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SURFICIAL GEOLOGY OF THE HACKETTSTOWN QUADRANGLE
MORRIS, WARREN, AND HUNTERDON COUNTIES, NEW JERSEY
OPEN-FILE MAP OFM 79

Pamphlet containing tables 1 and 2 accompanies map

INTRODUCTION

The Hackettstown quadrangle is located in northwestern New Jersey, in the Highlands physiographic province. Surficial deposits in the Hackettstown quadrangle include glacial, river, hillslope, and wetland sediment and weathered-rock material. The deposits were laid down during repeated periods of glaciation and cold climate in a landscape previously shaped by two major episodes of river incision. Glacial sediments were laid down during three glaciations: the late Wisconsinan glaciation (~20,000 radiocarbon years ago), an intermediate glaciation of pre-Wisconsinan age (most likely the Illinoian glaciation, ~150,000 years ago), and an older glaciation of pre-Illinoian age (possibly as much as 2.1 million years ago). Hillslope and alluvial-fan deposits and some of the river sediments were laid down primarily under cold-climate conditions during the glacial periods. Wetland and floodplain sediments are primarily of postglacial age. Weathered-bedrock materials are produced continuously under both cold and temperate climate by mechanical and chemical breakdown of bedrock.

The accompanying map and sections show the surface extent and subsurface relations of these deposits. Their composition and thickness, and the events they record, are provided in the *Description of Map Units*. Well and boring data used to map the elevation of the bedrock surface and to infer the thickness and subsurface distribution of the sediments are provided in tables 1 and 2 (in pamphlet). Figure 1 shows geomorphic and glacial features in the quadrangle, and figure 2 shows the thickness of surficial deposits and weathered bedrock. The chronologic relationships of the deposits and episodes of erosion are shown in the *Correlation of Map Units*. The hydrology of the surficial deposits and the history of geomorphic and glacial events in the quadrangle and adjacent areas are briefly described in the two following sections. Bedrock was mapped by Volkert and others (2002).

HYDROLOGY OF SURFICIAL DEPOSITS

Surficial deposits in the Hackettstown quadrangle are generally too thin or insufficiently permeable to be aquifers, although several domestic wells draw water from sandy and gravelly beds within the terminal moraine (unit Qnm), or from weathered rock beneath the moraine (wells 22, 26, 59, 60, 61, 160, 161 in table 1). Other wells draw water from granular weathered gneiss (unit Qwg, wells 35, 37, 38, 76, 84, 156) and granular materials within weathered carbonate rock (unit Qwcb, wells 80, 81, 82, 85, 111, 133, 151, 158), which may include collapsed glacial sand and gravel, gneiss colluvium, alluvial-fan gravel, or carbonate-rock gravel. Glaciofluvial cobble-to-boulder gravel (unit Qwf) in terraces bordering the Musconetcong River, and underlying the floodplain of the river, is highly permeable but is generally too thin to supply wells. The gravel stores and recharges water to the underlying carbonate-rock aquifer, and provides base flow to the Musconetcong River, particularly in Hackettstown where the gravel is thickest and most extensive. A well field along the river in Hackettstown (wells 65, 66, 67, 68) draws water from carbonate rock underlying 30 to 50 feet of gravel. One well (68) taps the gravel. The hatchery directly west of the wellfield is supplied by an infiltration canal that collects water emerging from the gravel at the base of the fluvial scarp along the west edge of the floodplain.

Hydraulic conductivities of surficial deposits may be estimated from aquifer-test and laboratory data on similar deposits in New Jersey (Stanford, 2000; Mennel and Canace, 2002). Sand and gravel deposits (units Qwf, Qsu, Qaf, Qal, Qis, Qst, and Qif) are highly permeable: estimated hydraulic conductivities range from 10^1 to 10^3 feet per day (ft/d). Weathered rock, colluvium, and till with a silty sand matrix (parts of Qwg, Qcg, Qn, Qnm, Qf) are also permeable: estimated hydraulic conductivities range from 10^{-1} to 10^2 ft/d. Weathered rock and till with a clayey silt to silty clay matrix (parts of Qwcb, Qws, Qf, and Qpt) are of low permeability: hydraulic conductivities range from 10^{-5} to 10^{-3} ft/d. Fine sand and silt alluvial deposits (parts of units Qal, Qaf), silty to sandy silt till (parts of Qpt, Qf, Qn, Qnm), and silty weathered rock and colluvium (parts of Qwcb, Qws, Qwg, Qcg) are somewhat more permeable: estimated hydraulic conductivities are 10^{-3} to 10^{-1} ft/d. Wetland deposits (Qs) and fill have varied hydraulic conductivities that depend on the clay and silt content of the material. Peat with little mineral soil, and fill composed of sand, cinders, gravel, demolition debris, slag, and trash, may be highly permeable.

GEOMORPHIC AND GLACIAL HISTORY

The oldest landscape feature in the quadrangle is the gently rolling summit of Schooleys Mountain (erosion surface S1 on fig. 1). This summit flat is part of a regional low-relief upland erosion surface, termed the “Schooley peneplain” by Davis and Wood (1889), and “Kittatinny base level” by Salisbury (1898), that was thought to be the product of fluvial erosion during an extended period of stable base level, and then preserved as upland remnants on resistant rock during later fluvial incision as base level lowered. This view fell into disfavor in the latter half of the twentieth century, in part because it had been widely and, in some cases, uncritically, applied to dissimilar landforms and broad regions. More recently, improved records of past sea level indicate that the stepwise drops in base level needed to produce and incise planation surfaces in coastal areas of low tectonic activity have occurred within the past 30 million years, suggesting that an updated version of the peneplain theory is plausible in these settings. Sea-level data, and the age and topographic position of fluvial and marine sediments in the mid-Atlantic region, indicate that the Schooley surface reached its final form in the middle to late Miocene (15-10 million years ago (Ma)) and was isolated on resistant-rock uplands by river incision in the late Miocene and early Pliocene (10-4 Ma) (Stanford and others, 2001). While erosion on moderate to gentle slopes has continuously modified the Schooley surface, it has done so at a rate much slower than that in the valleys, preserving the general form, if not the details, of the surface.

Lowering sea level between 10 and 4 Ma led to river incision along belts of carbonate rock to form the Musconetcong River and South Branch of the Raritan River (hereafter referred to simply as the Raritan) valleys, with floors about 500 feet below the former base level on the Schooley surface. Another period of stable sea level from approximately 4 to 3 Ma halted river incision and led to a period of valley widening, forming erosion surface S2 (fig. 1) on shale and carbonate rock in the Musconetcong and Raritan valleys.

The pre-Illinoian glacier advanced into this terrain. It covered the entire quadrangle and advanced as far south as the Somerville area, 20 miles south of Hackettstown. Magnetically reversed pre-Illinoian sediment (Ridge, 2004), weathering properties, erosional preservation, and pollen in basal lake sediment of probable pre-Illinoian age in Budd Lake (Harmon, 1968; Stanford and others, 2001), all indicate that the pre-Illinoian glaciation occurred in the late Pliocene or early Pleistocene, sometime between 2.5 and 0.8 Ma. Today, remnants of deeply weathered pre-Illinoian till (Qpt) occur on flat uplands on carbonate and shale rock in the Musconetcong and Raritan valleys, and on flat terrain on top of Schooleys Mountain, where they have been protected by erosion. In several places where the till lies on carbonate rock, for example, near Rockport and Stephensburg in the Musconetcong valley and, possibly, east of Long Valley in the Raritan valley, the deposits may have been lowered since their deposition as much as 200 feet by dissolution of the underlying rock.

Sea level lowered again during and after the pre-Illinoian glaciation, leading to a second period of fluvial incision in the early and middle Pleistocene. The Musconetcong and Raritan rivers cut inner valleys to depths of 100-200 feet within the older, broader valleys. Headwater valleys atop Schooleys Mountain were deepened by stream erosion and groundwater seepage to as much as 60 feet lower than the land surface at the time of the pre-Illinoian glaciation.

A pre-Wisconsinan glacier entered this terrain during the middle Pleistocene, probably during the Illinoian glaciation about 150,000 years ago, but perhaps earlier. It advanced to position M1 (fig. 1). This glaciation has not been directly dated, but its deposits are far less weathered and eroded than those of the pre-Illinoian, indicating a significantly more recent age. Deposits of this glacier include till (Flanders Till of Stone and others, 2002, unit Qf) and sand and gravel (Qis, Qif) laid down by meltwater in glaciofluvial plains, fans, and proglacial lakes. Lakes formed in the headwater areas of the Mine Brook valley, which was dammed by ice in the Musconetcong valley (M2 on fig. 1), and in a small subvalley on the south side of Trout Brook, along the base of Upper Pohatcong Mountain, which was dammed by the ice front to the north (M1 on fig. 1). Glaciofluvial gravel forms a plain along the Musconetcong River with a surface 15-20 feet above the late Wisconsinan glaciofluvial plain, although it has been extensively eroded and covered by later alluvial-fan and colluvial deposits. Meltwater draining from the Illinoian terminal position down a tributary valley into the Raritan valley on Schooleys Mountain deposited an alluvial fan (unit Qif) at the mouth of the tributary. Some of this gravel was carried down the main valley and today forms a sparse lag at two places on straths about 20 feet above the modern valley bottom. Erosion by the Raritan after the pre-Wisconsinan glaciation, assisted by meltwater draining from glacial Lake Budd during the late Wisconsinan glaciation, deepened this valley and removed most of the pre-Wisconsinan gravel.

A period of stream and hillslope erosion followed the pre-Wisconsinan glaciation, partially eroding the pre-Wisconsinan glacial deposits. During periods of cold climate, primarily during the early and late Wisconsinan, forest cover was reduced and permafrost developed, impeding soil drainage and thereby waterlogging the surficial material during thaws. Weathered-rock material and glacial sediment on steep hillslopes became unstable and moved downslope to accumulate as aprons of colluvium (Qcg, Qcs). Where the material was transported downslope into steep tributary channels, streams flushed it into main valleys to form alluvial fans (Qaf). Till on moderate-to-steep slopes on Upper Pohatcong and Schooleys Mountains was entirely eroded. Erratics are common in colluvium and alluvial fans within the pre-Wisconsinan limit (M1 on fig. 1), evidence of a formerly more extensive till cover.

Most of the colluvium at the surface is lightly weathered and probably of Wisconsinan age. Older, weathered colluvium, deposited during earlier periods of cold climate, likely occurs in the subsurface of thick aprons. Older colluvium containing weathered and decomposed gneiss clasts (Qcgo) crops out beyond the distal edge of Wisconsinan colluvium at the foot of Upper Pohatcong Mountain near Rockport, and colluvium containing weathered gneiss clasts was observed in one outcrop, and described in a well log (well 80, table 1), beneath fresh-clast colluvium in the apron along the west base of Schooleys Mountain.

The late Wisconsinan glacier advanced to its maximum position (M3 on fig. 1) by about 21,000 radiocarbon years ago, based on radiocarbon dates of pre-advance organic material in a sediment core from Budd Lake (Harmon, 1968; Stanford and Witte, 2002) and on Long Island, New York (Sirkin and Stuckenrath, 1980). At its maximum position the glacier deposited the terminal moraine (Qnm), a belt of till (Netcong Till of Stone and others, 2002) as much as 150 feet thick laid down over a period perhaps as long as 1000 years as the glacier margin alternately advanced and retreated within a 0.5- to 1.5-mile-wide belt back from its maximum limit. The surface of the moraine is a complex of ridges, swales, plateau-like uplands, and knolls (shown by symbols on the map), with as much as 100 feet of relief. Many of the ridges are gently arcuate and trend subparallel to each other and to the general trend of the moraine. These features suggest deposition along glacier margins. Some ridges are asymmetric in cross section. Some asymmetric ridges have gentle north slopes, suggesting push or overriding by moving ice; other ridges have gentle south slopes (including a series along the front of the moraine north of Hatchery Brook) that suggest they are flowtill aprons deposited against the front of the glacier. On steep slopes within the moraine, long scarps trending along slope similarly suggest deposition of material against the glacier front to form a till embankment. Other ridges are shorter and meet at high angles, suggesting deposition amid blocks of stagnant ice. Knolls and plateaus lack the sharp topography of the ridges and may have been subglacially shaped.

While ice stood at the moraine, meltwater deposited a large gravel plain in the Musconetcong valley (Qwf), headed at the moraine in Hackettstown, and a small gravel plain along Hatchery Brook on the west side of Hackettstown. Cobble-to-boulder lags (Qmt) formed on valley bottoms washed by meltwater. One lag is in the Raritan valley downstream from Budd Lake, which carried the outflow from glacial Lake Budd (Stanford and others, 1996), and another is in a small tributary to Hatchery Brook, down which meltwater drained from the terminal moraine. A little farther west, at the headwaters of Hatchery Brook, meltwater cut a channel in the moraine and deposited a gravel fan at its mouth (Qmf). One small lacustrine deposit (Qsu) was laid down in a small valley on the west slope of Schooleys Mountain, which was dammed when ice was at its maximum position, in a manner similar to the Mine Brook valley during the pre-Wisconsinan glaciation.

Radiocarbon dates on postglacial organic material indicate that the ice front had likely retreated from the terminal moraine by 20,000 radiocarbon years ago (Cotter and others, 1986). After retreat, the Musconetcong River eroded a narrow valley as much as 60 feet deep through the moraine, and incised between 10 and 20 feet into the glaciofluvial deposit downvalley from the moraine. Floodplain deposits (Qal) were then laid down in and along these inset channels. The meltwater terrace in the Raritan valley downstream from Budd Lake was likewise incised by the Raritan River. As climate warmed, forest cover returned and hillslopes stabilized. Deposition of colluvium and alluvial fans ceased and streams and groundwater seepage eroded and incised the colluvial aprons and alluvial fans in places. Some of the larger basins within the moraine, or in valleys dammed by the moraine (like Budd Lake and the headwaters of Hatchery Brook), held water, allowing accumulation of silt, clay, and peat to form wetland deposits (Qs). Floodplain and wetland deposition continue today.

DESCRIPTION OF MAP UNITS

Postglacial Deposits--These include man-made fill, stream deposits in fans (Qaf), modern channels and floodplains (Qal, Qcal), and low terraces (Qst), and wetland deposits in swamps and marshes (Qs).

ARTIFICIAL FILL--Sand, gravel, silt, clay, and rock fragments, and man-made materials including cinders, ash, brick, concrete, wood, slag, asphalt, metal, glass, and trash. Color variable but generally dark brown, gray, or black. In highway and railroad fills, dams, dikes, made land, waste-rock disposal piles, and small trash fills. As much as 20 feet thick. Many small areas of fill are not mapped.

Qal ALLUVIUM--Sand, silt, pebble-to-cobble gravel, cobble-to-boulder gravel, minor clay and peat; fine sediment is dark brown, brown, yellowish-brown, gray; moderately to well sorted, stratified. Contains variable amounts of organic matter. Sand and gravel are deposited in active channels. Sand, silt, clay and peat are deposited in back channels, overbank areas, and groundwater-seepage areas, chiefly on broad floodplains. Alluvium includes cobble-to-boulder lags from erosion of till (Qnm) and glaciofluvial gravel (Qwf, Qif) along the Musconetcong River and gneiss colluvium (Qcg) and pre-Illinoian till (Qpt) along the Raritan River. As much as 15 feet thick.

Qaf ALLUVIAL FAN DEPOSITS--Pebble-to-cobble gravel, cobble-to-boulder gravel, sand, silt; brown, yellowish-brown, gray; moderately sorted, stratified. As much as 25 feet thick (estimated).

Qst STREAM TERRACE DEPOSITS—Fine-to-medium sand, silt, pebble-to-cobble gravel; brown, very pale brown, yellowish-brown, light gray; moderately to well sorted, stratified. As much as 10 feet thick. Forms several small terraces with surfaces 3 to 10 feet above the modern floodplain in the Musconetcong and Raritan valleys.

Qs SWAMP AND MARSH DEPOSITS--Peat and organic silt, clay, and minor fine sand; black, dark brown, and gray. As much as 90 feet thick at Budd Lake (Harmon, 1968) but generally less than 20 feet thick elsewhere (Waksman and others, 1943). Deposition of lacustrine sediment in Budd Lake likely began in pre-Wisconsinan, and, possibly, in pre-Illinoian, time but elsewhere these deposits are of late Wisconsinan and Holocene age.

Qcal ALLUVIUM AND COLLUVIUM, UNDIVIDED--Interbedded colluvium as in units Qcg and Qcs, and alluvium consisting of dark brown to yellowish-brown or reddish-yellow silty sand, sandy silt, to clayey silt, with some organic matter and beds and lag veneers of subangular to subrounded cobbles and boulders of gneiss (adjacent to units Qwg and Qcg), shale and carbonate-rock chips and flagstones (adjacent to units Qws and Qwcb), and rounded erratic cobbles and boulders of quartzite, chert, and gray sandstone and mudstone (adjacent to units Qpt and Qf). As much as 15 feet thick. Lag deposits are dominant in steeper reaches of valleys. Fine sediment, with variable organic matter, discontinuously overlies and infills lag deposits in gently sloping reaches. In some steep, narrow valleys, lags have moved downvalley to accumulate as bouldery lobes. This movement may have occurred in periglacial climate when ice filled the interstices between boulders.

Glacial Deposits--These include till and meltwater sediments. Till is a poorly sorted, nonstratified sediment containing gravel and boulders, deposited directly from glacial ice (Qn, Qnm, Qf, and Qpt). The meltwater sediments are moderately- to well-sorted and stratified, and include sand and gravel laid down in ice-dammed ponds (Qsu, part of Qis), glaciofluvial plains (Qwf, Qmt, part of Qis), and alluvial fans (Qmf, Qif).

Qn **Qnt** NETCONG TILL—Yellowish-brown, very pale brown (oxidized) to light gray and brownish-gray (unoxidized) silty sand to sand with many (10-40% by volume) subrounded to subangular pebbles and cobbles, and some (5-10% by volume) to many subrounded boulders. Depth of oxidation ranges from 5 to 30 feet. Till matrix is generally compact, nonplastic, nonsticky, nonjointed, but may have a weak to moderate subhorizontal fissility. Gravel chiefly consists of gneiss, with some gray carbonate rock, gray-to-brown mudstone and sandstone, and dark-gray chert, and a trace of white-to-gray quartzite. Boulders are chiefly gneiss, a few are carbonate rock and quartzite. Unit Qn is as much as 100 feet thick. Well records indicate that Qn in the northwest corner of the quadrangle overlies weathered gneiss and weathered carbonate rock (wells 1-4, table 1). Basal parts of Qn here may consist largely of glacially deformed gneiss saprolite and carbonate-rock residuum. Unit Qnt delineates areas where Qn is generally less than 20 feet thick

Qnm TILL OF THE TERMINAL MORAINE—Netcong Till, as in Qn, forming ridge-and-swale and knoll-and-basin topography. Includes minor interbeds and small deposits of sorted, stratified sand and pebble-to-cobble gravel in places. As much as 150 feet thick.

Qwf GLACIOFLUVIAL DEPOSITS—Cobble-to-boulder gravel, cobble gravel, pebble-to-cobble gravel, and fine-to-coarse sand; well- to moderately sorted; bedding in gravel is horizontal, thick, and poorly defined; sand is cross-bedded to horizontally bedded. Color of non-gravel sediment is yellowish-brown to brown. Gravel consists chiefly (50-80%) of gneiss, with many (10-40%) gray mudstone and sandstone, gray to white quartzite, gray carbonate rock, and dark gray chert, and a trace (<1%) of reddish-brown quartzite. Gneiss clasts may have surface staining or a thin weathering rind and carbonate clasts are lightly weathered to partially decomposed. As much as 50 feet thick. Form a glaciofluvial plain in the Musconetcong valley headed at the terminal moraine, and a smaller plain in the Hatchery Brook valley, deposited by meltwater draining from the terminal moraine in the headwaters of the valley.

Qsu UPLAND LACUSTRINE DEPOSIT—Pebble-to-cobble gravel, some cobble-to-boulder gravel, and fine-to-coarse sand. Gravel composition as in unit Qwf. As much as 40 feet thick. Deposited in a small ice-dammed tributary valley on Schooleys Mountain when late Wisconsinan ice was at its maximum extent. Outlet for pond was southward around a shoulder of Schooleys Mountain into the Musconetcong valley (fig. 1).

Qmt MELTWATER TERRACE DEPOSITS—Cobble gravel and cobble-to-boulder lag with some dark brown, brown, and yellowish-brown fine-to-coarse sand and organic silt as interstitial infill. Clasts are gneiss, with few to some quartzite erratics. Maximum thickness 5 feet. These are lags formed by erosion of weathered gneiss and colluvium by meltwater draining from glacial Lake Budd (in the Raritan valley) and the terminal moraine (in the Hatchery Brook valley).

Qmf MELTWATER FAN DEPOSIT—Pebble-to-cobble gravel, some cobble-to-boulder gravel, with a matrix of yellowish-brown silty fine-to-coarse sand. Gravel is chiefly gray sandstone and mudstone, gray carbonate rock, and gneiss, with a few chert and reddish-brown sandstone clasts. As much as 25 feet thick. Deposited at the mouth of a meltwater channel in the headwaters of Hatchery Brook.

Qf FLANDERS TILL—Brown, brownish-yellow, and very pale brown silty sand to sandy silt with some (5-10% by volume) to many (10-40%) subrounded to subangular pebbles and cobbles, and few (1-5%) to some subrounded boulders. Till matrix is generally compact, nonplastic, nonsticky, nonjointed, but may have a weak to moderate subhorizontal fissility. Gravel consists chiefly of gneiss, with a little gray mudstone, sandstone, chert, carbonate rock, and white-to-gray quartzite, and a trace of reddish-brown sandstone and quartzite. Boulders are chiefly gneiss; some are white-to-gray quartzite. Carbonate clasts are fully decomposed to depths of more than 20 feet; gneiss clasts have weathering rinds generally more than 0.25-inch thick. Some mudstone clasts are also deeply weathered or decomposed. As much as 20 feet thick. Of pre-Wisconsinan age, occurs on gentle to moderate slopes, and possibly in the subsurface beneath colluvium, north of glacial margin M1 (fig. 1).

Qis PRE-WISCONSINAN STRATIFIED DEPOSITS—Pebble-to-cobble gravel, fine-to-coarse sand, silty sand, minor cobble-to-boulder gravel. Sand and silty sand is yellowish-brown to brown. Gravel chiefly consists of gneiss, with some gray sandstone and mudstone, quartzite, and chert, and a trace of reddish-brown sandstone and quartzite. Gneiss clasts have weathering rinds or are partly decomposed, carbonate clasts are fully decomposed. As much as 40 feet thick. Deposited in ice-dammed ponds in the Mine Brook valley, with outlets either eastward into the Raritan valley or southward across a shoulder of Schooleys Mountain into the Musconetcong valley, and in a southerly tributary to Trout Brook, with outlet southward into the Hances Brook valley, and in a glaciofluvial plain in the Musconetcong valley with a surface 15-20 feet above the late Wisconsinan plain.

Qf-Qis FLANDERS TILL AND PRE-WISCONSINAN STRATIFIED DEPOSITS, UNDIVIDED—Till as in unit Qf and pebble-to-cobble gravel and sand as in unit Qis, interbedded or alternating at fine scale.

Qif PRE-WISCONSINAN MELTWATER-FAN DEPOSIT—Pebble-to-cobble gravel with a matrix of yellowish-brown medium-to-coarse sand. Gravel consists chiefly of gneiss with a few gray sandstone, mudstone, and quartzite clasts. Gneiss clasts have weathering rinds or are partly decomposed. As much as 20 feet thick. Deposited at the mouth of a pre-Wisconsinan meltwater channel draining down a tributary valley into the Raritan River.

Qpt PRE-ILLINOIAN TILL—Yellowish-brown to reddish-yellow silty clay to sandy clayey silt with some (5-10% by volume) to many (10-40%) subrounded to subangular pebbles and cobbles and few (1-5%) to some subrounded boulders. Gravel includes, in approximate order of abundance, gray and white gneiss, gray quartzite and quartzite-conglomerate, gray mudstone and sandstone, dark-gray chert, and reddish-brown quartzite-conglomerate. Boulders are chiefly gray gneiss and gray to white quartzite and quartzite-conglomerate. The mudstone, sandstone, and gneiss gravel clasts have weathering rinds or are completely decomposed. As much as 30 feet thick. Equivalent to the Port Murray Formation, till facies, of Stone and others (2002).

Hillslope Deposits--Nonstratified, poorly sorted sediment deposited at the foot of hillslopes by mass movement.

Qta TALUS—Angular to subangular boulders and cobbles of gneiss, with little or no matrix material, forming steep aprons at the base of cliffs on Schooleys Mountain. As much as 20 feet thick. Many small talus deposits, chiefly within unit Qwgt, are not mapped.

Qct TILL COLLUVIUM—Material as in unit Qn, but noncompact and nonfissile, forming a flowtill apron along the front of the terminal moraine northwest of Hackettstown. As much as 20 feet thick.

Qcg GNEISS COLLUVIUM--Yellowish-brown, reddish-yellow, brown sandy silt, silty sand, sandy clayey silt with some (5-10% by volume) to many (10-40%) subangular gneiss pebbles and cobbles, in places underlain by, or interbedded with, thinly layered reddish-yellow to pinkish-white clayey sand and sandy clay with few angular pebbles and cobbles. Long dimensions of clasts typically lie parallel to the hillslope. Upper blocky colluvium is derived from downslope movement of fractured, weathered bedrock; lower, layered colluvium is derived from downslope movement of saprolite. Within the limit of pre-Wisconsinan glaciation (M1 on figure 1), colluvium includes a few (<5%) erratic pebbles and cobbles of quartzite and gray sandstone and mudstone from erosion of Flanders Till. Elsewhere, colluvium may include rare (<0.1%) quartzite and chert erratics from erosion of pre-Illinoian till. Colluvium on moderate-to-gentle slopes includes cobble-to-boulder lags formed by seepage erosion of weathered gneiss. As much as 70 feet thick.

Qcgo OLDER GNEISS COLLUVIUM—Colluvium as in unit Qcg, but gneiss clasts have weathering rinds or are partially decomposed, indicating pre-Wisconsinan age. As much as 30 feet thick. Crops out beyond the distal edge of fresh-clast colluvium at the foot of Upper Pohatcong Mountain near Rockport. Also present in subsurface beneath unit Qcg in other thick colluvial aprons.

Qcs SHALE COLLUVIUM--Brown, yellowish-brown, light gray clayey silt with some (10-40% by volume) gray shale chips. As much as 10 feet thick.

Weathered Bedrock Material--Nonstratified, poorly sorted sediment formed by mechanical and chemical weathering of bedrock.

Qws **Qwst** WEATHERED SHALE--Yellowish-brown, brown clayey silt to silty clay with many angular to subangular gray shale chips. Generally less than 5 feet thick. Qwst indicates areas where weathered material is generally absent and thin shale rubble overlies bedrock.

Qwg **Qwgt** WEATHERED GNEISS--Yellowish-brown, yellow, very pale brown, reddish-yellow, silty sand, silty clayey sand to sandy clayey silt, locally micaceous, with varyied amounts of subangular pebbles and cobbles of gneiss. Includes mixed clast-and-matrix sediment, granular decomposed rock, fractured-rock rubble, and saprolite that preserves original rock structure. Clasts vary from unweathered to fully decomposed. Well records indicate that, on gentle to moderate slopes, clast-and-matrix sediment (described by drillers as “overburden”, “hardpan”, “sandy hardpan”, and “clay hardpan”), which is fractured rock mixed with sandy-clayey saprolitic material by colluviation, cryoturbation, and bioturbation, is generally between 5 and 30 feet thick. It commonly overlies or grades downward into saprolite (described by drillers as “rotten rock”, “sandstone”, “rotten granite”, and “soft granite”) that may be as much as 80 feet thick over unweathered rock. On steep slopes, fractured-rock rubble, generally less than 20 feet thick, overlies unweathered bedrock. Total thickness of weathered material is as much as 150 feet but is generally less than 25 feet (fig. 2). The uppermost, clast-and-matrix material may contain traces of erratic pebbles and cobbles of quartzite, chert, and gray sandstone and mudstone, especially within the pre-Wisconsinan glacial limit. Qwgt indicates areas where weathered material is thin or absent and fractured outcrop is abundant, typically on the steepest slopes and narrow ridgetops.

Qwcb **Qwcbt** WEATHERED CARBONATE ROCK—Yellow, very pale brown, reddish-yellow, light gray clayey silt to silty clay, minor sandy silt, with some (5-10% by volume) to many (10-40%) light gray to yellow angular chips and pebbles of carbonate rock. Includes few to some pebbles and cobbles of quartzite, gray sandstone and mudstone, chert, and variably weathered gneiss, and deformed beds and lenses of sand and silty sand, originating from solution collapse and mixing of overlying glacial, colluvial, and alluvial deposits (units Qf, Qpt, Qis, Qcg, Qaf). Thickness is highly variable. Greatest thicknesses (100-300 feet) are along the base of bordering gneiss uplands (fig. 2). Here, acidic groundwater seepage and runoff draining from the uplands infiltrates into and dissolves the carbonate rock. Lesser thicknesses (10-40 feet) occur away from the valley walls, where there is less contact with acidic water. Geomorphic evidence for this variation in solution rates includes numerous solution basins, and a linear topographic low transverse to the general direction of stream drainage, along the base of Fox Hill in Long Valley and the base of Upper Pohatcong Mountain in the Musconetcong valley. These solution features compare to few basins, and higher topography, on carbonate rock in the center of the valleys. Qwcbt indicates areas where weathered material is thin or absent and fractured outcrop abundant.

Qwq WEATHERED QUARTZITE—Subangular cobbles of gray to brown quartzite with brown to yellowish-brown silty medium-to-coarse sand matrix. As much as 10 feet thick (estimated). Occurs in two small outcrop areas of Hardyston Quartzite at the base of Fox Hill in Long Valley.

MAP SYMBOLS

Contact--Long-dashed where approximately located, short-dashed where gradational or feather-edged, dotted where removed by excavation or concealed by fill or water.

Material observed in hand-auger hole, exposure, or excavation

Excavation perimeter--Line marks limit of excavation. Outlines pits and quarries.

Bedrock ridge or scarp--Line on crest. Low ridges or scarps formed on shale and carbonate bedrock.

Meltwater channel—Line in channel bottom, arrow shows direction of flow.

Fluvial scarp—Line at top, ticks on slope.

Landslide scarp—Line on crest, barbs on slope.

Slump block—Mass of gneiss colluvium displaced downslope at base of landslide scarp.

Sand and gravel pit--Inactive in 2009.

Quarry or mine--Inactive in 2009.

Strath—Fluvial erosion surface cut into weathered carbonate rock at mouth of Hances Brook. Of pre-Wisconsinan age.

Pre-Wisconsinan gravel lag—Subrounded quartzite, chert, and gneiss cobbles on straths at two places in the Raritan valley.

157 **Well with log in table 1--**Location accurate within 100 feet.

147 **Well with log in table 1--**Location accurate within 500 feet.

47 **Well with reported thickness of surficial material—**Data in table 2**.** Location accurate within 100 feet.

214 **Well with reported thickness of surficial material—**Data in table 2**.** Location accurate within 500 feet.

550 **Elevation of bedrock surface--**Contour interval 50 feet. Includes top surface of weathered bedrock. Shown only in the Musconetcong valley around Hackettstown, where surficial deposits are thickest.

r **Large or isolated bedrock outcrop--**Small outcrops within units Qwg, Qwcb, Qws, Qwgt, Qwcb, and Qwst are not shown, and some small outcrops along streams or in artificial cuts are also not shown. Refer to Volkert and others (2002) for these outcrop locations.

47 **Well on sections--**Projected to line of section. Owing to projection, depths of contacts on section may not be identical to those in well.

Solution basin--Line on rim, pattern in basin. Small, shallow basins (maximum depth 5 feet) formed from dissolution of underlying carbonate rock. Larger basins with accumulations of peat are mapped as unit Qs.

Topographic features of the terminal moraine

Asymmetric ridge—Line at crest, barbs on gentle slope. Includes both flowtill aprons and push ridges.

Narrow ridge—Line on crest.

Broad ridge—Line on crest.

Scarp—Line at top, balls on slope.

Hill—Line around base, symbol on summit.

Plateau—Line along rim (raised in places), ruling on summit.

Basin—Line along rim, pattern in basin. Larger basins with accumulations of peat are mapped as unit Qs.

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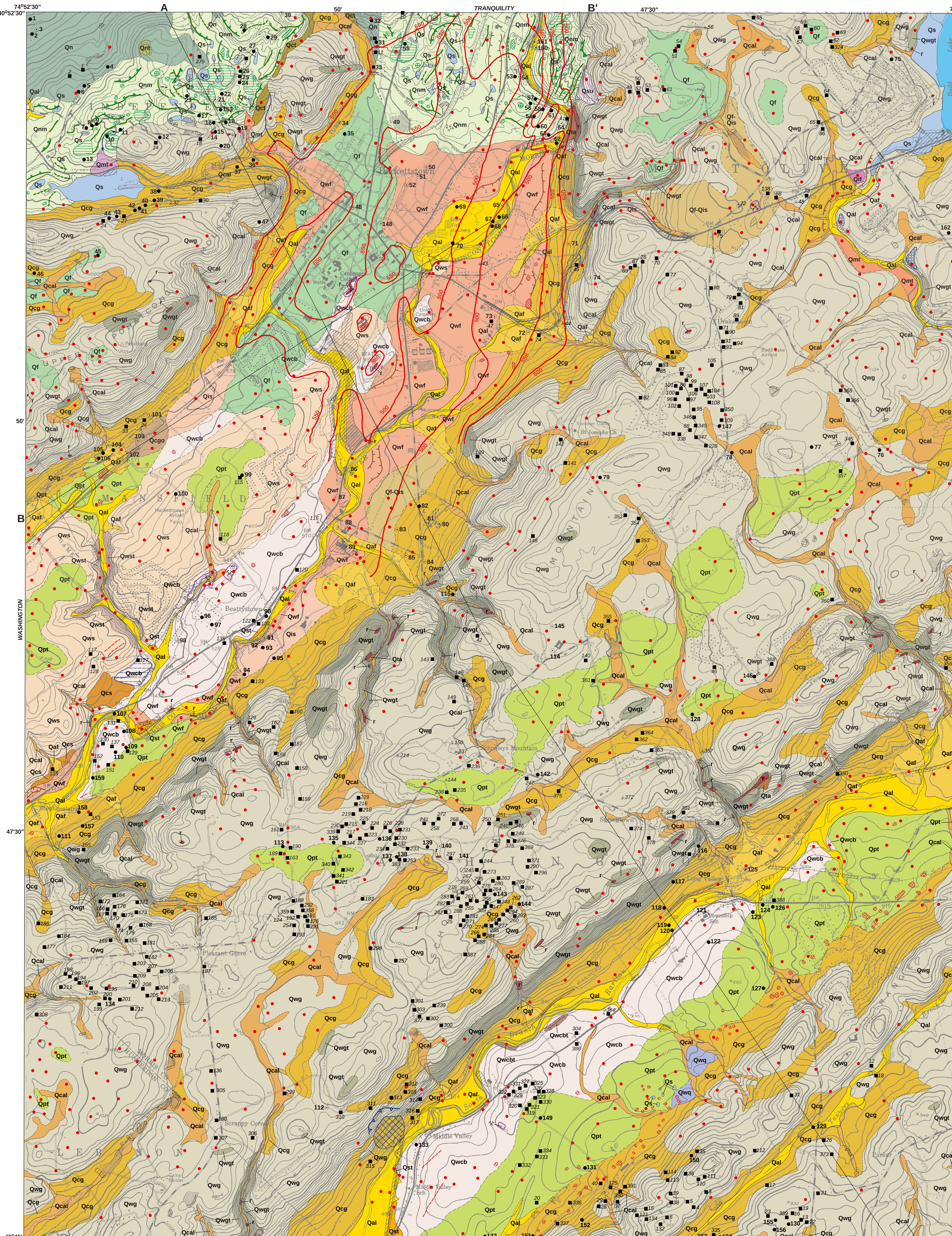


Base map from U. S. Geological Survey, 1953
Photorevised 1971
Corner ticks are on North American Datum of 1927

Geology mapped 1988, 2008-2009
Cartography by S. Stanford

Research supported by the U. S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number 08HQAG0098.

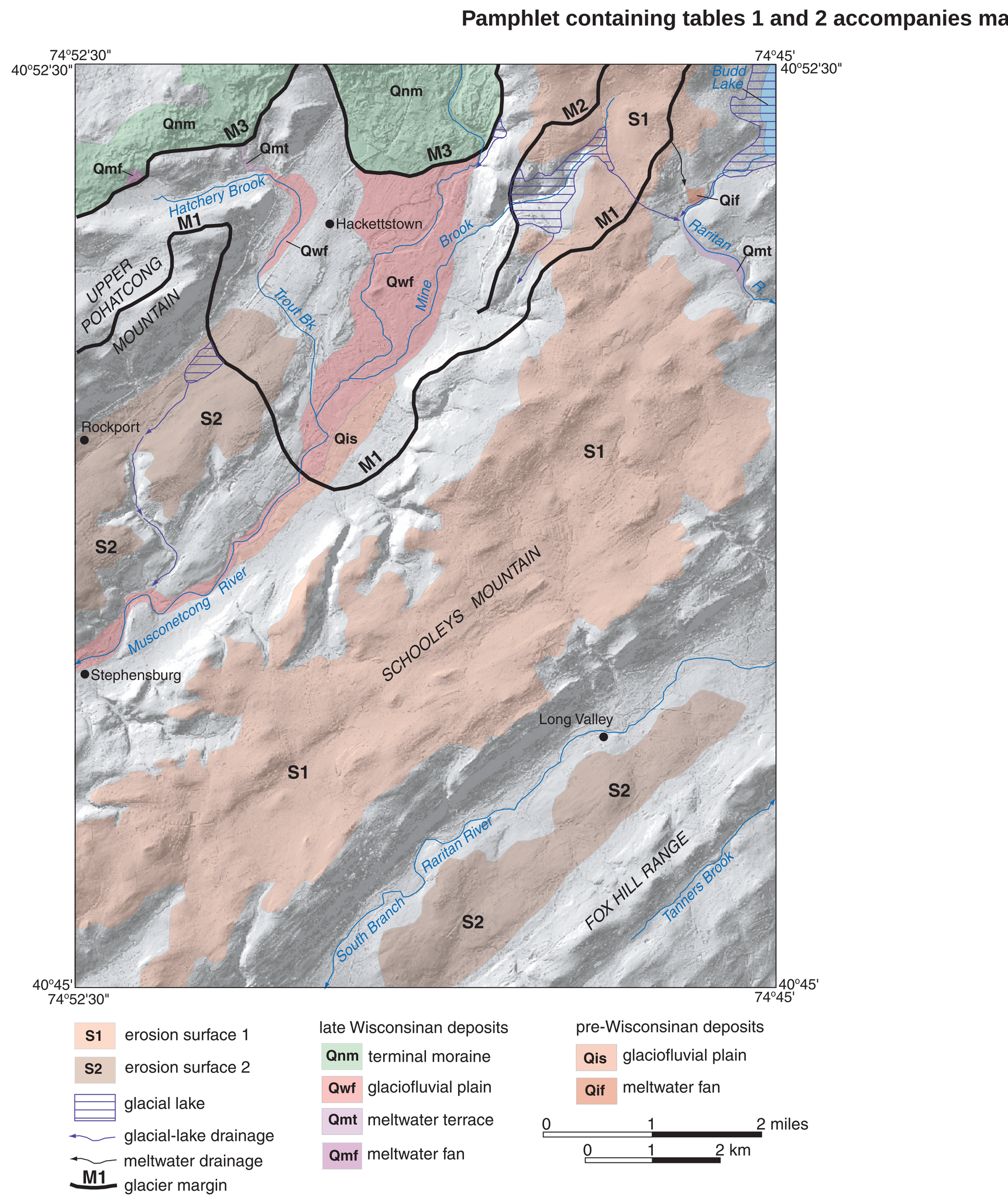


Figure 1.--Geomorphic and glacial features of the Hackettstown quadrangle. Abbreviations for erosion surfaces are: S1=regional low-relief erosion surface of late Miocene age, S2=erosion surface on shale and carbonate rock in the Musconetcong and Raritan valleys, of Pliocene age. Abbreviations on glacier margins are: M1=maximum extent of pre-Wisconsinan (probable Illinoian) ice, M2=ice margin during existence of pre-Wisconsinan glacial lake in Mine Brook valley, M3=maximum extent of late Wisconsinan ice. Extent of glaciofluvial deposits and terminal moraine also shown. Topographic image from N. J. Highlands Water Protection and Planning Council Geographic Information System LiDAR digital data with 2 m horizontal resolution.

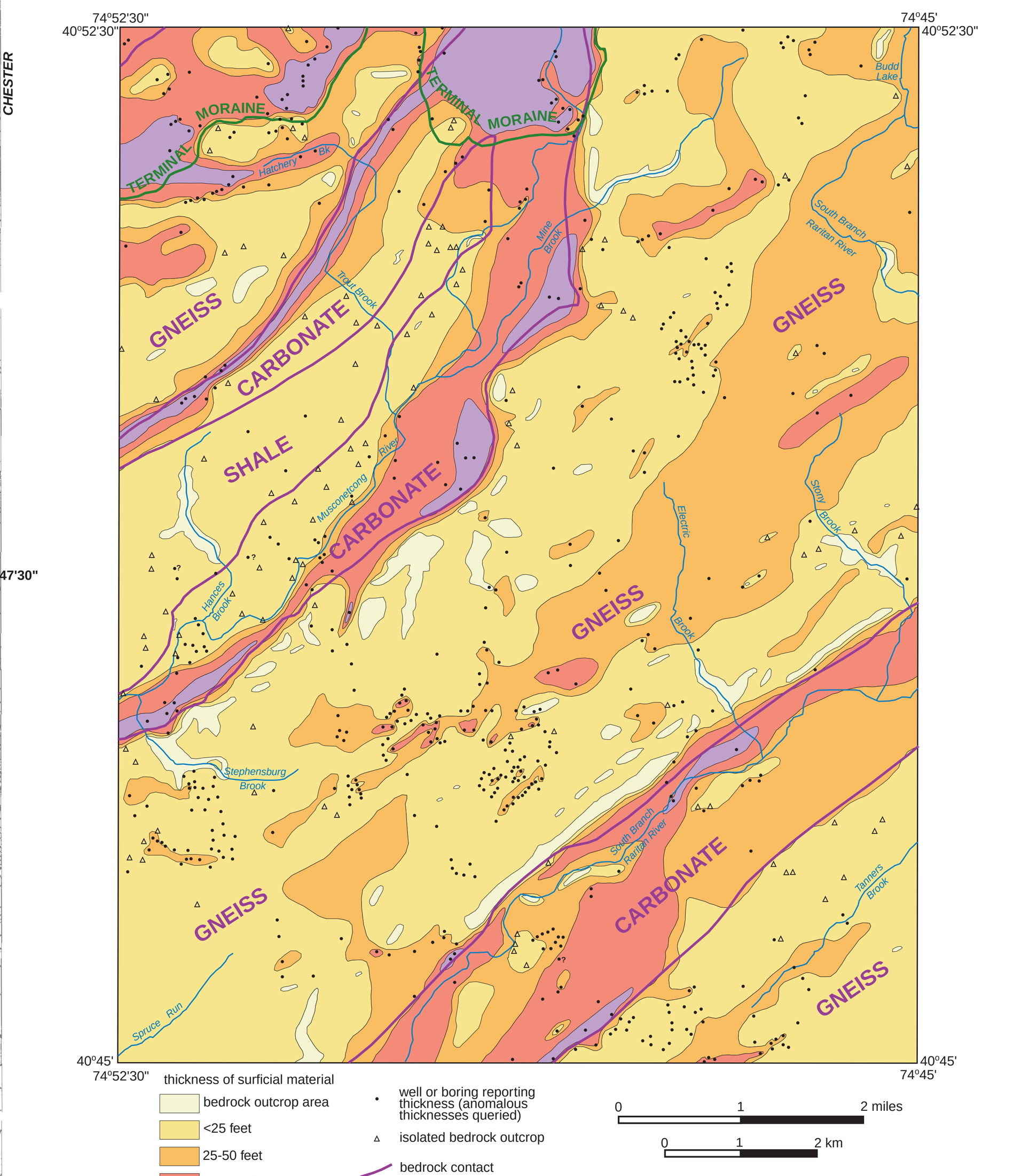


Figure 2.--Thickness of surficial material, including weathered rock, in the Hackettstown quadrangle. Note thick weathered carbonate rock adjacent to gneiss uplands, and thick till in the terminal moraine. Bedrock contacts from Volkert and others (2002). Gneiss includes small areas of quartzite.

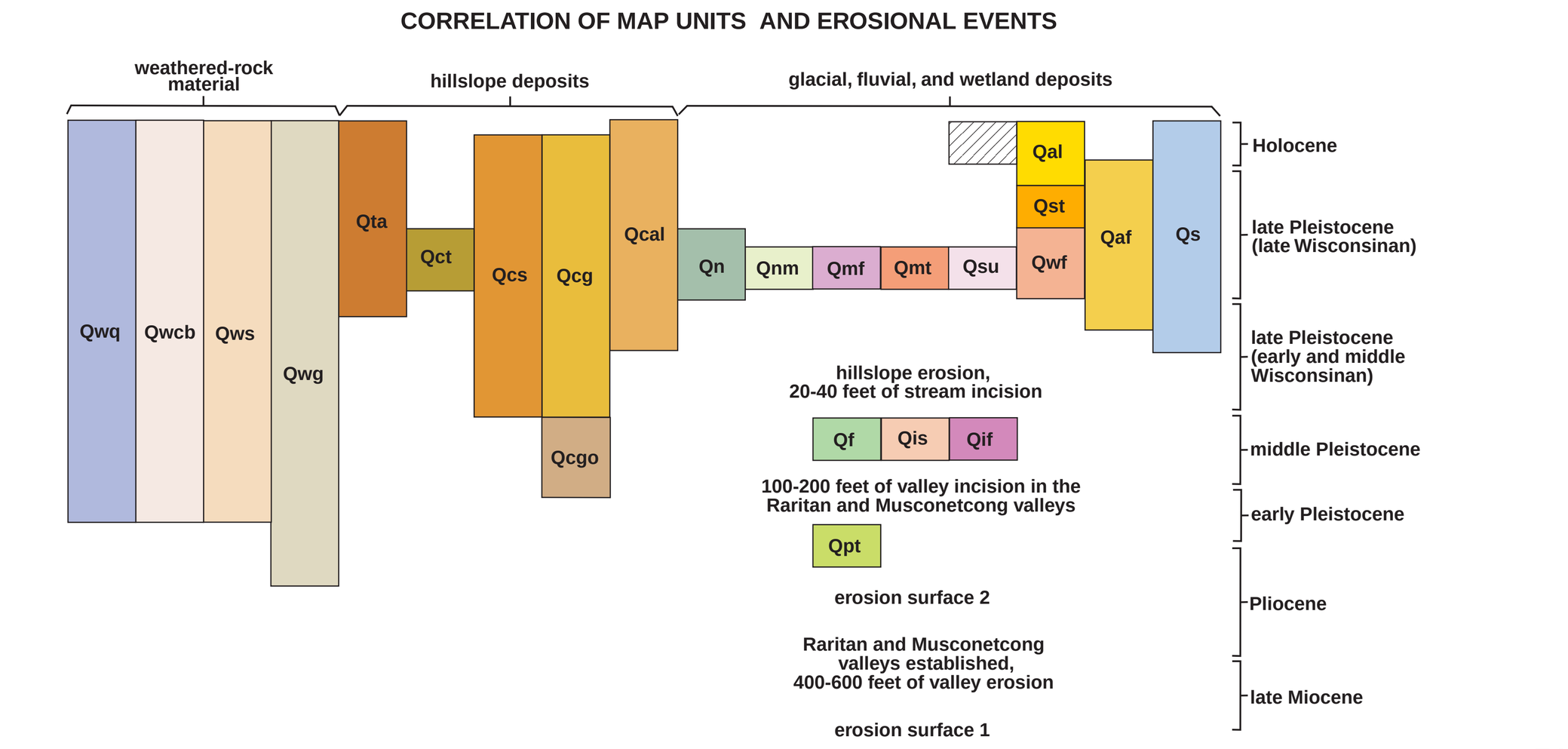
SURFICIAL GEOLOGY OF THE HACKETTSTOWN QUADRANGLE MORRIS, WARREN, AND HUNTERDON COUNTIES NEW JERSEY

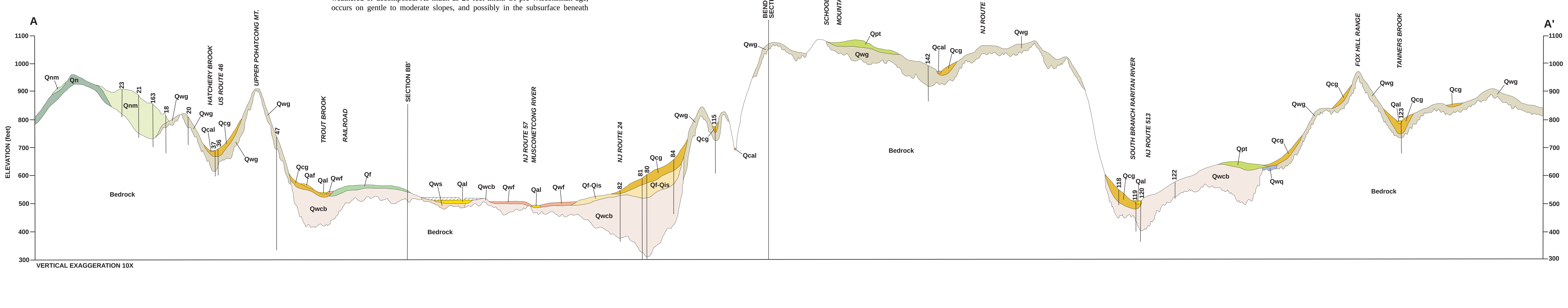
by
Scott D. Stanford
2010

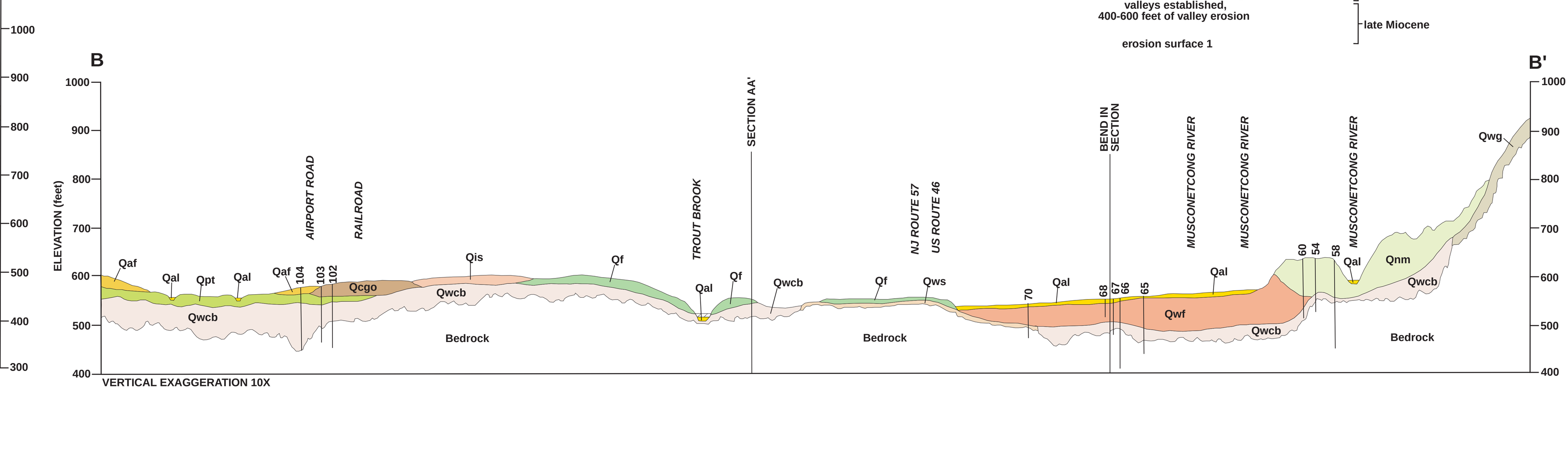
SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

CORRELATION OF MAP UNITS AND EROSIONAL EVENTS







Surficial Geology of the Hackettstown Quadrangle
Morris, Warren, and Hunterdon Counties, New Jersey

New Jersey Geological Survey
Open-File Map OFM 79
2010

pamphlet with tables 1 and 2 to accompany map

Table 1.--Selected well and boring records.

Well No.	Identifier[1]	Driller's log with depth and description[2]	
1	24-16279	0-215	yellow limestone and clay (Qn over Qwcb)
2	24-14119	0-NR	sand, boulders (Qn)
		NR-140	limestone
		cased to 120 feet, approximate thickness of surficial material	
3	24-13644	0-NR	boulders, gravel (Qn)
		NR-120	limestone
		cased to 100 feet, approximate thickness of surficial material	
4	24-23024	0-25	sand, clay, weathered rock (Qn over Qwg)
		25-58	brown weathered rock (Qwg)
		58-473	granite rock, weathered from 103-185
5	24-17802	0-72	clay-sand (Qn)
		72-225	granite
6	24-16878	0-40	sand and clay (Qn)
		40-168	granite
7	24-13082	0-120	sand, large gravel, clay (Qnm)
		120-145	brown hardpan (Qnm or Qwg)
		145-147	granite
8	24-13081	0-95	gray clay, large gravel (Qnm)
		95-114	soft brown sandstone (Qwg)
		114-147	gray granite
9	24-16418	0-68	sand, clay, large gravel (Qnm)
		68-98	granite
10	24-19566	0-133	sand mixed with gravel (Qnm)
		133-200	granite rock
11	24-12903	0-77	sand, brown clay, gravel (Qnm)
		77-148	gray granite
12	24-15632	0-10	hardpan (Qwg)
		10-98	sandstone (Qwg, gneiss saprolite)
13	24-21634	0-44	brown clay, sand, gravel (Qnm)
		44-166	soft sandstone, brown and gray (Qwg, gneiss saprolite)
		166-198	granite
14	24-169	abbreviated log	
		0-19	sand, clay, and boulders (Qwg)
		19-66	limestone rock (gneiss)

15	24-23888	0-26	sand, clay, weathered rock (Qwg)
		26-173	granite
16	24-13795	0-4	stony overburden (Qwg)
		4-71	granite
17	24-18294	0-76	sand, silt, gray clay, gravel (Qnm)
		76-98	brown sandstone (Qwg)
18	24-14284	0-10	sand, gravel, and clay (Qnm)
		10-23	rotten granite (Qwg)
		23-123	granite
19	24-11798	0-15	sand and boulders (Qwg)
		15-348	gray granite
20	24-13886	0-27	sandy overburden (Qwg)
		27-98	gray granite
21	24-4168	0-120	clay and hardpan (Qnm)
		120-138	granite
22	24-13363	0-85	gravel, clay, and sand (Qnm)
		85-90	sand, gravel (Qnm or Qwg)
		cased to 87, yield 20 gpm	
23	24-18294	0-76	sand, silt, gray clay, gravel (Qnm)
		76-98	brown sandstone (Qwg)
24	24-15866	0-144	clay, sand, gravel (Qnm)
		144-198	granite
25	24-13162	0-148	sand, gravel, clay (Qnm)
		148-172	gray granite
26	24-13160	0-100	gravel, sand, clay (Qnm)
		cased to 100, yield 9 gpm	
27	24-15174	0-98	gravel and clay (Qnm)
		98-103	sand, gravel, and water (Qnm or Qwg)
28	24-19990	0-48	fractured rock (Qnm)
		48-505	granite gneiss
29	24-18974	0-93	sand, clay, large gravel (Qnm)
		93-173	granite
30	24-8063	abbreviated log	
		0-35	clay, gravel , stumps, water, some gravel (fill? and Qnm)
		35-137	gray clay, sand, large gravel (Qnm)
		137-167	brown and white rotten sandstone and clay (Qwg)
		167-207	granite
31	24-18165	0-30	clay, sand, gravel (Qn)
		30-98	granite
32	24-15684	0-62	hardpan and gravel (Qn)
		62-299	granite
33	24-2413	0-34	clay and boulders (Qcal over Qcg or Qnm)
		34-136	granite
34	24-2237	0-11	clay and boulders (Qcg)
		11-90	clay and stones (Qcg over Qf and Qwcb)
		90-94	boulders (Qf)
		94-103	clay and stones (Qf and Qwcb)
		103-105	boulders (Qf)

35	24-6461	0-10	clay (Qf)
		10-16	limestone boulder (Qf)
		16-24	clay and gravel (Qf)
		24-30	granite boulder (Qf)
		30-58	sandy clay (Qf and Qwcb)
		58-395	limestone
36	24-20824	0-30	clay and dirt (Qcg)
		30-50	hard sandstone (Qwg)
		50-100	sandstone (Qwg)
37	24-23189	0-20	sand, clay (Qcg)
		20-33	sandstone (Qwg)
		33-61	soft sandstone (Qwg)
		61-75	hard sandstone (Qwg)
		75-90	sandstone, granite mix (Qwg and unweathered gneiss)
		90-133	sandstone, granite mix, yield 10 gpm
		133-165	quartz granite
38	24-13992	0-197	sand (Qcg over Qwg)
		197-200	boulder (Qwg)
		200-222	sand and rotten limestone (Qwg)
		222-234	limestone (gneiss)
39	24-15658	0-235	clay, hardpan (Qcg over Qwg)
		235-245	soft sandstone (Qwg)
		cased to 242, yield 8 gpm	
40	24-20836	0-92	soft hardpan (Qcg over Qwg)
		92-197	granite
41	24-20835	0-61	clay, hardpan (Qcg over Qwg)
		61-148	granite
42	24-20834	0-43	sandy hardpan (Qcg)
		43-148	granite
43	24-20829	0-4	clay (Qwg)
		4-44	sand and clay (Qwg)
		44-54	soft sandstone (Qwg)
		54-373	granite
44	24-20831	0-5	clay and large gravel (Qwg)
		5-17	sandy clay (Qwg)
		17-298	granite
45	24-18987	0-12	hardpan (Qcg)
		12-25	fractured rock (Qwg)
		25-71	porous limestone (Qwg)
		71-190	limestone (gneiss)
46	24-21378	0-40	sand, clay (Qcg)
		40-60	broken sandstone (Qwg)
		60-348	granite
47	24-18223	0-45	sand and gravel (Qwg)
		45-400	limestone (gneiss)
48	24-327	0-20	clay and hardpan (Qf)
		20-64	slabby limestone (Qwcb)
		64-180	blue and gray limestone
49	24-11543	0-30	overburden with gravel (Qnm)
		30-110	limestone
50	24-3188	0-21	stones and clay (Qwf)
		21-57	sand and gravel (Qwf)
		57-107	hard black rock

		107-138	hard gray rock
51	24-3187	0-30	coarse sand, quartz and limestone fragments, some boulders (Qwf)
		30-35	same, some large limestone fragments (Qwf)
		35-40	medium gravel, mostly limestone (Qwf and Qwcb)
		40-49	brown medium-grained clayey sand (Qwf and Qwcb)
		49-80	medium and coarse sand, mixture of quartz and limey shale (Qwcb)
		80-150	limestone bedrock
52	24-3258	0-38	sand and gravel (Qwf)
		38-42	clay and stones (Qwf and Qwcb)
		42-45	rotten limestone (Qwcb)
		45-285	hard black rock
53	24-5582	0-60	clay and boulders (Qnm)
		60-80	very dirty sand and gravel (Qnm)
		80-86	boulder or ledge rock (Qnm)
		86-160	decayed limestone (Qwcb)
		160-173	soft and hard layers limestone
54	24-3421	0-56	clay, boulders, hardpan (Qnm)
		56-110	limestone, blue and gray
55	24-15069	0-50	clay, gravel (Qnm)
		50-55	gravel (Qnm)
		55-120	clay, gravel (Qnm)
		120-140	brown sand, clay (Qnm)
		140-166	clay, gravel (Qnm)
		166-200	rock—limestone
		200-222	soft granite
56	24-13342	0-71	dense gravel and sand (Qnm)
		71-160	dark brown clay and sand (Qnm and Qwcb)
		160-165	rotten brown limestone
57	24-15065	0-131	sand, gravel (Qnm)
		131-134	limestone
58	24-13972	0-8	overburden and boulders (Qnm)
		8-11	boulders (Qnm)
		11-25	sand and gravel and boulders (Qnm)
		25-28	boulders (Qnm)
		28-90	sand and gravel and boulders, no water (Qnm)
		90-95	rotten limestone and clay (Qwcb)
		95-175	limestone
		175-180	brown seam, water (Qwcb)
59	24-15924	0-99	sand and gravel (Qnm)
		cased to 99, yield 18 gpm	
60	24-16329	0-4	clay, gravel (Qnm)
		4-8	boulder (Qnm)
		8-75	gravel (Qnm)
		75-76	boulder (Qnm)
		76-80	gravel (Qnm)
		80-108	(not reported)
		108-110	boulder (Qnm)
		110-112	clay and gravel (Qnm)
		112-122	clay and limestone (Qwcb)
61	24-17266	0-18	clay (Qnm)
		18-23	limestone (Qnm, boulder)
		23-108	clay (Qnm)
		108-110	limestone (boulder in Qnm or bedrock)
		110-125	clay (Qnm or Qwcb)
		cased to 108, yield 20 gpm	
62	24-15479	0-54	brown clay, sand, gravel, silt (Qal over Qnm)

		54-72	limestone
63	24-21060	0-39	gravel (Qnm)
		39-100	limestone
64	24-1472	0-30	boulders, clay, hardpan (Qnm)
		30-152	orange sticky clay, some streaks of hardpan, looks like decayed limestone formation (Qwcb)
		152-158	limestone
65	24-5529	0-3	yellow clay (Qal)
		3-47	sand and gravel (Qwf)
		47-69	yellow mud, broken rock (Qwcb)
		69-90	rotten limestone (Qwcb)
		90-118	limestone
66	24-7212	0-10	clay and rocks (Qal over Qwf)
		10-15	rocks (Qwf)
		15-25	dirty gravel (Qwf)
		25-33	yellow clay (Qwf or Qwcb)
		33-45	dirty sand and gravel (Qwf, possibly in Qwcb)
		45-65	limestone with mud seams
		65-143	limestone
67	24-6999	0-10	clay and rocks (Qal over Qwf)
		10-24	sand and gravel (Qwf)
		24-30	sand (Qwf)
		30-42	yellow clay with stones (Qwcb)
		42-57	rotten limestone (Qwcb)
		57-58	hard limestone
68	24-5556	0-15	clay and boulders (Qal over Qwf)
		15-37	sand and gravel (Qwf)
69	24-7711	0-42	sand, gravel, and boulders (Qal over Qwf)
		42-103	soft black limestone (Qwcb)
		103-135	hard blue limestone
		135-150	yellow rotten limestone (Qwcb)
70	24-7712	0-41	overburden, sand and gravel streaks (Qal over Qwf)
		41-70	black limestone with cracks every few feet
71	24-4308	0-65	clay and hardpan (Qcg)
		65-205	granite
72	24-3816	0-183	clay and hardpan and slabs of limestone 5 to 6 feet thick, white and soft limestone (Qcg over Qwcb)
		183-218	sandstone rock
73	24-1950	0-15	boulders and gravel, as river bottom (Qwf)
		15-55	yellow and orange clay and hardpan (Qwcb)
		55-100	seamy limestone
74	24-14703	0-8	sandy overburden (Qwg)
		8-300	soft layers, sandstone (Qwg)
		300-400	granite
75	24-15965	0-32	clay and hardpan (Qwg)
		32-245	mostly granite, a few streaks of ore rock
76	24-13059	0-20	overburden (Qwg)
		20-60	sand (Qwg)
		60-70	sand, gravel (Qwg)
77	24-50785	abbreviated log	
		0-16	brown sand and gravel (Qwg)
		16-22	broken brown rock (Qwg)
		22-36	brown rock and brown clay (Qwg)

		36-120	granite
78	24-34614	abbreviated log	
		0-27	brown silty clay and gravel (Qcal over Qwg)
		27-30	broken rock (Qwg)
		30-95	brown, gray rock, weathered in places (gneiss)
79	24-38047	abbreviated log	
		0-6	brown overburden and rock (Qwg)
		6-270	blue, gray, brown rock, weathered in places (gneiss)
80	24-5807	abbreviated log	
		0-30	clayey material with rounded and angular dolomite and gneiss pebbles (Qcg over Qf)
		30-85	slightly clayey material with rounded gneiss pebbles, some weathered, and a few dolomite pebbles (Qf and Qis)
		85-312	angular and some rounded pebbles and fragments of gneiss and dolomite in clay (Qwcb with collapsed Qcg and Qf)
81	R24-14-351	0-270	clay and shale (Qcg over Qwcb)
		270-355	clay, caving in (Qwcb)
82	24-6692	0-7	clay and stones (Qcg)
		7-164	leached limestone and a few granite stones (Qcg and Qf over Qwcb)
		164-167	soft limestone (Qwcb)
83	24-15026	0-25	gravel, sand (Qcg over Qf)
		25-35	clay (Qf and Qwcb)
		35-43	clay, mixed with gravel (Qf and Qwcb)
		43-105	limestone
		105-123	brown limestone
84	24-3919	0-157	clay and hardpan (Qcg over Qf)
		157-187	sandstone rock (Qwg)
85	24-8791	0-70	clay and boulders (Qcg over Qf)
		70-91	clay (Qwcb)
		91-95	soft limestone (Qwcb)
86	24-6998	0-34	clay and rocks (Qal over Qwf)
		34-35	limestone
		35-70	yellow clay (Qwcb)
		70-217	limestone
87	24-3178	0-33	sandy clay (Qwf over Qwcb)
		33-90	highly weathered limey shale and crystalline dolomitic limestone (Qwcb)
88	24-4808	0-80	boulders and clay (Qwf over Qwcb)
		80-151	soft and hard gray limestone
89	24-7034	0-15	gravel, clay, rocks (Qwf)
		15-55	gravel and clay (Qwf and Qf over Qwcb)
		55-75	sand, clay, and gravel (Qf and Qwcb)
		75-173	limestone and broken limestone
90	24-22657	0-15	clay (Qwcb)
		15-25	clay, gravel (Qwcb)
		25-36	gravel, sand (Qwcb)
		36-115	limestone
91	24-1406	0-38	boulders, clay, and gravel mixed (Qwf over Qwcb)
		38-72	gray and blue limestone
92	24-1557	0-30	boulders, clay, hardpan (Qwf over Qwcb)
		30-78	gray and blue limestone
93	24-14216	0-20	hardpan (Qis)

		20-42	gravel (Qis)
		42-69	clay and gravel (Qis and Qwcb)
		69-77	clay (Qwcb)
		77-95	limestone
94	24-14914	0-35	sand, gravel (Qis)
		35-98	rotten yellow limestone (Qwcb)
95	24-10740	0-20	gray, yellow clay mixed (Qcg over Qwcb)
		20-25	layer limestone
		25-35	clay with gravel, sand (Qwcb and Qf and Qis)
		35-45	clay, sand (Qwcb and Qis)
		45-55	clay, gravel (Qwcb and Qf and Qis)
		55-88	limestone
96	24-14893	0-4	overburden (Qwcb)
		4-8	soft limestone (Qwcb)
		8-230	limestone
97	24-15596	0-9	sand, soft brown clay (Qwcb)
		9-173	limestone
98	24-6907	0-80	rotten limestone (Qwcb)
		80-225	limestone
99	24-12529	0-15	brown clay and shale (Qpt over Qws)
		15-98	gray shale
100	24-15994	0-7	dirt and shale (Qws)
		7-198	slate
101	24-19437	0-114	clay hardpan (Qcg over Qwcb)
		114-135	limestone
102	24-23995	0-68	clay and gravel (Qcgo over Qwcb)
		68-123	limestone
103	24-21934	0-21	brown clay and gravel (Qcgo)
		21-115	gray fractured limestone
104	24-21400	0-125	sand and gravel (Qaf over Qpt and Qwcb)
105	24-18780	0-140	clay (Qcg over Qwcb)
106	24- 23071	0-130	clay (Qf over Qwcb)
		130-160	broken rock and limestone
107	24-1722	0-23	clay and hardpan (Qal over Qwcb)
		23-72	gray and blue limestone
108	24-10278	0-8	broken-up limestone (Qwcb)
		8-72	limestone, rotten from 65-72
109	24-12034	0-12	overburden (Qpt over Qwcb)
		12-123	limestone
110	24-21363	0-12	fractured rock (Qwcb)
		12-255	fractured shale
111	24-23187	0-5	hardpan (Qcg)
		5-235	hard-packed sand, fine gravel, small pieces of brown limestone (Qcg over Qwcb)
112	24-1499	0-49	clay, boulders, and rotten granite (Qwg)
		49-61	soft granite rock (Qwg)
		61-80	granite rock
113	24-18693	0-30	sandy clay (Qwg)

		30-40	sandstone (Qwg)
		40-200	granite
114	24- 5427	0-12	hardpan, boulders (Qwg)
		12-310	very hard rock
115	24-10345	0-6	overburden (Qcg)
		6-20	sand and gravel (Qcg)
		20-24	boulders (Qcg)
		24-40	sand and gravel (Qwg)
		40-45	rotten granite (Qwg)
		45-170	granite, rotten seams at 52-53 and 168-170
116	R1A	abbreviated log	
		0-25	orange, brown, gray fine-to-coarse sand, some clayey silt, some gravel and boulders (Qwg)
		25-41	gneiss
117	R8A	abbreviated log	
		0-36	light brown to brown fine-to-medium sand, some silt and clayey silt, little gravel (Qcg over Qwg)
118	R16	abbreviated log	
		0-25	light brown to orange brown fine-to-coarse sand, some silt, clayey silt, and gravel (Qcg)
		25-46	brown, tan, gray fine-to-coarse sand, little silt, trace gravel (Qcg)
119	S7+7A	abbreviated log	
		0-19	light brown fine-to-medium sand, some silt, little gravel (Qal)
		19-54	tan, orange-yellow, light yellow silt, fine-to-coarse sand, little gravel, trace clay (Qcg and Qwcb)
		54-101	gray and brown dolomite and intervals of tan silt
120	S11	abbreviated log	
		0-29	yellowish brown fine-to-coarse sand, little gravel, trace clayey silt (Qal over Qcg)
		29-144	yellow and gray clayey silt with pieces of weathered dolomite, little fine-to-coarse sand (Qwcb)
121	24-2077	0-25	yellow clay (Qwcb)
		25-39	hardpan and broken rock (Qwcb)
		39-213	limestone rock
122	R25	abbreviated log	
		0-44	orange clayey silt with dolomite decomposed to angular sand and medium-to-fine gravel (Qwcb)
		44-54	gray dolomite
123	R33	abbreviated log	
		0-25	tan, brown, white silt and fine-to-coarse sand with weathered granitic rock fragments (Qpt over Qwcb)
		25-30	gray and brown dolomite
124	S18	abbreviated log	
		0-39	gray to tan silty clay with fine-to-coarse sand, little medium-to-fine gravel (Qpt over Qwcb)
		39-44	rock fragments
		44-54	gray and brown dolomite
125	24-2724	0-22	mountain grit (Qaf)
		22-133	soft limestone rock (Qwcb)
		133-228	limestone rock
126	24-22216	abbreviated log	
		0-15	clayey silt, trace gravel, gneiss boulder from 6-6.5 (Qpt)
		15-17	silt with some clay, little angular gravel—decomposed bedrock (Qwcb)
127	24-39260	0-6	clay (Qpt)

		6-8	boulders (Qpt)
		8-25	clay (Qpt or Qwcb)
		25-30	large gravel (Qpt or Qwcb)
		30-545	limestone
128	24-20048	0-14	clayey sand (Qpt)
		14-20	till, very hard drilling, boulder at 14 (Qpt)
		20-28	clayey sand (Qpt or Qwg)
		28-29	till, very hard drilling (Qpt or Qwg)
129	24-2624	abbreviated log	
		0-20	clay and sand, granitic rock fragments (Qcg)
		20-48	clay and soft rock, granitic rock fragments, a few cherts and quartzites (Qcg with Qpt-derived material)
		48-51	rotten granite (Qwg)
		51-107	granite rock
130	24- 13930	0-6	overburden with boulders (Qwg)
		6-24	sand and gravel (Qwg)
		24-165	granite, soft from 160-165
131	24-10343	0-5	overburden (Qpt)
		5-76	clay and gravel (Qpt and Qwcb)
		76-94	limestone
		94-116	rotten limestone (Qwcb)
		116-330	gray limestone
		330-348	granite
132	24-15307	0-25	sand and stone (Qpt)
		25-75	clay (Qwcb)
		75-80	shale
		80-148	limestone
133	24-9579	0-50	clay and boulders (Qwcb with collapsed Qcg or Qpt)
		50-58	clay and sand (Qwcb)
		59-60	gravel (Qwcb, with collapsed Qcg or Qpt), yield 20 gpm
134	24-21711	0-14	stony hardpan (Qwg)
		14-44	sandstone (Qwg)
		44-198	granite
135	24-16095	0-14	hardpan (Qwg)
		14-56	soft sandstone (Qwg)
		59-198	granite
136	24-15364	0-21	hardpan (Qwg)
		21-80	sandstone (Qwg)
		80-123	granite
137	24-14786	0-45	clay (Qwg)
		45-58	rotten granite (Qwg)
		58-83	granite
138	24-14387	0-30	clay and gravel (Qwg)
		30-40	rotten rock (Qwg)
		40-75	granite
139	24-13140	0-40	clay (Qwg)
		40-65	sand and clay (Qwg)
		65-273	granite
140	24-12225	0-32	overburden (Qwg)
		32-50	rotten granite (Qwg)
		50-223	granite
141	24-14683	0-20	clay (Qwg)
		20-70	rotten granite (Qwg)
		70-148	granite

142	24-15015	0-20	clay (Qwg)
		20-75	very rotten granite (Qwg)
		75-123	granite
143	24-17661	0-12	stony hardpan (Qwg)
		12-32	sandstone (Qwg)
		32-344	granite
144	24-17696	0-22	clay hardpan (Qcg over Qwg)
		22-54	sandstone (Qwg)
		54-122	granite
145	24-12396	0-15	overburden (Qwg)
		15-40	very soft granite (Qwg)
		40-320	granite
146	24-22922	0-12	brown clay (Qwg)
		12-39	white clay (Qwg)
		39-250	granite
147	24-15757	0-13	hard-packed sand and granite stones (Qwg)
		13-205	granite
148	Hackettstown Theater well	0-30	hardpan, broken rock (Qf)
		30-186	blue limestone
149	24-16481	0-92	hardpan, sand, gravel (Qpt over Qwcb?)
		92-105	sandstone (Qwcb?)
		105-198	granite (should be limestone, log may have been switched with another well by driller)
150	24-15477	0-12	overburden (Qwg)
		12-55	soft sandstone
		55-98	granite
151	24-13590	0-10	overburden (Qcg)
		10-60	clay (Qwcb)
		60-235	clay and gravel (Qwcb and collapsed Qcg and Qpt)
152	24-16157	0-74	clay, sand, soft sandstone (Qwg)
		74-198	granite
153	24-12346	0-60	overburden, clay, sand (Qcg over Qwg)
		60-88	rotten granite (Qwg)
		88-122	granite
154	24-16579	0-113	soft sandstone and clay (Qcg over Qwg)
		113-147	granite
155	24-15165	0-11	stony sand and clay (Qwg)
		11-173	granite
156	24-15166	0-56	clay, sand, hardpan (Qwg)
		56-65	soft granite (Qwg)
157	24-20584	0-135	rotten limestone (Qcg over Qwcb)
		135-155	limestone
158	24-12619	0-85	dirt (Qcg over Qwcb)
		85-118	rotten rock and sand (Qwcb)
159	24-14089	0-34	hardpan (Qpt over Qwcb)
		34-55	rotten limestone (Qwcb)
		55-73	limestone
160	N 24-4-695	0-30	drab-colored clay, sand, and gravel (Qal over Qnm)
		30-40	slightly clayey gray medium-to-coarse sand (Qnm)

		40-50	gravel and sand (Qnm)
		50-105	yellow clay, sand, gravel (Qnm and Qwcb)
161	24-10139	0-10	boulders (Qal)
		10-15	sand gravel (Qnm)
		15-56	boulders (Qnm)
		56-98	clay-gravel (Qnm)
		98-120	water-bearing sand and gravel (Qnm)
162	25-16478	0-25	hardpan (Qwg)
		25-30	soft rock (Qwg)
		30-130	granite
163	24-19228	0-120	clay and boulders (Qnm)
		120-150	limestone (gneiss)

[1]Identifiers of the form 24-xxxx or 25-xxxx are well permit numbers issued by the N. J. Department of Environmental Protection, Bureau of Water Allocation. Identifiers of the form "Rxx-xx-xxx" are the N. J. Atlas Sheet coordinates of well records in the Bureau of Water Allocation well files that do not have permit numbers. Identifiers of the form "Nxx-xx-xxx" are N. J. Atlas Sheet coordinates of well logs in the N. J. Geological Survey permanent note collection. Identifiers of the form "Rxx" or "Sxx" are borings drilled in 1996 for Louis A. Berger and Associates, Inc., for a proposed highway, with logs on file at the N. J. Geological Survey. The log of the "Hackettstown Theater well" is from records of the William A. Stothoff Co. collected for a 1963 well compilation by A. N. Quick on file at the N. J. Geological Survey, Bureau of Geology and Topography.

[2] Depth (in feet below land surface) and driller's or logger's description is provided. Notation "NR" indicates depth of contact is not reported. Inferred map units and author's comments are indicated in parentheses. All descriptions are reproduced as they appear in the original source, except for minor format, punctuation, and spelling changes. Logs identified as "abbreviated" have been condensed for brevity, or have minor details omitted. Many bedrock descriptions have been condensed; these are not identified as abbreviated. Map units are inferred from the known extent of materials at the surface and from known depositional settings, in addition to the drillers' descriptions. For wells completed in surficial material, the yield (in gallons per minute, gpm) and depth to which the well is cased, if reported, are included after the description.

Table 2.—Selected wells and borings recording thickness of surficial material. All depths are in feet below land surface.

Well Number	Identifier[1]	Depth to base of surficial material[2]	Depth to base of saprolite[3]	Total depth
1	24-17442	22		305
2	24-19043	8		200
3	24-23542	40		300
4	24-12383	15		98
5	24-14049	12		298
6	24-20237	8		548
7	24-19118	>80		80
8	24-10673	20		147
9	24-18166	32		148
10	24-20672	39		248
11	24-15437	61		98
12	24-14223	10	15	160
13	24-13225	18		98
14	24-18834	9		123
15	24-14565	12		198
16	24-13931	18		248
17	24-10418	6		122
18	24-15632	10		98
19	24-13153	40		197
20	24-10834	5		300
21	24-20940	7		423
22	24-16681	23		98
23	24-16680	16		123
24	24-19209	9		298
25	24-14570	5		399
26	24-18662	17		200
27	24-20830	8		198
28	24-13139	6		50
29	24-13141	20		95
30	24-22527	28		268
31	24-18917	5		298
32	24-20871	29		225
33	24-17129	50		130
34	24-19437	114		135
35	24-15633	20		123
36	14-14976	6		573
37	24-15200	6		440
38	24-14405	8		448
39	24-14230	6		173
40	24-12068	101		223
41	24-18190	0		150
42	24-15440	20		245
43	24-21954	>75		75
44	24-17057	90		300
45	24-5786	23		127
46	24-9129	25		145
47	24-17817	45		123
48	24-19791	18		300
49	24-21939	30		400
50	24-19654	20		200
51	24-21973	20		100
52	24-20862	20		200
53	24-14658	12		190
54	24-21972	15		125
55	24-24523	15		150
56	24-12570	35		148

57	24-22954	18		305
58	24-22951	22		155
59	24-24284	22		180
60	24-24286	18		380
61	24-17054	8		148
62	24-21352	55		125
63	24-21353	40		125
64	24-21354	62		100
65	24-20866	7		298
66	24-15758	6		198
67	24-22136	29		75
68	24-19280	60		175
69	24-22137	20		100
70	24-10110	89		236
71	24-11869	23		98
72	24-24156	26		198
73	24-16076	12		98
74	24-13742	106		107
75	24-23802	53		175
76	24-14310	40		123
77	24-22483	6		198
78	24-14167	8		248
79	24-14166	6		123
80	24-23811	15		298
81	24-18538	8		100
82	24-9367	10		250
83	24-13184	12		198
84	24-22538	27		148
85	24-12207	13		123
86	24-19152	17		123
87	24-19144	42		198
88	24-20608	5		525
89	24-11848	10		98
90	24-12358	16		98
91	24-20188	17		100
92	24-10710	6		172
93	24-20187	16		285
94	24-12061	15		110
95	24-19157	9		173
96	24-18895	19		148
97	24-19145	32		148
98	24-19146	21		198
99	24-19148	31		198
100	24-19153	31		273
101	24-19154	11		148
102	24-19156	10		173
103	24-18896	20		123
104	24-18897	13		148
105	24-19150	39		198
106	24-19149	14		98
107	24-19151	14		123
108	24-19158	15		123
109	24-18548	22		123
110	24-16905	15		325
111	24-17365	15		300
112	24-17703	12		198
113	24-15867	17		123
114	24-15270	20		123
115	24-12530	15		98
116	24-7825	10		235
117	24-20849	40		150
118	24-15634	26		173
119	24-15175	15		148

120	24-15268	12		148
121	24-14450	28		122
122	24-20716	13		223
123	24-18457	15		90
124	24-9672	45	60	277
125	24-16553	12		173
126	24-15532	18		130
127	24-21172	5		98
128	24-21171	6		147
129	24-22482	5		148
130	24-22383	20		100
131	24-24245	6		65
132	24-14581	8		173
133	24-15786	21		65
134	24-14870	23		173
135	24-19210	5		210
136	24-19787	18		298
137	24-12034	12		123
138	24-5-737	66		NR
139	24-21504	11		225
140	24-14069	5	25	348
141	24-14361	44	65	245
142	24-22251	15		200
143	24-14217	26		198
144	24-9060	6		189
145	24-13581	30		420
146	24-21335	18		298
147	24-19788	18		205
148	24-22921	7		300
149	24-18352	6		200
150	24-7430	17		123
151	24-16162	12		98
152	24-13124	3		140
153	24-14627	>120		120
154	24-17733	60		150
155	24-23928	14	149	248
156	24-17255	20		225
157	24-13879	17		173
158	24-13725	6	20	248
159	24-20231	7		373
160	24-20583	177		305
161	24-20024	38	46	227
162	24-13474	13		198
163	24-17549	30	45	100
164	24-19293	18		248
165	24-16908	18		375
166	24-20416	14		198
167	24-20417	28		498
168	24-20418	12		448
169	24-18829	18		605
170	24-15719	24		148
171	24-18600	11		298
172	24-19206	20		198
173	24-19207	16		149
174	24-19740	8		499
175	24-20230	7		248
176	24-12690	3		145
177	24-17352	6		150
178	24-17471	8		123
179	24-19295	16		648
180	24-14866	40		150
181	24-17485	12		548
182	24-20741	6		548

183	24-16028	5		123
184	24-13822	20		200
185	24-15491	4		173
186	24-21208	50		95
187	24-2284	45		82
188	24-10545	19		147
189	24-18706	50		150
190	24-21325	39		175
191	24-12005	28		151
192	24-12057	14		102
193	24-12161	11		177
194	24-21721	10	28	473
195	24-21715	11		398
196	24-21722	19	29	573
197	24-21720	28		173
198	24-21723	30		598
199	24-21707	8	19	295
200	24-21708	25		298
201	24-21226	43		323
202	24-21718	6		248
203	24-21231	15		248
204	24-20736	10		248
205	24-20735	12		248
206	24-20729	11		248
207	24-20728	12		223
208	24-20733	6		198
209	24-21065	6		423
210	24-21227	23		198
211	24-21700	9	31	598
212	24-21066	8		273
213	24-20738	12	21	323
214	24-15785	8		298
215	24-15807	25		123
216	24-16773	17		148
217	24-15922	11		298
218	24-15983	36	56	173
219	24-15984	22	55	195
220	24-15985	14		298
221	24-16942	12		98
222	24-15360	18		198
223	24-15361	20		310
224	24-15362	11		398
225	24-15366	31		273
226	24-15369	14		98
227	24-15773	21		410
228	24-16626	12		198
229	24-16627	23		223
230	24-14066	64	>72	72
231	24-14168	14		198
232	24-14384	65		97
233	24-17018	15		555
234	24-18833	42		98
235	24-16935	25		300
236	24-21772	22		355
237	24-1680	35		140
238	24-16934	21		223
239	24-18247	12		505
240	24-17361	2		425
241	24-13580	8		198
242	24-18828	8		585
243	24-13544	20		223
244	24-17281	8		200
245	24-12922	18		298

246	24-14711	5		445
247	24-21190	80		275
248	24-18658	10		520
249	24-16455	38		300
250	24-12360	47		98
251	24-12860	8		98
252	24-13362	48		273
253	24-19664	22		300
254	24-12162	9		202
255	24-17160	35		570
256	24-16457	15		428
257	24-13183	8		548
258	24-13973	8		350
259	24-17256	6		450
260	24-17963	12		123
261	24-17659	7		198
262	24-18596	9		198
263	24-17734	8		700
264	24-17495	15		600
265	24-17964	7		173
266	24-17962	35		123
267	24-16307	7		448
268	24-17965	37		123
269	24-19083	14		505
270	24-15260	11		148
271	24-16790	14		198
272	24-17966	45		123
273	24-18598	11		348
274	24-19837	27		123
275	24-20017	18		325
276	24-10558	10		100
277	24-16826	9		265
278	24-16963	10		323
279	24-17332	11		223
280	24-17324	18		573
281	24-17325	6		148
282	24-21970	23		248
283	24-21969	19		248
284	24-19160	14		148
285	24-19838	7		148
286	24-15648	8		345
287	24-19635	20		205
288	24-18528	35		205
289	24-16288	18		198
290	24-17499	8		323
291	24-12479	20		102
292	24-12481	30		102
293	24-12826	12		198
294	24-17657	30		198
295	24-17658	18		98
296	24-18006	9		173
297	24-18008	8		298
298	24-22429	22		480
299	24-11160	20		135
300	24-17845	25		250
301	24-14517	9		198
302	24-15346	5		373
303	24-20232	14		173
304	24-23094	75		175
305	24-19633	17		305
306	24-22087	22		148
307	24-11630	18		140
308	24-12291	5		350

309	24-15836	8		147
310	24-22616	30		300
311	24-10199	20		90
312	24-12152	6		72
313	24-13426	30		275
314	24-17098	25		70
315	24-15173	43		110
316	24-14759	18		218
317	24-10505	>110		110
318	24-12620	28		123
319	24-15581	<65		172
320	24-15868	9		198
321	24-15869	29		140
322	24-15870	16		198
323	24-15966	32		173
324	24-18305	20		148
325	24-16089	35		173
326	24-16259	35		193
327	24-16260	38		198
328	24-16310	38		173
329	24-16608	32		148
330	24-16752	48		148
331	24-16754	35		198
332	24-20337	74		173
333	24-24513	62		198
334	24-16775	38		173
335	24-17258	45		200
336	24-14210	>122		122
337	24-10629	14		234
338	24-15651	5		323
339	24-16093	6		298
340	24-16099	16		98
341	24-16101	21		198
342	24-16104	10	66	98
343	24-16107	10		298
344	24-16109	23	57	298
345	24-19082	30		400
346	24-16037	12		123
347	24-16255	7		385
348	24-16257	11		148
349	24-16156	11		148
350	24-16791	28		123
351	24-16509	8		450
352	24-22430	12		330
353	24-21595	16		248
354	24-22411	29	40	173
355	24-20785	18		370
356	24-9181	24		173
357	24-10466	119		198
358	24-12938	22		120
359	24-12939	22		148
360	24-14476	9		450
361	24-13127	27		223
362	24-22084	21		373
363	24-22085	48		152
364	24-22086	36		369
365	24-20011	40		200
366	24-20013	40		200
367	24-6342	21		146
368	24-13699	8		97
369	24-9743	3		223
370	24-11962	14		148
371	24-12397	20		298

372	24-15138	6	22	247
373	24-15145	20		73
374	24-17364	40		250
375	25-20505	63	80	148
376	24-9720	70		198
377	24-14562	10		100
378	24-23031	34	48	198
379	24-13403	7		172
380	24-14549	45		320
381	24-14698	11		148
382	24-17571	9		223
383	24-15226	17		222
384	24-9987	15		125
385	24-5498	10		300
386	24-10206	60		125
387	24-10435	6		223
388	24-21523	19		84
389	24-13932	30		400
390	24-15311	10		123
391	24-15312	13		148

[1]Identifiers of the form 24-xxxxx and 25-xxxxx are well permit numbers issued by the N. J. Department of Environmental Protection. Identifiers of the form 24-x-xxx are N. J. Atlas Sheet coordinates of well logs in the N. J. Geological Survey permanent note collection.

[2]Described by drillers as “overburden”, “hardpan”, “clay and gravel”, “clay”, “sand and clay”, “sandy hardpan”, and “stony hardpan”.

[3]Described by drillers as “sandstone”, “rotten rock”, “rotten granite”, and “soft sandstone”.