MAP NO. GEO-092-024000-SMAP

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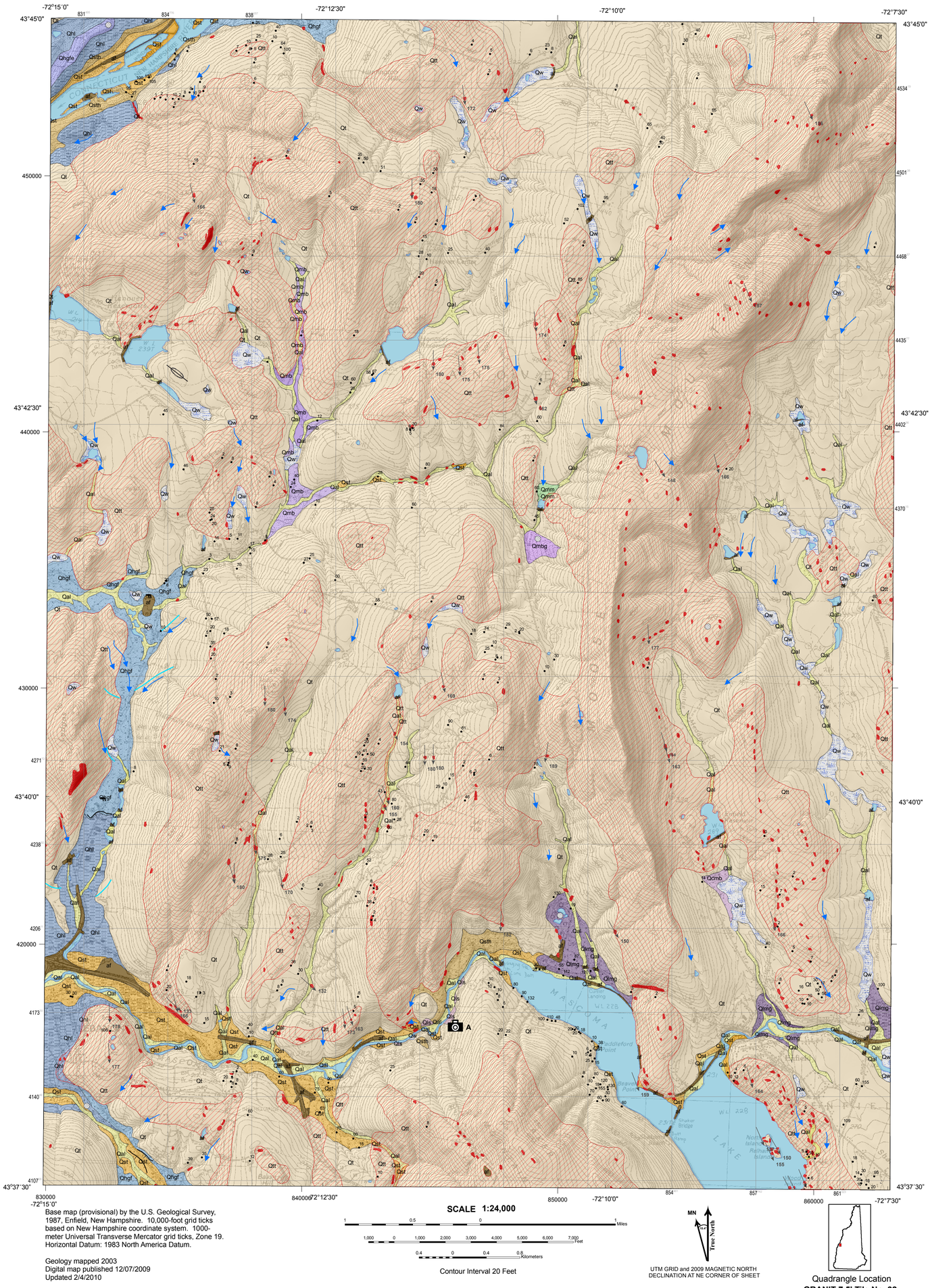
SURFICIAL GEOLOGIC MAP OF THE ENFIELD QUADRANGLE
Grafton County, New Hampshire

USGS science for a changing world



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 is 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 northwest corner 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, which is located just downstream in the Hanover quadrangle

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)

Qls — **Modern landslide scar and deposits (Holocene)**- Consists mainly of till and slumped till materials. Found along the walls of the Mascoma River Gorge in the vicinity and downstream of the intersection of Routes 4 and 4A for about ½ mile. Most recent landslides are on the south side of the river where the bank has been undercut by an abandoned gravel roadbed carved into the valley walls. These landslides include one that moved in 2003 and several that have revegetated completely, with many others intermediate between the two extremes in development. Many landslides, both vegetation-stabilized and active, are present in this area but not all are mapped. The head of the largest active landslide scarp is within 10's of feet of Route 4. The author of this report predicts reactivation of this slide in the near future. As much as 6 meters (20 feet) thick. However, some of the landslide deposits have been removed from the gravel road surface by man or carried away by the river where the deposit has slumped into the river

Qmm — **Alluvial fan and shallow lacustrine deposits in the Moose Mountain Road area (Holocene and Late Pleistocene)**- Consists of sand, gravel, silt and clay laid down on a relatively flat surface as alluvial fan and shallow lake deposits at the foot of the steep western side of Moose Mountain, just south of Moose Mountain Road. Generally 0.5 to 1.5 meters (1 to 5 feet) thick

Qst — **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, 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. Most streams have more than one higher stream terrace level included in this unit. In particular, see the two separate levels of the unit along the north side of the Mascoma River valley about 0.3-0.4 miles (0.5-0.7 km) downstream from the Routes 4-4A intersection. These two represent abandoned channels of the late-glacial Mascoma River. The lower of these terraces is depicted on a map from Goldthwait (1925, Fig. 21, p. 67-69). In places, these deposits may be very thin or missing on the present terrace surface. From 0.5 to 5 meters (1 to 10 feet) thick

GLACIOFLUVIAL DEPOSITS (Holocene and Pleistocene)

Qcmb — **Undifferentiated alluvial and outwash deposits in the Committee Meadow Brook area (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)

Qmb — **Undifferentiated alluvial and outwash deposits in the Mink Brook area upstream of Etna (Holocene and Pleistocene)** Sand, gravel, and silt. Consists of glaciofluvial outwash and/or alluvial deposits laid down by melt water or meteroic water in contact with or beyond the ice margin. Thickness varies from 0 to 6 meters (0 to 20 feet)

Qmbg — **Ice-contact and outwash deposits in the Mink Brook area (Pleistocene)** Sand, gravel, and silt. Consists of deposits laid down by melt water in contact with or beyond the ice margin. Thickness varies from 0 to 12 meters (0 to 40 feet)

Qlmg — **Ice-contact and/or outwash deposits of Glacial Lake Mascoma (Pleistocene)** Sand, gravel, silt, and clay. Consists of glaciofluvial outwash and/or ice-contact deposits underlain by lacustrine silt and clay deposits in places. Deposited within or beyond adjacent ice and graded to glacial Lake Mascoma, which was dammed by thick till (Qt) deposits in the valley of the Mascoma River between Mt. Tug and Shaker Mountain. Thick till deposits in this area have been progressively cut down by the river as evidenced by abandoned high stream terraces and their deposits (Qsth). May include esker, delta, and/or fan deposits. A well hole near the southern end of the deposit near Route 4 encountered [units in feet]: 30 coarse gravel/ 57 silt and clay/ bedrock (Flanagan, 1996, LHW 217). Thickness varies from 0 to 27 meters (0 to 90 feet)

Qt / **Qtt** — **Till (PLEISTOCENE)** - Nonsorted to poorly sorted mixture of clay, silt, sand, pebbles, cobbles, and boulders; a predominantly sandy diamicton containing some gravel. Light to dark gray. 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. Denny (1958. p. 76-77) described sandy and compact till in the valley of Stoney Brook, near the south edge of the map. Qtt - Thin till; depth to bedrock generally 3 meters (10 feet) or less

af — **Artificial Fill**- Man-made. Material varies from natural sand and gravel to quarry waste to sanitary landfill, includes highway and railroad embankments and dredge spoil areas. 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

EXPLANATION OF MAP SYMBOLS

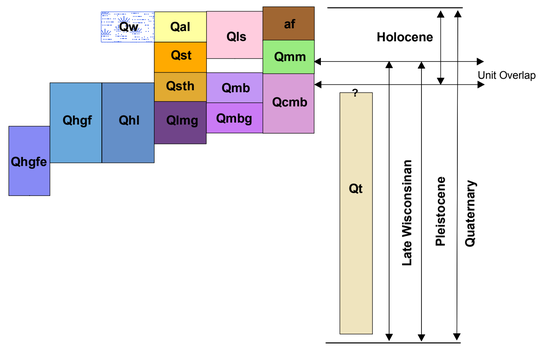
- **Contact**
- **Meltwater channel** - Channel cut by glacial meltwater
- **Bedrock Exposure** - In part from aerial photographs, soil surveys, and previous maps. Not all individual outcrops are shown on the map
- **Glacial striations** - Observation is at tip of arrow. Arrow indicates direction of ice flow. Number is azimuth measurement. Striations include those from Goldthwait and others, 1951.
- **Long axis of drumlin** - generally parallel to inferred direction of ice movement
- **Moraine** - Line shows inferred crest of moraine ridge deposited by glacier margin
- **Scarp** - May be either erosional (stream cut terrace scarp) or constructional (delta foreset slope) landform
- F — **Glacial lake delta or fan deposit** - Elevation is either for topset-foreset contact at Cutting Corner (Etna) measurement of 197.5 meters (657 feet) from Koteff and Larsen (1989) or rough estimate from topographic map as in the Etna-Great Hollow Road queried delta or fan deposit identified in this report relative to a flat surface at about 185 meters (609 feet) south of the Cutting Corner
- **Dug hole, roadcut, or other temporary excavation**- Showing observed materials
- A — **Location of designated map photo**
- 40 — **New Hampshire Geological Survey well database**- Point indicates well location, number indicates depth to bedrock surface in feet

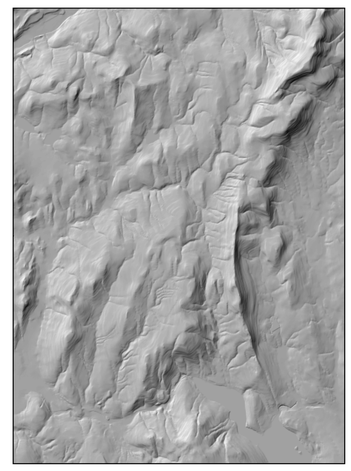
MATERIALS OBSERVATIONS

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





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 boulder 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 ice movement. 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.

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 a 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 sedimentation (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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DISCLAIMER

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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 was measured at 197.5 meters by Koteff and Larsen (1989). A probable second delta or fan surface at an elevation slightly above 192 meters is noted on the map along Etna Road about 24 kilometers (1.5 miles) south of the measured delta. 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 — Kame-delta, shore, nearshore, and 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

PHOTO

Photo A: 2003 Landslide of till in the Mascoma River gorge (mapped as Qls). The toe of this landslide reached the nearby riverbed but was removed by workers from the gravel road surface at the bottom of the photo. The stump diameter in the left foreground is about 25 centimeters (10 inches).

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

By Carol T. Hildreth

Surficial Geologic Map Series GEO-092-024000-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 02HQAG0057, the Town of Hanover (NH) and by the New Hampshire Geological Survey, NH Department of Environmental Services.

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