MAP NO. GEO-091-024000-SMAP

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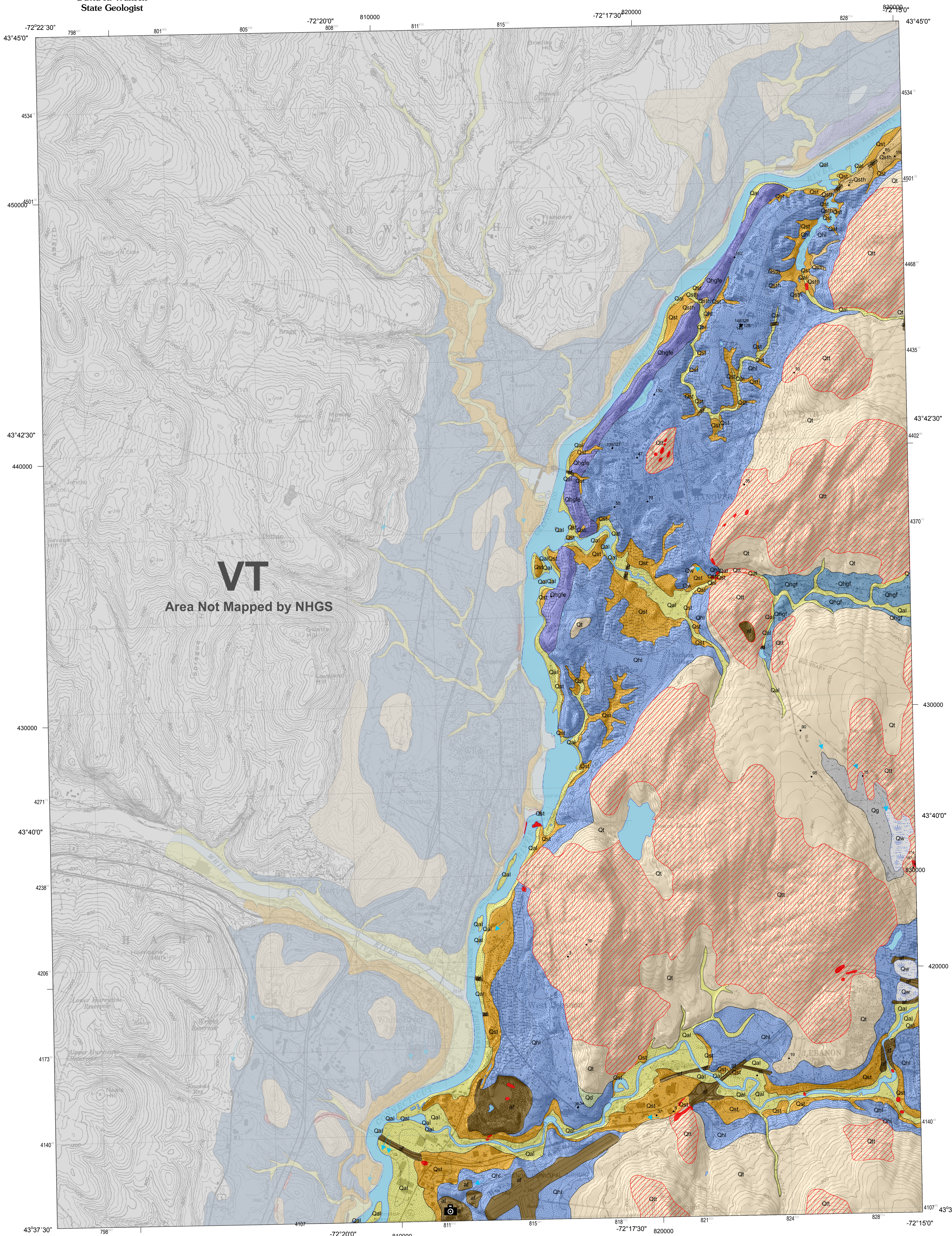
SURFICIAL GEOLOGIC MAP OF THE HANOVER QUADRANGLE

Grafton County, New Hampshire



Base map (provisional) by the U.S. Geological Survey, 1987, Hanover, New Hampshire. 10,000-foot grid ticks based on New Hampshire coordinate system. 1000-meter Universal Transverse Mercator grid ticks, Zone 19. Horizontal Datum: 1983 North America Datum.

Geology mapped 2004
Digital map published 2009
Updated 7/23/2010

SCALE 1:24,000

Contour Interval 20 Feet

UTM GRID and 2009 MAGNETIC NORTH DECLINATION AT NE CORNER OF SHEET

Quadrangle Location
GRANIT 7.5" Tile No. 91

DESCRIPTION OF MAP UNITS

Qal — **Alluvium (Holocene)** - Sand, silt, gravel, and muck in flood plains along present-day rivers and streams. As much as 3 meters (10 feet) thick. Extent of alluvium indicates most areas flooded in the past that may be subject to future flooding. In places the unit indistinguishable from, grades into, or is interbedded with swamp deposits (Qw). Note: Well-sorted surficial materials along the margins of the Connecticut River in the northern part of the map are mapped as Qst deposits because the river level is 20-40 feet higher here than it would be naturally, due to the Wilder Dam, just a few miles downstream

Qw — **Wetland deposits (Holocene)** - Muck, peat, silt, and sand deposited in poorly drained areas. Generally 0.5 to 3 meters (1 to10 feet) thick, but may be much thicker in large bogs. In places, this unit is indistinguishable from, grades into, or is interbedded with stream alluvium (Qal)

Qd — **Dune sand (Holocene and Pleistocene)** - Sand and silt. Consists of sand dunes deposited on hillsides by winds that scoured Glacial Lake Hitchcock bottom deposits after the lake dried. Thickness varies. As much as 6 meters (20 feet) thick

Qst — **Stream terrace deposits (Holocene and Late Pleistocene)** - Sand, silt, clay, gravel and occasional muck on terraces cut into glacial deposits in major stream valleys. These terraces formed in part during late-glacial time as streams cut their channels through local base level deposits following the retreat of the ice sheet. The base level of the Connecticut River, to which the streams ultimately drain, also dropped after the draining of Glacial Lake Hitchcock. In some places, erosional scarps are present and mapped in this unit; in which case, several terrace levels may be represented by this unit but are not mapped separately because they are very narrow and sparse. In places, these deposits may be thin or missing on the present terrace surface, in which case the terrace is directly underlain by the material that was eroded out to form the terrace. These terrace remnants range from 0.5 to 5 meters (1 to 15 feet) thick

Qsth — **High-level stream terrace deposits (Holocene and Late Pleistocene)** Sand, silt, gravel and occasional muck on terraces cut into glacial deposits in major stream valleys. These terraces formed in part during late-glacial time as the streams cut down their channels through local base level deposits following the retreat of the ice sheet. The base level of the Connecticut River also dropped after the draining of Glacial Lake Hitchcock. These high-level terraces are mapped only in the Connecticut and Mascoma River. In the Connecticut River Valley, these deposits probably represent the lowering of Glacial Lake Hitchcock to the Lily Pond Stage. Some streams have more than one higher stream terrace level included in this unit because the terrace remnants are too small to map at this scale. These terraces have been differentiated by the present author on a map from Goldthwaite (1925, Fig. 20, p. 66). In places, these deposits may be very thin or missing on the present terrace surface. From 0.5 to 3 meters (1-10 feet) thick

GLACIOFLUVIAL DEPOSITS (Holocene and Pleistocene)

Qg — Undifferentiated outwash deposits in the valley between Mt. Support and Quarry Hill (Holocene and Pleistocene)
Sand, gravel, and silt. Consists of thin glaciofluvial outwash and/or alluvial deposits laid down by melt water in contact with or beyond the ice margin. Thickness varies from 0 to 6 meters (0 to 20 feet)

GLACIOFLUVIAL AND GLACIOLACUSTRINE DEPOSITS (Pleistocene)

Glacial Lake Hitchcock Deposits

Sand, gravel, silt, and clay deposited by glacial melt water in contact with or beyond adjacent ice as kame-delta, shore, nearshore, outwash and bottom-set beds of Glacial Lake Hitchcock, whose level was controlled by a glacial drift dam at Rocky Hill, Connecticut, and a spillway at New Britain, Connecticut. Glacial Lake Hitchcock occupied the Connecticut Valley for several thousand years between 15,000-16,000 years ago to about 12,000-11,000 years ago. The front of the Late-Wisconsinan ice sheet may have still been in contact with the lake near its northern end when the Rocky Hill drift dam failed and the lake drained. Unit Qhl consists mostly of bottom-set beds, mostly silt and clay varves (rhythmic couplets generally less than 2.5 centimeters [1 inch] thick) whose overall thickness is as much as 76 meters (250 feet) (Campbell and Hartshorn, 1980). Unit Qhgf consists mostly of kame-delta, fan and glaciofluvial outwash deposits built into and graded to the lake level. The topset-foreset contact elevation of a delta at Etna, in the adjacent Enfield quadrangle, was measured at 197.5 meters by Koteff and Larsen (1989). Unit Qhgfe is an esker (Lyons, 1955) that was deposited by melt water in a tunnel within the glacier and was subsequently covered by draped lake-bottom silt and clay deposits several meters or more thick.

Qhl — Lake bottom and nearshore deposits as much as 76 meters (250 feet) thick

Qhgf — Outwash deposits as much as 30 meters (100 feet) thick

Qhgfe — Esker deposits draped by 1 to 6 meters (3 to 20 feet) of silt, clay, and fine sand lake-bottom deposits. Esker as much as 30 meters (100 feet) thick

Qt / **Qtt** — **Till (PLEISTOCENE)** - Non-sorted to poorly sorted mixture of clay, silt, sand, pebbles, cobbles, and boulders; a predominantly sandy mixture containing some gravel. Light to dark gray in color. Varying proportions of silt and sand for the matrix, which ranges form loose to compact and contains a variety of irregularly shaped rock fragments, most of which are less than 10 centimeters (4 inches) long. Most of the uplands in the quadrangle are mantled by till deposited directly by the ice sheet. Generally underlies most other deposits. Thickness varies and generally is less than 6 meters (20 feet) but is probably more than 30 meters (100 feet) under some drumlins and streamlined hills. Qtt - Thin till; depth to bedrock generally 3 meters (10 feet) of less

af — **Artificial Fill**- Manmade. Material varies from natural sand and gravel to quarry waste and sanitary landfill. Includes highway and railroad embankments, airport runways, and the shell of dams. This material is mapped only where it can be identified using the topographic contour lines or where actually observed. Minor artificial fill is present in virtually all developed areas and bridge abutments throughout the quadrangle. Thickness of fill varies

Area in Vermont Not Mapped by NHGS

Geologic unit contacts shown in this part of the map area are based on interpretation of previous surficial geologic mapping in Vermont combined with limited reconnaissance fieldwork by the author.

EXPLANATION OF MAP SYMBOLS

Contact

Meltwater channel - Channel cut by glacial meltwater

158 **Glacial grooves and striations** - Observation is at tip of arrow. Arrow indicates direction of ice flow. Number is azimuth measurement

Bedrock Exposure - In part from aerial photographs, soil surveys, and previous maps. Not all individual outcrops are shown on map.

B **Location of designated map photo**

40 **New Hampshire Geological Survey well database**- Point indicates well location, number indicates depth to bedrock surface in feet

MATERIALS OBSERVATIONS

Texture of stratified deposits - Indicated to a depth of at least 5 feet

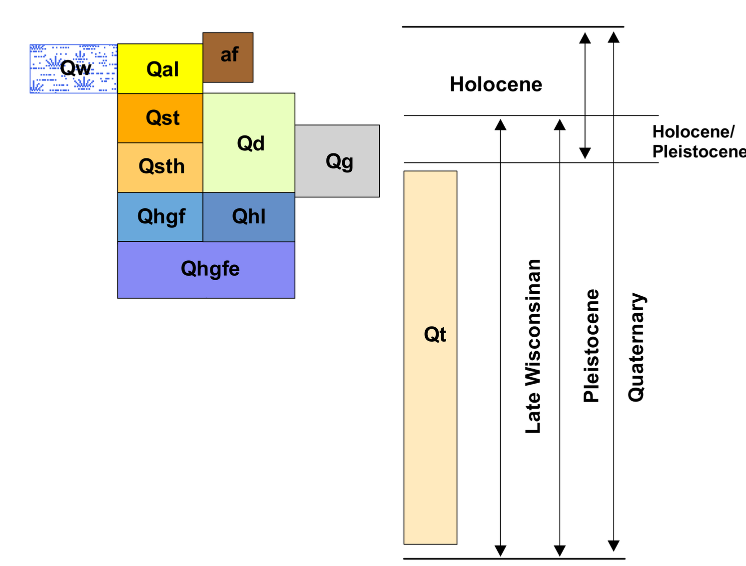
Gravel

Mixed sand and gravel

Sand with minor silt

Silt and clay, with minor sand

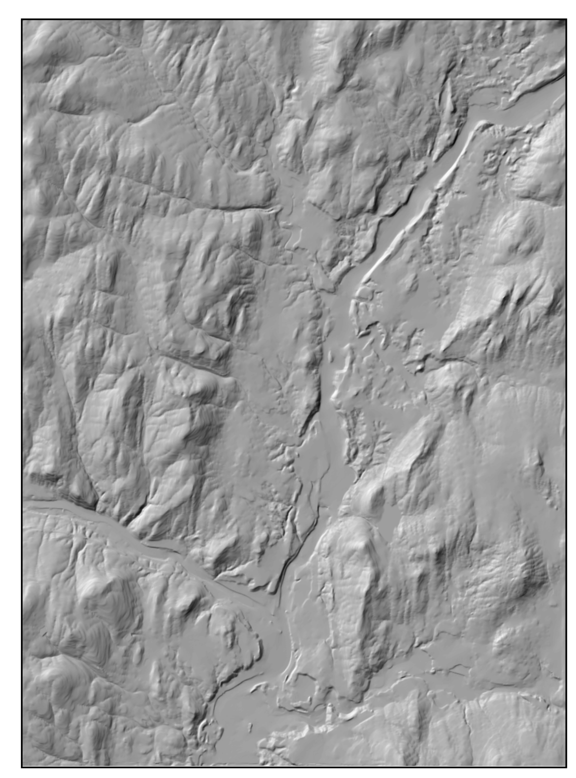
CORRELATION OF MAP UNITS



PHOTOS

Photo A: This photo shows a typical till exposure in New Hampshire. Note the variety of particle sizes from angular boulders to gray compact clay. (Image source: Lee Wilder, NHGS)

Photo B: This photo shows relatively thick varves (rhythmically bedded fine sand, silt, and clay bottom deposits) of Glacial Lake Hitchcock located in a pit in West Lebanon, near the airport. (Image source: Lee Wilder, NHGS)



Hillshade Map: Sun direction 45° west of north, Sun angle 45°
Source: USGS National Elevation Dataset 10 Meter

Glacial Geology of New Hampshire

During the Pleistocene epoch, between 2 million and 10,000 years ago, continental glaciers advanced repeatedly from ice centers in northern Canada into New England. Pre-existing drainages established by millions of years of weathering and stream erosion were modified by glacial erosion, which deepened valleys and carved signature 'U-shaped' notches, such as Crawford Notch, in the White Mountains. Evidence of glacial erosion can be found across much of the state on scratched and polished bedrock surfaces as sets of parallel grooves oriented in the direction of glacial flow (striations). Vertical erosion of bedrock by glaciers may have been as much as 200 feet locally, but averages much less (Goldthwait et al., 1951).

In New Hampshire, sedimentary evidence remains for two glacial advances. A glaciation that occurred perhaps as much as 120,000 years ago is known from a gray, highly compacted till (sediment with an assortment of grain sizes ranging from clay to boulders deposited by glacial ice, commonly referred to as 'hardpan'). Glacial geologists call this Illinoian till. This till often contains a brown oxidized layer at its surface. Such oxidation is evidence of surface weathering during an intervening ice-free phase between glacial advances (interglacial period). This till is generally overlain by a less compact, sandier, light-brown till deposited during the most recent glaciation known to geologists as the Wisconsinan (Koteff and Pessl, 1985). This two-till stratigraphy is commonly observed in exposures of the cores of drumlins, which are teardrop-shaped mounds of glacially-streamlined sediment with their long axes oriented parallel to the direction of glacier flow. Thickness of glacial sediments may locally approach 400 feet in valleys and over 100 feet in drumlins, but 10 to 40 foot thicknesses are more commonly encountered, and many upland areas have little to no glacial cover.

The global climate warmed 25,000 years ago causing the Wisconsinan ice sheet to retreat from its maximum extent, which reached as far south as Long Island, New York, and Nantucket Island, Massachusetts. Recent work utilizing annual layers in glacial lake sediments, known as varves, in concert with radiocarbon dating, suggests glaciers began their retreat from southern New Hampshire approximately 16,000 years ago. Ice then retreated to the vicinity of the White Mountains before readvancing briefly 14,000 years ago. Moraines, which are ridge-like accumulations of unsorted rock debris of all sizes formed at the margin of the ice sheet, were emplaced at this time in the Bethlehem-Littleton area where stillstands and minor glacial readvances occurred. A final retreat of ice across the New Hampshire-Quebec border occurred by 12,300 years ago (Ridge, 2003).

As the glacier thinned and receded, ice-bound sediments - boulders, gravel, sand, and clay - were transported and re-deposited by glacial meltwater. Many of New Hampshire's glacial deposits consist of these water-laid glacial lake and glacial stream deposits known as stratified drift. These deposits commonly serve as sources of sand and gravel for use as construction aggregates, and where continuous contain sufficient quantities of ground water to serve as aquifers.

Some sub-glacial stream deposits of sand and gravel became distinctive sinuous ridges (eskers) as their enclosing ice-tunnels melted away. Other common meltwater deposits include deltas formed in glacial lakes, which pooled at the margin of the retreating ice. Upland streams also fed into these lakes, forming sand-and-gravel deltas along the valley margins. Where meltwater deposits formed in contact with glacial ice (ice-contact deposits), they often recorded systematic retreat of the ice sheet through changes in morphology, sediment texture, and structure. Ice-contact deposits that record successive occurrences of ice-marginal positions are termed morphosequences and are common in major river valleys across the state (Koteff and Pessl, 1981).

Large glacial lakes formed in the Connecticut and Merrimack River valleys as the ice sheet blocked north-draining rivers and deltas blocked drainage in larger valleys to the south. In the deeper waters of larger lakes, alternating layers of lake-bottom silt and clay were deposited that retain signatures of the seasonal variations in meltwater flow (varves). Many smaller lakes formed in tributary valleys; indeed most of the water-laid glacial sediments in New Hampshire were deposited into ponded water.

The immense mass of the continental ice sheet depressed the surface of the continent. When the ice sheet retreated to the vicinity of the White Mountains, the continental landmass was relieved of the enormous weight of ice and began to rebound. (Koteff et al., 1993). Rebound of the continent allowed drainage networks to take their modern form as streams cut terraces through older glacial sediments and deposited alluvium in their floodplains in post-glacial times.

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Surficial Geologic Map of the Hanover Quadrangle Grafton County, New Hampshire

By Carol T. Hildreth

Surficial Geologic Map Series GEO-091-024000-SMAP

Cartography By: Kristen Svendsen and Ernst Kastning

Funding for the preparation and digitization of this map was provided by the U.S. Geological Survey STATEMAP program cooperative agreement number 03HQAG0111, the Town of Hanover (NH), and by the New Hampshire Geological Survey, NH Department of Environmental Services.

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