Department) (Page, 1967; Stone, 1982). Each published geologic map presents a detailed description of local geologic map units, the genesis of the deposits, and age correlations among units. Previously unpublished field compilation maps exist on paper or mylar sheets and these have been digitally rendered for the present map compilation. Regional summaries based on the Massachusetts surficial geologic mapping studies discuss the ages of multiple glaciations, the nature of glaciofluvial, glaciolacustrine, and glaciomarine deposits, and the processes of ice advance and retreat across Massachusetts (Koteff and Pessl, 1981; papers in Larson and Stone, 1982; Oldale and Barlow, 1986; Stone and Borns, 1986; Warren and Stone, 1986).

This compilation of surficial geologic materials is an interim product that defines the areas of exposed bedrock and the boundaries between glacial till, glacial stratified deposits, and overlying postglacial deposits. This work is part of a comprehensive study to produce a statewide digital map of the surficial geology at a 1:24,000-scale level of accuracy. This surficial geologic map layer covering 24 quadrangles revises previous digital surficial geologic maps (Stone and others, 1993; MassGIS, 1999) that were compiled on base maps at regional scales of 1:125,000 and

1:250,000. The purpose of this study is to provide fundamental geologic data for the evaluation of natural resources, hazards, and land information within the Commonwealth of Massachusetts.

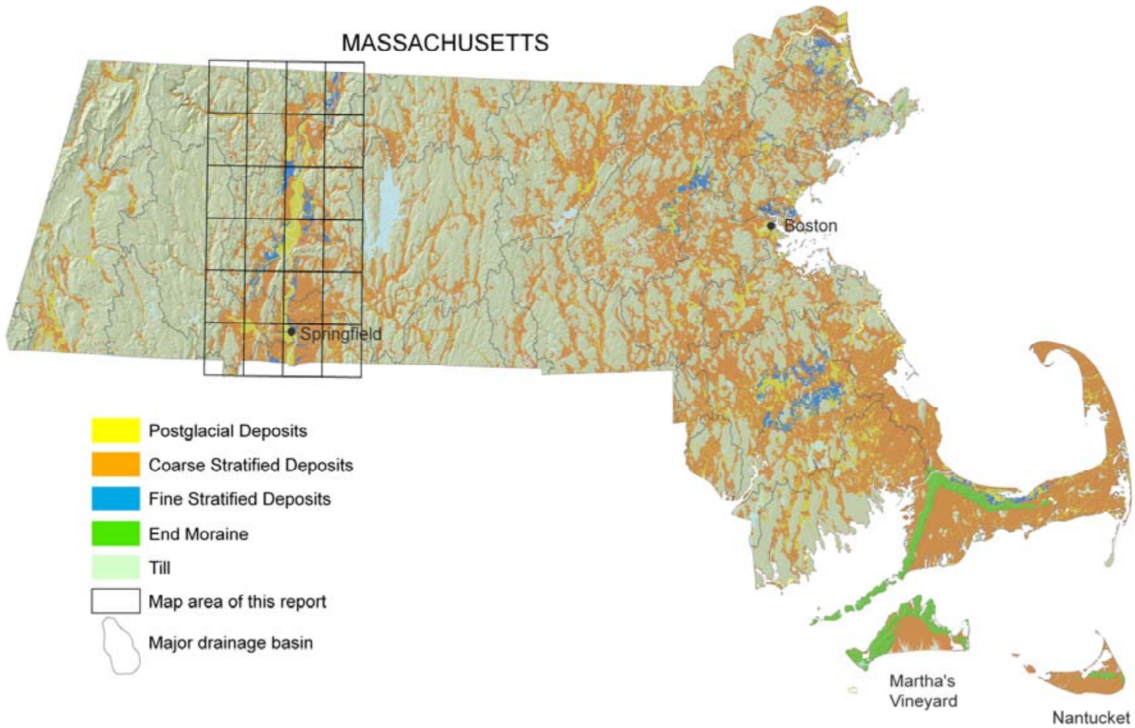


Figure 1. General distribution of glacial and postglacial deposits in Massachusetts (Stone and others, 1993; MassGIS, 1999) and 1:24,000-scale quadrangles covered by this report.

Surficial Materials in Massachusetts

Most of the surficial materials in Massachusetts are deposits of the last two continental ice sheets that covered all of New England in the latter part of the Pleistocene ice age (Schafer and Hartshorn, 1965; Oldale and others, 1982; Stone and Borns, 1986). The glacial deposits are divided into two broad categories, ***glacial till*** and ***glacial stratified deposits***. Till, the most widespread glacial deposit, was laid down directly by glacier ice. Glacial stratified deposits are concentrated in valleys and lowland areas and were laid down by glacial meltwater in streams, lakes, and the sea in front of the retreating ice margin during the last deglaciation. Postglacial sediments, primarily floodplain alluvium and swamp deposits, make up a lesser proportion of the unconsolidated materials.

Glacial till deposits consist of nonsorted, generally nonstratified mixtures of mineral and rock particles ranging in grain size from clay to large boulders. The matrix of most tills is composed dominantly of fine sand and silt. Boulders, within and on the surface of tills, range from sparse to abundant. Some tills contain lenses of sorted sand and gravel, and less commonly, masses of laminated fine-grained sediments. The color and lithologic characteristics of till deposits vary across Massachusetts but generally reflect the composition of the local underlying and northerly adjacent bedrock, from which the till was derived. Till blankets the bedrock surface in variable thickness, ranging from a few inches to more than 200 ft, and commonly underlies stratified meltwater deposits. Tills deposited during the last two glaciations occur in superposition within Massachusetts (Koteff, 1966; Newton, 1978; Weddle and others, 1989). The upper till was deposited during the last (late Wisconsinan) glaciation; it is the most extensive till and commonly is observed in surface exposures, especially in areas where till thickness is less than 10 to 15 ft (thin-till unit on the map). The lower till ("old" till) was deposited during an earlier glaciation (probably Illinoian). The lower till has a more limited distribution; it is principally a subsurface deposit that constitutes the bulk of material in drumlins and other hills, where till thickness is greater than 15 ft. The distribution of lower till is shown primarily by the thick-till unit on the map. The lower till generally is overlain by a thin mantle of upper till in these areas. In all exposures showing the superposed two tills, the base of the upper till truncates the weathered surface of the lower till. The lower part of the upper till commonly displays a zone of shearing, dislocation, and brecciation in which clasts of lower till were mixed and incorporated into the upper till during the last glaciation.

End moraine deposits are composed predominantly of bouldery ablation till but also locally may include sorted sediments. These deposits were laid down by glacial-melting processes along active ice margins during retreat of the last (late Wisconsinan) ice sheet. Extensive end moraines on Nantucket and Martha’s Vineyard (fig. 1) are related to the terminal position of the late-Wisconsinan ice sheet, and the end moraines on Cape Cod are associated with recessional positions of the last ice sheet. Less extensive end moraines occur locally elsewhere in southeastern Massachusetts, in the Boston area, and in the Gloucester-Rockport area of northeastern Massachusetts.

Glacial stratified deposits consist of layers of well-sorted to poorly sorted gravel, sand, silt, and clay laid down by flowing meltwater in glacial streams, lakes, and marine embayments that occupied the valleys and lowlands of Massachusetts during retreat of the last ice sheet. Textural variations within the meltwater deposits occur both areally and vertically because meltwater-flow regimes were different in glaciofluvial (stream), glaciodeltaic (where a stream entered a lake or the sea), glaciolacustrine (lake bottom), and glaciomarine (marine bottom) depositional environments. Grain-size variations also resulted from meltwater deposition in positions either proximal to, or distal from, the retreating glacier margin, which was the principal sediment source. A common depositional setting contained a proximal, ice-marginal meltwater stream in which horizontally bedded glaciofluvial gravel and (or) sand and gravel were laid down; farther downvalley, the stream entered a glacial lake where glaciodeltaic sediments were deposited, consisting of horizontally layered sand and gravel delta-topset beds overlying inclined layers of sand in delta-foreset beds. Farther out in the glacial lake, very fine sand, silt, and clay settled out on the lake bottom in flat-lying, thinly bedded glaciolacustrine layers. Thick sequences having these textural variations commonly are present in the vertical section of meltwater deposits across the State (Stone and others, 1992). Most of the meltwater sediments in Massachusetts were deposited in or graded to large and small glacial lakes. These large and small lakes formed in northerly sloping valleys and basins where they were dammed by the ice margin (ice-dammed lakes) and in southerly sloping valleys and basins where they were dammed by slightly earlier deltaic sediments (sediment-dammed lakes). The largest glacial lake in Massachusetts was an extensive sediment-dammed lake (glacial Lake Hitchcock) which occupied the Connecticut Valley area at altitudes below 365 ft during the retreat of the last ice sheet. Lake Hitchcock was dammed behind a mass of earlier deltaic sediments in the Cromwell-Rocky Hill area of central Connecticut, and the lake lengthened northward into northern Vermont and New Hampshire as the ice sheet retreated.

Detailed geologic maps can show meltwater sedimentary units within each glacial lake or valley outwash system (Jahns, 1941, 1953; Koteff, 1966). These units, known as *morphosequences* (Koteff, 1974; Koteff and Pessl, 1981), are the smallest mappable stratigraphic units depictable on detailed geologic maps. Morphosequences are bodies of stratified meltwater sediments that are contained in a continuum of landforms, grading from ice-contact forms (eskers, kames) to non-ice-contact forms (flat valley terraces, delta plains) that were deposited simultaneously at and beyond the margin of the ice sheet, and were graded to a specific base level. Each morphosequence consists of a proximal part (head) deposited within or near the ice margin and a distal part deposited farther away from the ice margin. Both grain size and ice-melt collapse deformation of beds decrease from the proximal to the distal part of each morphosequence. The head of each morphosequence is either ice marginal (ice contact) or near ice marginal. The surface altitude of fluvial sediments in each morphosequence was controlled by a specific base level, either a glacial-lake or marine water plane or a valley knickpoint. Few morphosequences extend distally more than 6 miles, and most are less than a mile in length. In any one basin, individual morphosequences were deposited sequentially as the ice margin retreated systematically northward. Consequently, in many places the distal, finer grained facies of a younger morphosequence stratigraphically overlies the proximal, coarse-grained facies of a preceding morphosequence.

Figure 2 shows an example of the variability of sediment types in the subsurface of glacial stratified deposits. The figure schematically shows the relationship between coarse-grained deltaic deposits (sand and gravel and sand) and extensive fine-grained lake (or marine) deposits (fine sand, silt, and clay) in the subsurface. Such coarse- and fine-grained units are common in most of the valleys and lowlands of Massachusetts (Langer, 1979; Stone and others, 1979; Stone and others, 1992; Stone and others, 2005). On these interim maps, coarse-grained and fine-grained textural variations within glacial stratified deposits are shown only where they occur at land surface. Subsurface textural variations are not shown.

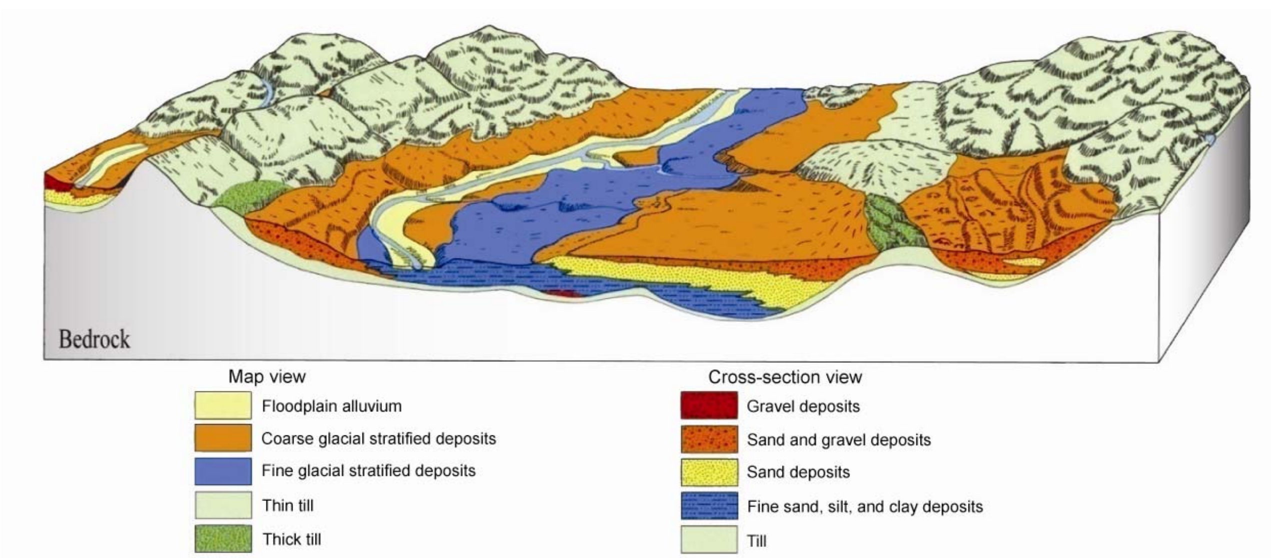


Figure 2. Block diagram illustrating the typical areal and vertical distribution of glacial and postglacial deposits overlying bedrock (modified from Stone and others, 1992).

The areal distribution of till and stratified deposits is related to the physiography of the State (fig. 1). The thickness of these materials varies considerably within these regions because of such factors as the high relief of the bedrock surface, changing environments of deposition during deglaciation, and various effects of postglacial erosion and removal of glacial sediments. In highland areas, notably in the western and central regions, till is the major surficial material and is present as a discontinuous mantle of variable thickness over the bedrock surface. Till is thickest in drumlins (reportedly as much as 230 ft thick) and on the northwest slopes of most bedrock hills. Glacial meltwater deposits that average 50 ft in thickness (Stone and others, 1993) overlie the till in small upland valleys and north-sloping basins between bedrock hills. Glacial stratified deposits are the predominant surficial materials in the Connecticut River valley, the northeastern and southeastern lowlands, and on Cape Cod and the islands. These deposits generally overlie till; however, well logs indicate that in some places till is not present and the stratified deposits lie directly on bedrock. On Cape Cod and the islands, in the southeastern lowland, and in parts of the Connecticut River valley, these deposits completely cover the till-draped bedrock surface.

Postglacial deposits locally overlie the glacial deposits throughout the State. Alluvium underlies the floodplains of most streams and rivers. Swamps occur in low-lying, poorly drained areas in upland and lowland settings, but swamp deposits are shown only where they are estimated to be at least 3 ft thick. Salt-marsh and estuarine deposits are present mainly along the tidal portions of streams and rivers entering the offshore areas. Beach and dune deposits occur along the shoreline.

Description of Map Units

Postglacial Deposits

Artificial fill—Earth materials and manmade materials that have been artificially emplaced, primarily in highway and railroad embankments, and in dams; may also include landfills, urban development areas, and filled coastal wetlands

Floodplain alluvium—Sand, gravel, silt, and some organic material, stratified and well sorted to poorly sorted, beneath the floodplains of modern streams. The texture of alluvium commonly varies over short distances, both laterally and vertically, and generally is similar to the texture of adjacent glacial deposits. Along smaller streams, alluvium is commonly less than 5 ft thick. The most extensive deposits of alluvium on the map are along the Connecticut, Deerfield, Westfield, and Chicopee Rivers, where the texture is predominantly sand, fine gravel, and silt, and total thickness is as much as 25 ft. Alluvium typically overlies thicker glacial stratified deposits

Swamp deposits—Organic muck and peat that contain minor amounts of sand, silt, and clay, stratified and poorly sorted, in kettle depressions or poorly drained areas. Swamp deposits are shown only where they are estimated to be at least 3 ft thick.

Most swamp deposits are less than 10 ft thick. Swamp deposits overlie glacial deposits or bedrock. They locally overlie glacial till even where they occur within thin glacial meltwater deposits

Early Postglacial Deposits

Alluvial-fan deposits—Generally coarse gravel and sand deposits on steep slopes where high gradient streams entered lower gradient valleys. Some alluvial fans in this area were graded to lowering levels of glacial Lake Hitchcock. Some fans continue to form today

Stream-terrace deposits—Sand, gravel, and silt deposited by meteoric water (locally distal meltwater) on terraces cut into glacial meltwater sediments along rivers and streams. Most stream-terrace deposits are less than 10 ft thick and overlie thicker glacial deposits; textures are usually similar to underlying glacial meltwater deposits. Many stream terraces in the Connecticut River valley are composed of fine to medium sand and overlie lake-bottom silt and clay

Inland-dune deposits—Fine to medium, well-sorted sand in transverse, parabolic, and hummocky dunes as much as 60 ft thick. Deposits occur chiefly in the glacial Lake Hitchcock basin where sand derived from extensive glacial-lake deltas that were not yet vegetated was deposited in dune forms by early postglacial winds. Dune sand is now fixed by vegetation except where disturbed by human activities

Talus deposits—Angular, loose blocks of basalt and diabase accumulated by rockfall and creep at the base of bedrock cliffs along linear traprock ridges in the Mesozoic lowland. Talus deposits form steep, unstable slopes. Generally less than 20 ft thick

Glacial Stratified Deposits

Sorted and stratified sediments composed of gravel, sand, silt, and clay (as defined in particle-size diagram, fig. 3) deposited in layers by glacial meltwater. These sediments occur as four basic textural units—gravel deposits, sand and gravel deposits, sand deposits, and fine deposits. On this interim surficial geologic map layer, gravel, sand and gravel, and sand deposits are not differentiated and are shown as *Coarse Deposits* where they occur at land surface. *Fine Deposits* also are shown where they occur at land surface. Textural changes occur both areally and vertically (fig. 2); however, subsurface textural variations are not shown on this interim map.

PARTICLE DIAMETER											
	10	2.5	.16	.08	.04	.02	.01	.005	.0025	.00015	inches
	256	64	4	2	1	.5	.25	.125	.063	.004	mm
Boulders	Cobbles	Pebbles	Granules	Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	
GRAVEL PARTICLES				SAND PARTICLES				FINE PARTICLES			

Figure 3. Grain-size classification used in this report, modified from Wentworth (1922).

Coarse deposits include *Gravel deposits* composed of at least 50 percent gravel-size clasts; cobbles and boulders predominate; minor amounts of sand occur within gravel beds, and sand comprises few separate layers. Gravel layers generally are poorly sorted, and bedding commonly is distorted and faulted due to postdepositional collapse related to melting of ice. *Sand and gravel deposits* occur as mixtures of gravel and sand within individual layers and as layers of sand alternating with layers of gravel. Sand and gravel layers generally range from 25 to 50 percent gravel particles and from 50 to 75 percent sand particles. Layers are well to poorly sorted; bedding may be distorted and faulted due to postdepositional collapse. *Sand deposits* are composed mainly of very coarse to fine sand, commonly in well-sorted layers. Coarser layers may contain up to 25 percent gravel particles, generally granules and pebbles; finer layers may contain some very fine sand, silt, and clay

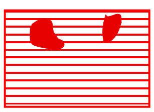
Fine deposits include very fine sand, silt, and clay that occur as well-sorted, thin layers of alternating silt and clay (varves), or as thicker layers of very fine sand and silt. Very fine sand commonly occurs at the surface and grades downward into rhythmically bedded silt and clay varves. In some places on the lake-bottom surface of glacial Lake Hitchcock, fine deposits are overlain by as much as 30 ft of fine to medium sand, deposited as the lake lowered; this sand has not been mapped separately

Glacial Till Deposits

Thin till—Nonsorted, nonstratified matrix of sand, some silt, and little clay containing scattered pebble, cobble, and boulder clasts; large surface boulders are common; mapped where till is generally less than 10 to 15 ft thick including areas of shallow bedrock. Predominantly consists of upper till of the last glaciation; loose to moderately compact, generally sandy, commonly stony. Two facies are present in some places: a looser, coarser grained ablation facies, melted out from supraglacial position; and an underlying more compact, finer grained lodgement facies deposited subglacially. In general, both ablation and lodgement facies of upper till derived from fine-grained bedrock are finer grained, more compact, less stony and have fewer surface boulders than upper till derived from coarse-grained crystalline rocks. Fine-grained bedrock sources include the red Mesozoic sedimentary rocks of the Connecticut River lowland, marble in the western river valleys, and fine-grained schists in upland areas

Thick till—Nonsorted, nonstratified matrix of sand, some silt, and little clay containing scattered pebbles, cobbles, and boulders in the shallow subsurface; at greater depths consists of compact, nonsorted matrix of silt, very fine sand, and some clay containing scattered small gravel clasts. Mapped in areas where till is greater than 10 to 15 ft thick, chiefly in drumlin landforms in which till thickness commonly exceeds 100 ft (maximum recorded thickness is 230 ft). Although upper till is the surface deposit, the lower till constitutes the bulk of the material in these areas. Lower till is moderately to very compact and is commonly finer grained and less stony than upper till. An oxidized zone, the lower part of a soil profile formed during a period of interglacial weathering, is generally present in the upper part of the lower till. This zone commonly shows closely spaced joints that are stained with iron and manganese oxides

Bedrock Areas



Bedrock outcrops and areas of abundant outcrop or shallow bedrock—Solid color shows extent of individual bedrock outcrops; stipple pattern indicates areas of shallow bedrock ***or*** areas where small outcrops are too numerous to map individually; in areas of shallow bedrock, surficial materials are less than 5 to 10 ft thick. These units are not mapped consistently among all quadrangles; see Appendix for level of bedrock outcrop mapping in each quadrangle

Map Compilation

This compilation is the sixth in a series of interim products and shows surficial geology in an area of 24 7.5-minute quadrangles in the Connecticut Valley region of west-central Massachusetts. The quadrangles are Heath, Colrain, Bernardston, Northfield, Ashfield, Shelburne Falls, Greenfield, Millers Falls, Goshen, Williamsburg, Mount Toby, Shutesbury, Westhampton, Easthampton, Mount Holyoke, Belchertown, Woronoco, Mount Tom, Springfield North, Ludlow, Southwick, West Springfield, Springfield South, and Hampden (fig. 4; fig. 5, area G). Figure 5 shows all of the compilation areas for surficial geology in Massachusetts. The surficial geologic maps are being produced sequentially by letter designation (although publication of area G precedes that of area F).

The surficial geologic map layer was compiled in several steps:

1) Paper copies of the published surficial geologic maps for 15 quadrangles were scanned and georeferenced by MassGIS;
2) The Office of the Massachusetts State Geologist vectorized the georeferenced images in order to digitally retain the original linework of the published maps (Mabee and others, 2004);
3) Digital geologic map units were compiled and grouped into basic units in four shapefile layers: *Postglacial deposits* including artificial fill, swamp deposits, and floodplain alluvium; *early postglacial deposits* including alluvial-fan, stream-terrace, inland-dune, and talus deposits; *glacial stratified deposits* including coarse-grained and fine-grained deposits; and *glacial till and bedrock* including thin till, thick till (drumlins), outcrops and areas of shallow bedrock. The distribution of glacial stratified deposits beneath adjacent overlying postglacial deposits and water bodies was inferred by the compilers;
4) The same basic units as those listed above were compiled and digitized for 9 unpublished quadrangles from scanned field maps by U.S. Geological Survey personnel;
5) The 24 individual quadrangle maps were joined and edge-matched in order to form a seamless digital geologic map layer. Discrepancies along quadrangle boundaries were resolved, and thick-till areas and shallow bedrock areas were added by the compilers in quadrangles where these units had not been previously mapped.

Figure 4. The 24 USGS 7.5-minute, 1:24,000-scale quadrangles in this compilation. Sheet numbers refer to Adobe PDF map files of individual quadrangles.

All geologic mapping was completed at 1:24,000 scale (several quadrangles were previously published at 1:31,680 scale). The 1:24,000-scale, 10-ft (and 20-ft) contour interval topographic base maps (1958–1977 editions) used for this mapping effort are included as part of the digital data package in the *24k_basemaps* folder. The GIS folder included with this report contains four ArcGIS shapefiles, which show the distribution of geologic units that cover the entire map area and are intended for use at quadrangle scale. The shapefiles can be clipped by quadrangle or by town boundary. Unlike the units in conventional geologic maps, the digitally defined map units are arranged in layers according to superposition. The shapefile for till and bedrock is the bottom layer, which is overlain by the succeeding stratified deposits shapefile layer; these materials are shown everywhere they occur, including beneath postglacial and early postglacial deposits such as swamp deposits and stream-terrace deposits, and also beneath water bodies. The postglacial shapefile should be placed on top because these materials overlie the other three layers. Instructions for using the digital files are included in the README file and metadata.

In addition to the seamless digital layers that cover the entire compilation area, Adobe PDF map files of the surficial geology layers shown with 1:24,000-scale topographic base map images have been generated for each quadrangle (see Sheets 1–24, fig. 4).

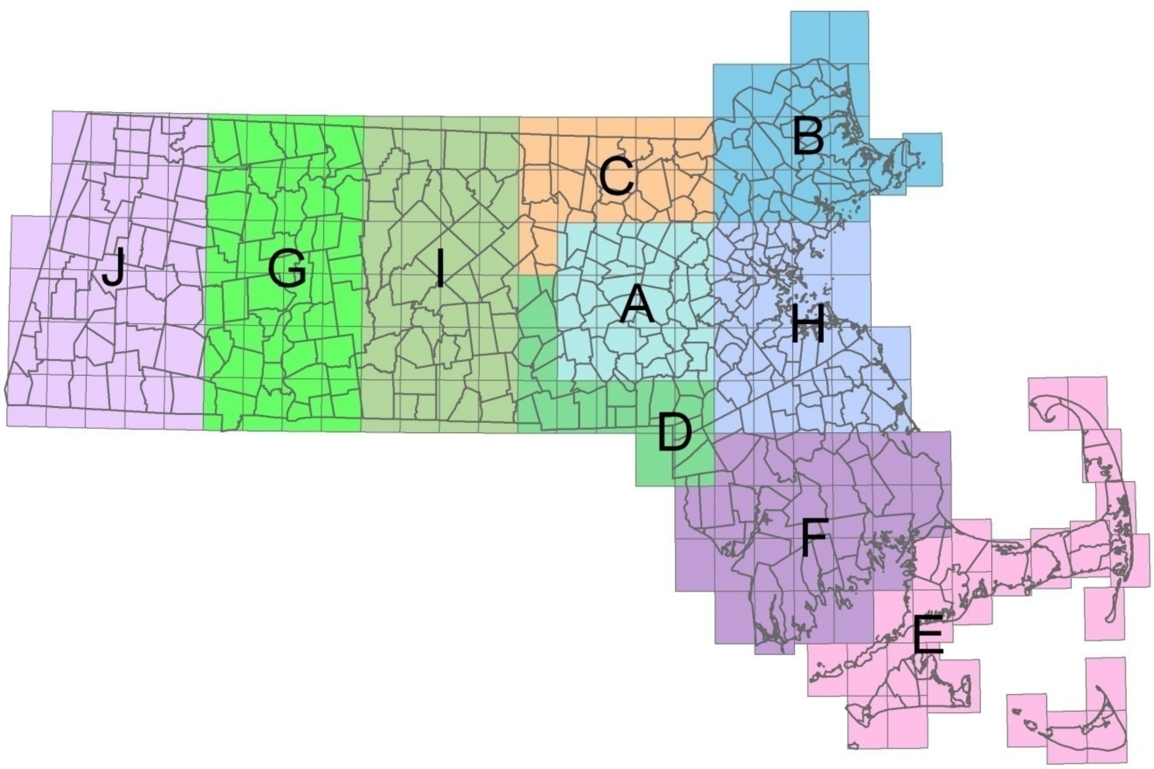


Figure 5. Compilation areas in Massachusetts. Letters represent sections of Open-File Report 2006-1260. Sections published to date are available online at *http://pubs.usgs.gov/of/2006/1260/.*

References Cited

Balk, Robert, 1956a, Bedrock geology of the Massachusetts portion of the Bernardston quadrangle, Massachusetts-Vermont: U.S. Geological Survey Geologic Quadrangle Map GQ–90, scale 1:31,680.

Balk, Robert, 1956b, Bedrock geology of the Millers Falls quadrangle, Massachusetts: U.S. Geological Survey Geologic Quadrangle Map GQ–93, scale 1:31,680.

Balk, Robert, 1957, Geology of the Mount Holyoke quadrangle, Massachusetts: Geological Society of America Bulletin, v. 68, no. 4, p. 481–504, map scale 1:31,680.

Caggiano, J.A., Jr., 1978, Surficial and applied surficial geology of the Belchertown quadrangle, Massachusetts: Amherst, Mass., University of Massachusetts, Ph.D. dissertation, 238 p.

Campbell, K.J., and Hartshorn, J.H., 1980, Surficial geologic map of the Northfield quadrangle, Massachusetts, New Hampshire, and Vermont: U.S. Geological Survey Geologic Quadrangle Map GQ–1440, 1 sheet, scale 1:24,000.

Clark, S.F., Jr., 1987, Bedrock geologic map of the Westhampton quadrangle, Hampshire County, Massachusetts: U.S. Geological Survey Geologic Quadrangle Map GQ–1640, 1 sheet, scale 1:24,000.

Colton, R.B., and Hartshorn, J.H., 1970, Surficial geologic map of the West Springfield quadrangle, Massachusetts and Connecticut: U.S. Geological Survey Geologic Quadrangle Map GQ–892, scale 1:24,000.

Hartshorn, J.H., and Koteff, Carl, 1967, Geologic map of the Springfield South quadrangle, Hampden County, Massachusetts, and Hartford and Tolland Counties, Connecticut: U.S. Geological Survey Geologic Quadrangle Map GQ–678, scale 1:24,000.

Hatch, N.L., Jr., and Hartshorn, J.H., 1968, Geologic map of the Heath quadrangle, Massachusetts-Vermont: U.S. Geological Survey Geologic Quadrangle Map GQ–735, scale 1:24,000.

Hatch, N.L., Jr., 1981, Reconnaissance bedrock geologic map of the Ashfield quadrangle, Franklin County, Massachusetts: U.S. Geological Survey Miscellaneous Field Studies Map MF–855, 1 sheet, scale 1:24,000.

Hatch, N.L., Jr., and Warren, C.R., 1982, Geologic map of the Goshen quadrangle, Franklin and Hampshire Counties, Massachusetts: U.S. Geological Survey Geologic Quadrangle Map GQ–1561, 1 sheet, scale 1:24,000.

Hildreth, C.T., and Colton, R.B., 1982, Surficial geologic map of the Hampden quadrangle, Massachusetts and Connecticut: U.S. Geological Survey Geologic Quadrangle Map GQ–1544, 1 sheet, scale 1:24,000.

Jahns, R.H, 1941, Outwash chronology in northeastern Massachusetts [abs.]: Geological Society of America Bulletin, v. 52, no. 12, pt. 2, p. 1910.

Jahns, R.H, 1951, Surficial geology of the Mount Toby quadrangle, Massachusetts: U.S. Geological Survey Geologic Quadrangle Map GQ–9, scale 1:31,680.

Jahns, R.H, 1953, Surficial geology of the Ayer quadrangle, Massachusetts: U.S. Geological Survey Geologic Quadrangle Map GQ–21, scale 1:31,680.

Jahns, R.H, 1966, Surficial geologic map of the Greenfield quadrangle, Massachusetts: U.S. Geological Survey Geologic Quadrangle Map GQ–474, scale 1:24,000.

Koteff, Carl, 1966, Surficial geologic map of the Clinton quadrangle, Worcester County, Massachusetts: U.S. Geological Survey Geologic Quadrangle Map GQ–567, scale 1:24,000.

Koteff, Carl, 1974, The morphologic sequence concept and deglaciation of southern New England, *in* Coates, D.R., ed., Glacial geomorphology: Binghamton, N.Y., State University of New York, Annual Geomorphology Symposia Series, Proceedings, v. 5, p. 121–144.

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

Langer, W.H., 1979, Map showing distribution and thickness of the principal fine-grained deposits, Connecticut Valley urban area, central New England: U.S. Geological Survey Miscellaneous Investigations Series Map I–1074–C, 2 sheets, scale 1:125,000.

Larsen, F.D., 1972, Surficial geology of the Mount Tom quadrangle, Massachusetts, U.S. Geological Survey Open-File Report OF–72–219, 273 p., 4 map sheets, scale 1:24,000.

Larson, G.J., and Stone, B.D., eds., 1982, Late Wisconsinan glaciation of New England: Dubuque, Iowa, Kendall/Hunt, 252 p.

Leo, G.W., 1974, Map showing unconsolidated materials, Ludlow quadrangle, Massachusetts: U.S. Geological Survey Miscellaneous Field Studies Map MF–503–C, scale 1:24,000.

Mabee, S.B., Stone, B.D., and Stone, J.R., 2004, Precise conversion of paper geologic maps to value-added digital products; the Massachusetts method for surficial geology: Geological Society of America Abstracts with Programs, v. 36, no. 2, p. 78.

MassGIS (Massachusetts Office of Geographic Information), 1999, Surficial geology (1:250,000), October 1999 [statewide data layer]: Vector digital data available at *http://www.mass.gov/mgis/sg.htm*.

Newton, R.M., 1978, Stratigraphy and structure of some New England tills: Amherst, Mass., University of Massachusetts, unpublished Ph.D. dissertation, 256 p.

Oldale, R.N., and Barlow, R.A., 1986, Geologic map of Cape Cod and the Islands, Massachusetts: U.S. Geological Survey Miscellaneous Investigations Series Map I–1763, 1 sheet, scale 1:100,000.

Oldale, R.N., Valentine, P.C., Cronin, T.M., Spiker, E.C., Blackwelder, B.W., Belknap, D.F., Wehmiller, J.F., and Szabo, B.J., 1982, Stratigraphy, structure, absolute age, and paleontology of the upper Pleistocene deposits at Sankaty Head, Nantucket Island, Massachusetts: Geology, v. 10, no. 5, p. 246–252.

Page, L.R., 1967, The role of the United States Geological Survey in Massachusetts, in Farquhar, O.C., ed., Economic geology in Massachusetts: Amherst, Mass., University of Massachusetts, p. 9–28.

Retelle, M.J., 1979, Surficial geology of the southern half of the Bernardston quadrangle, Massachusetts and Vermont: Amherst, Mass., University of Massachusetts, unpublished M.S. thesis, 98 p.

Schafer, J.P., and Hartshorn, J.H., 1965, The Quaternary of New England, *in* Wright, H.E., Jr., and Frey, D.G., eds., The Quaternary of the United States: Princeton, N.J., Princeton University Press, p. 113–128.

Schnabel, R.W., 1971, Surficial geologic map of the Southwick quadrangle, Massachusetts and Connecticut: U.S. Geological Survey Geologic Quadrangle Map GQ–891, scale 1:24,000.

Segerstrom, Kenneth, 1955a, Surficial geology of the Colrain quadrangle, Massachusetts-Vermont: U.S. Geological Survey Geologic Quadrangle Map GQ–82, scale 1:31,680.

Segerstrom, Kenneth, 1955b, Surficial geology of the Williamsburg quadrangle, Massachusetts: U.S. Geological Survey Geologic Quadrangle Map GQ–80, scale 1:31,680.

Segerstrom, Kenneth, 1959, Surficial geology of the Shelburne Falls quadrangle, Massachusetts: U.S. Geological Survey Geologic Quadrangle Map GQ–116, scale 1:31,680.

Stanley, R.S., Clark, S.F., Jr., and Hatch, N.L., Jr., 1982, Bedrock geologic map of the Woronoco quadrangle, Hampden and Hampshire Counties, Massachusetts: U.S. Geological Survey Geologic Quadrangle Map GQ–1565, 1 sheet, scale 1:24,000.

Stone, B.D., 1982, The Massachusetts State surficial geologic map, *in* Farquhar, O.C., ed., Geotechnology in Massachusetts: Boston, University of Massachusetts, p. 11–28.

Stone, B.D., Beinikis, A.I., and Foster, Richard, 1993, Sand and gravel resources of Massachusetts: Boston, Massachusetts, New England Governors' Conference, 2 map sheets, scale 1:250,000.

Stone, B.D., and Borns, H.W., Jr., 1986, Pleistocene glacial and interglacial stratigraphy of New England, Long Island, and adjacent Georges Bank and Gulf of Maine, *in* Sibrava, Vladimir, Bowen, D.Q., and Richmond, G.M., eds., Quaternary glaciations in the Northern Hemisphere: Quaternary Science Reviews, v. 5, p. 39–52.

Stone, J.R., 1978, Preliminary map of surficial deposits in the Shutesbury quadrangle, Massachusetts: U.S. Geological Survey Open-File Report OF–78–285, 7 p. and 1 map sheet, scale 1:24,000.

Stone, J.R., London, E.H., and Langer, W.H., 1979, Map showing textures of unconsolidated materials, Connecticut Valley urban area, central New England: U.S. Geological Survey Miscellaneous Investigations Series Map I–1074–B, 3 sheets, scale 1:125,000.

Stone, J.R., Schafer, J.P., London, E.H., and Thompson, W.B., 1992, Surficial materials map of Connecticut: U.S. Geological Survey Special Map, 2 sheets, scale 1:125,000.

Stone, J.R., Schafer, J.P., London, E.H., DiGiacomo-Cohen, M.L., Lewis, R.L., and Thompson, W.B., 2005, Quaternary geologic map of Connecticut and Long Island Sound basin: U.S. Geological Survey Scientific Investigations Map 2784, 2 sheets, scale 1:125,000, 72-p. pamphlet.

Warren, C.R., and Stone, B.D., 1986, Deglaciation stratigraphy, mode and timing of the eastern flank of the Hudson-Champlain lobe in western Massachusetts, *in* Cadwell, D.H., ed., The Wisconsinan Stage of the First Geological District, eastern New York: New York State Museum Bulletin, v. 455, p. 168–192.

Weddle, T.K., Stone, B.D., Thompson, W.B., Retelle, M.J., Caldwell, D.W., and Clinch, J.M., 1989, Illinoian and late Wisconsinan tills in eastern New England; transect from northeastern Massachusetts to west-central Maine, Trip A-2, *in* Berry, A.W., Jr., ed., Guidebook for field trips in southern and west-central Maine: New England Intercollegiate Geological Conference, 81st Annual Meeting, p. 25–85.

Wentworth, C.K., 1922, A scale of grade and class terms for clastic sediments: Journal of Geology, v. 30, no. 5, p. 377–392.

Appendix

Sources of Data by 7.5-Minute Quadrangle

Heath Quadrangle

Map units were reproduced from Hatch and Hartshorn (1968). Glacial Stratified Deposits include predominantly coarse-grained glaciofluvial and glaciodeltaic sediments graded to small glacial lakes in the Deerfield River, West Branch North River, and Mill Brook valleys. Thick-till areas were delineated based on topographic analysis. The shallow bedrock unit represents areas of abundant outcrop but is shown only where the bedrock mapper made structural measurements. Some areas of shallow bedrock were added to those shown on the published map using topographic analysis, but significant additional areas of shallow bedrock and bedrock outcrops occur, particularly in areas of thin till that have steep slopes and irregular topography. Some postglacial units were mapped using 2005 orthophoto images.

Colrain Quadrangle

Map units were modified from Segerstrom (1955a). Glacial Stratified Deposits include predominantly coarse-grained glaciofluvial and glaciodeltaic sediments graded to small glacial lakes in the Green River, Hinsdale Brook, and North River valleys and several tributary valleys. Coarse- and fine-grained deposits of glacial Lake Hitchcock occur in the southeast corner of the quadrangle. Bedrock outcrops were mapped mainly in areas of glacial stratified deposits. The shallow-bedrock unit is slightly modified from the Qgm (thin ground moraine) unit of Segerstrom (1955a), which is defined as “thin deposits of ground moraine (till) with many exposures of bedrock;” this unit is more extensive than in other quadrangles and is probably overmapped. The thick-till unit is slightly modified from the Qgd (drumlins) unit and includes some areas within the Qgt unit of Segerstrom (1955a). Additional areas of thick till may be expected in places not mapped as shallow bedrock, particularly beneath smooth slopes on the northerly sides of bedrock hills. Some postglacial units were mapped using 2005 orthophoto images.

Bernardston Quadrangle

Stone, J.R., 1975, unpublished field map; Larsen, F.D., 1977, unpublished field map. Mapping in part based on an unpublished M.S. thesis by Retelle (1979). Glacial Stratified Deposits include coarse- and fine-grained deposits of glacial Lake Hitchcock in the Green River, Fall River, and Connecticut River valleys, and deposits of local higher level lakes. Distribution of bedrock outcrops and shallow-bedrock areas is from Balk (1956a). The shallow-bedrock unit represents areas of small scattered bedrock outcrops. Some postglacial units were mapped using 2005 orthophoto images.

Northfield Quadrangle

Map units were reproduced from Campbell and Hartshorn (1980). Glacial Stratified Deposits are predominantly coarse- and fine-grained deposits of glacial Lake Hitchcock in the Connecticut River valley. Thick-till areas were mapped based on topographic analysis and the position of drumlin axes shown on the map of Campbell and Hartshorn (1980). The shallow-bedrock unit represents areas of thin surficial deposits and numerous bedrock outcrops.

Ashfield Quadrangle

Hartshorn J.H., 1975, unpublished field map. Glacial Stratified Deposits include predominantly coarse-grained glaciofluvial and glaciodeltaic sediments graded to small glacial lakes in the Deerfield River, Clesson Brook, and South River valleys. Distribution of bedrock outcrops and some shallow-bedrock areas is from Hatch (1981). Additional shallow-bedrock areas were interpreted from topographic analysis. Some postglacial units were mapped using 2005 orthophoto images.

Shelburne Falls Quadrangle

Map units were modified from Segerstrom (1959). Glacial Stratified Deposits include predominantly coarse-grained glaciofluvial and glaciodeltaic sediments graded to small ice-dammed glacial lakes in the South River, Bear River, and Deerfield River valleys. Coarse- and fine-grained deposits of glacial Lake Hitchcock occur in the eastern part of the quadrangle. Bedrock outcrops are mapped mainly in areas of glacial stratified deposits. The shallow-bedrock unit is modified from the Qgm (thin ground moraine) unit of Segerstrom (1959), which is defined as “thin deposits of ground moraine (till) with many exposures of bedrock;” this unit is more extensive than in other quadrangles and is probably overmapped. The thick-till unit is modified from the Qgd (drumlins) unit of Segerstrom (1959). Additional areas of thick till may be expected in places not mapped as shallow bedrock, particularly beneath smooth slopes on the northerly sides of bedrock hills.

Greenfield Quadrangle

Map units were reproduced from Jahns (1966). Glacial Stratified Deposits are predominantly coarse- and fine-grained deposits of glacial Lake Hitchcock in the Green River, Deerfield River, and Connecticut River valleys; other glaciofluvial and glaciolacustrine deposits graded to higher level ice-dammed lakes occur in tributary valleys. The shallow-bedrock unit is modified from the Qgm (thin ground moraine) unit of Jahns (1966), which is defined as “generally thin deposits of ground moraine (till) with many exposures of bedrock.” The thick-till unit is modified from the Qgd (drumlins) unit of Jahns (1966). Additional areas of thick till may be expected in places not mapped as shallow bedrock, particularly beneath smooth slopes on the northerly sides of bedrock hills.

Millers Falls Quadrangle

Stone, J.R., 1975, unpublished field map. Glacial Stratified Deposits include predominantly coarse-grained glaciofluvial and glaciodeltaic sediments graded to small glacial lakes in the Sawmill River and Millers River valleys and their tributary valleys. In the Connecticut River valley, coarse- and fine-grained sediments of glacial Lake Hitchcock are present. Distribution of bedrock outcrops and shallow-bedrock areas is from Balk (1956b). Additional bedrock outcrops and shallow-bedrock areas are most likely present, particularly in areas of thin till that have steep slopes and irregular topography. Some postglacial were units mapped using 2005 orthophoto images.

Goshen Quadrangle

Map units were modified from Hatch and Warren (1982). Glacial Stratified Deposits include ice-marginal glacial lake deposits in the Chapel Brook and West Branch Mill River valleys, which drained easterly toward the retreating ice lobe in the Connecticut valley, and remnants of sediment-dammed glacial lake deposits in the Westfield River valley. Bedrock outcrops include only those examined in the field during bedrock mapping (Hatch and Warren, 1982). The distribution of shallow-bedrock areas was interpreted by topographic analysis and the location of bedrock outcrops. Additional bedrock outcrops and shallow-bedrock areas are present, particularly in areas of thin till that have steep slopes and (or) irregular topography. Some postglacial units were mapped using 2005 orthophoto images.

Williamsburg Quadrangle

Map units were reproduced from Segerstrom (1955b). Glacial Stratified Deposits include ice-marginal glacial lake deposits in the Roaring Brook and West Brook valleys, which drained easterly toward the retreating ice lobe in the Connecticut valley, and sediment-dammed glacial lake deposits in the Mill River valley, in the southwestern part of the quadrangle. Coarse- and fine-grained deposits of glacial Lake Hitchcock occur in the eastern part of the quadrangle. Bedrock outcrops were mapped mainly in areas of glacial stratified deposits. The shallow-bedrock unit is slightly modified from the Qgm (thin ground moraine) unit of Segerstrom (1955b), which is defined as “thin deposits of ground moraine (till) with many exposures of bedrock;” this unit is more extensive than in other quadrangles and is probably overmapped. The thick-till unit is slightly modified from the Qgd (drumlins) unit of Segerstrom (1955b). Additional areas of thick till may be expected in places not mapped as shallow bedrock, particularly beneath smooth slopes on the northerly sides of bedrock hills.

Mount Toby Quadrangle

Map units were reproduced from Jahns (1951). Glacial Stratified Deposits include predominantly coarse- and fine-grained deposits of glacial Lake Hitchcock. Bedrock outcrops are mapped mainly in areas of glacial stratified deposits. The shallow-bedrock unit is slightly modified from the Qgm (thin ground moraine) unit of Jahns (1951), which is defined as “thin deposits of ground moraine (till) with many exposures of bedrock;” this unit is more extensive than in other quadrangles and is probably overmapped. The thick-till unit is slightly modified from the Qgd (drumlins) unit of Jahns

(1951). Additional areas of thick till may be expected in places not mapped as shallow bedrock, particularly beneath smooth slopes on the northerly sides of bedrock hills.

Shutesbury Quadrangle

Map units were reproduced from Stone (1978). Glacial Stratified Deposits include deposits of ice-dammed glacial lakes in the west- and northwest-draining valleys of Amethyst Brook, Dean Brook, Roaring Brook, and the Sawmill River, and deposits of sediment-dammed lakes in the south-draining valleys of the West Branch Swift River and Doolittle Brook. Coarse- and fine-grained deposits of glacial Lake Hitchcock are present in the southwestern part of the quadrangle. The shallow-bedrock unit is defined as areas where bedrock is inferred to be less than 10 ft beneath the surface and where numerous bedrock outcrops are likely to be found.

Westhampton Quadrangle

Warren, C.R., 1976, unpublished field map. Glacial Stratified Deposits include coarse-grained, ice-dammed glacial lake deposits in the Sodom Brook and North Branch Manhan River valleys, which drained easterly toward the retreating ice margin. Remnants of coarse-grained sediment-dammed glacial lake deposits are present in the south-draining Westfield River valley. Distribution of bedrock outcrops is from Clark (1987). Shallow-bedrock areas were interpreted from topographic analysis and the distribution of bedrock outcrops. Additional bedrock outcrops and shallow-bedrock areas are most likely present, particularly in areas of thin till that have steep slopes and (or) irregular topography. Some postglacial units were mapped using 2005 orthophoto images.

Easthampton Quadrangle

Larsen, F.D., 1976, unpublished field map. Glacial Stratified Deposits include coarse-grained, ice-dammed glacial lake deposits in the Meadow Brook, Turkey Brook, and North Branch Manhan River valleys, which drained easterly toward the retreating ice margin. Coarse- and fine-grained deposits of glacial Lake Manhan and glacial Lake Hitchcock are present in the lowland areas. Bedrock outcrops have not been mapped in this quadrangle; shallow-bedrock areas were delineated using topographic analysis. Additional shallow-bedrock areas are most likely present, particularly in areas of thin till that have steep slopes and (or) irregular topography. Some postglacial units were mapped using 2005 orthophoto images.

Mount Holyoke Quadrangle

Map units were modified from Balk (1957) using unpublished field maps from Larsen, F.D. (1976) and Stone, J.R. (1976). Glacial Stratified Deposits are predominantly coarse- and fine-grained deposits of glacial Lake Hitchcock. The shallow-bedrock unit is modified from the areas shown as bedrock units on the map of Balk (1957); these areas are likely to contain abundant bedrock outcrops. Thick-till areas were interpreted from topographic analysis. Some postglacial units were mapped using 2005 orthophoto images.

Belchertown Quadrangle

Map units were reproduced from Caggiano (1978). Glacial Stratified Deposits include coarse-grained deposits of sediment-dammed glacial lakes in the Jabish Brook and Broad Brook valleys and an ice-dammed glacial lake in the Knights Pond valley, and coarse- and fine-grained deposits of glacial Lake Hitchcock in the western part of the quadrangle. The shallow-bedrock unit is defined as areas where surficial material is less than 10 ft thick. Thick-till areas were mapped based on topographic analysis and on the position of drumlin axes shown on the map of Caggiano (1978). Some postglacial units were mapped using 2005 orthophoto images.

Woronoco Quadrangle

Warren, C.R., 1976, unpublished field map. Glacial Stratified Deposits include coarse-grained, ice-dammed glacial lake deposits in upland areas, and coarse- and fine-grained deposits of glacial Lake Westfield in the lowlands. Distribution of bedrock outcrops is from Stanley and others (1982). Shallow-bedrock areas were interpreted from topographic analysis and from the distribution of bedrock outcrops. Additional bedrock outcrops and shallow-bedrock areas are most likely present, particularly in areas of thin till that have steep slopes and irregular topography. Some postglacial units were mapped using 2005 orthophoto images.

Mount Tom Quadrangle

Map units were reproduced from Larsen (1972). Glacial Stratified Deposits include coarse- and fine-grained deposits of glacial Lake Westfield in the western part of the quadrangle, glacial Lake Manhan in the northern part, and glacial Lake Hitchcock in the eastern part. The shallow-bedrock unit is defined as areas of abundant outcrops. Thick-till areas were mapped based on topographic analysis and on the position of drumlin axes shown on the map of Larsen (1972).

Springfield North Quadrangle

Larsen, F.D., 1976, unpublished field map. Glacial Stratified Deposits include coarse- and fine-grained deposits of glacial Lake Hitchcock. Bedrock outcrops and shallow-bedrock areas were interpreted from topographic analysis and orthophoto imagery. Some postglacial units were mapped using 2005 orthophoto images.

Ludlow Quadrangle

Map units were modified from Leo (1974) using unpublished field maps by Larsen, F.D. (1976). Glacial Stratified Deposits include coarse-grained, ice-dammed glacial lake deposits in upland tributary valleys of the Chicopee River, and coarse-grained deltaic deposits of glacial Lake Hitchcock in the western part of the quadrangle. The shallow-bedrock unit is defined as areas of abundant outcrops. Thick-till areas were mapped based on topographic analysis.

Southwick Quadrangle

Map units were reproduced from Schnabel (1971). Glacial Stratified Deposits include ice-dammed glacial lake deposits in the Dickinson Brook and Munn Brook valleys, sediment-dammed glacial lake deposits in the vicinity of Congamond Lakes, and coarse-grained deposits of glacial Lake Westfield in the northeastern part of the quadrangle. The shallow-bedrock unit is defined as areas of abundant outcrops and patches of thin surficial material. Thick-till areas were mapped based on topographic analysis and on the position of drumlin axes shown on the map of Schnabel (1971).

West Springfield Quadrangle

Map units were reproduced from Colton and Hartshorn (1970). Glacial Stratified Deposits in the eastern half of this quadrangle include coarse- and fine-grained deposits of glacial Lake Hitchcock; the western half of the quadrangle includes predominantly coarse-grained deposits of glacial Lake Westfield. The shallow-bedrock unit is defined as large areas of nearly continuous bedrock outcrop. Thick-till areas were mapped based on topographic analysis and on the position of drumlin axes shown on the map of Colton and Hartshorn (1970).

Springfield South Quadrangle

Map units were reproduced from Hartshorn and Koteff (1967). Glacial Stratified Deposits are predominantly coarse- and fine-grained deposits of glacial Lake Hitchcock. The shallow-bedrock unit is defined as areas of scattered outcrops and areas of thinly veneered bedrock. Thick-till areas were mapped based on topographic analysis, on well and test-hole data, and on the position of drumlin axes shown on the map of Hartshorn and Koteff (1967).

Hampden Quadrangle

Map units were reproduced from Hildreth and Colton (1982). Glacial Stratified Deposits include coarse-grained deposits of a lowering series of ice-dammed glacial lakes in the upper Scantic River valley and its tributaries, and coarse-grained deposits of sediment-dammed glacial lakes in the lower Scantic and Mill River valleys. Coarse-grained deltaic deposits of glacial Lake Hitchcock are present in the northwestern part of the quadrangle. The shallow-bedrock unit is defined as areas of closely spaced outcrops and areas where surficial materials are less than 10 ft thick. Thick-till areas were mapped based on topographic analysis, on well and test-hole data, and on the position of drumlin axes shown on the map of Hildreth and Colton (1982).