DEPARTMENT OF ENVIRONMENTAL PROTECTION
NEW JERSEY GEOLOGICAL SURVEY

Prepared in cooperation with the
U. S. GEOLOGICAL SURVEY
NATIONAL GEOLOGIC MAPPING PROGRAM

Appendix of well and boring logs accompanies map

INTRODUCTION

Surficial materials in the Tranquility quadrangle consist of glacial, stream, wetland, and hillslope sediments, and weathered bedrock. The glacial sediments were deposited during two glaciations. They include sand, gravel, silt, and clay laid down by meltwater in glacial lakes and river plains; and till laid down by glacial ice as a discontinuous sheet on bedrock, in moraines, and in drumlins. The sand, gravel, silt, and clay, known collectively as stratified drift, are as much as 250 feet thick. Till is as much as 150 feet thick. The stream sediments include sand, gravel, and silt deposited in floodplains, stream terraces, and alluvial fans. The wetland sediments include peat and organic silt and clay deposited in marshes and swamps. Hillslope sediments include colluvium deposited in aprons along the base of hillslopes, and talus deposited at the base of cliffs. The stream, wetland, and hillslope deposits are generally less than 20 feet thick. The weathered bedrock generally consists of blocky, sandy silt to silty sand formed by chemical and mechanical decomposition of bedrock. It is irregularly distributed along zones of fracturing or compositional layering, and may be as much as 200 feet thick.

The accompanying map and sections show the surface extent and subsurface relations of these deposits. A brief summary of their resource and environmental characteristics is provided below. Appendix 1 (in pamphlet) lists water-well and test-boring logs used to plot bedrock-surface topography and to infer the subsurface distribution of deposits. Table 1 lists the composition of pebbles in the glacial deposits. The correlation chart shows the temporal relationships of the deposits. Figure 1 shows recessional ice margins and their associated deposits. The bedrock geology was mapped by Drake and others (1993).

The stratified drift is divided into units that represent both the ice-margin position and individual glacial-lake basin or glacial-stream valley in which the sediments were deposited. The name of the unit indicates the lake basin or valley, the number following the name indicates the ice margin position (or, in some cases, series of positions) within that basin or valley. Some of the glacial-lake deposits, such as lake-bottom and lacustrine-fan sediments and some small deltaic units, lack features that tie them to ice-margin positions and are not numbered. Likewise, some of the glacial-stream deposits cannot be traced to specific ice-margin positions, and are not numbered. The descriptions provide basic texture and thickness information for each stratified drift unit. Bedding, color, and sand and gravel composition are similar for many of the stratified drift units. Thus, these are described in the general headings for glacial-lake and glacial-stream deposits rather than in each unit description. Till is subdivided into three units based on age, color, grain-size, and gravel-clast composition. Moraines are mapped as morphologic varieties of these units.

RESOURCES AND ENVIRONMENTAL CHARACTERISTICS

Surficial deposits in the quadrangle yield ground water to domestic and public-supply wells; influence the movement of water and pollutants from the land surface into lakes, streams, and underlying glacial and bedrock aquifers; provide sand and gravel for construction; and support roads, railroads, and structures. Glacial aquifers are tapped by wells at several places. Yields and screened intervals for these wells are provided in Appendix 1. In the Pequest Valley, some domestic, and a few irrigation, wells draw water from glaciolacustrine sand and gravel aquifers (units Qpqf, Qpq4, Qpq7, Qpql) around Alphano (wells 60, 66-69, 76-78), Lake Tranquility (wells 38, 40, 53-55, 57, 171), and Brighton (wells 32, 33). In the Bear Creek Valley, several domestic wells near Johnsonburg (wells 16, 19, 20) tap unit Qpqf. In the Musconetcong Valley, several domestic wells (wells 131, 132, 134, 139, 144, 158, 164) tap glaciolacustrine sand and gravel (units Qwr1, Qwr2, and Qis) and sandy till (unit Qnm). Thick sandy till (units Qn and Qnm) and weathered gneiss (unit Qgw) also supply domestic wells around Petersburg (wells 79, 85, 86, 94, 95, 97-100). Thick glaciolacustrine deposits in the Pequest and Musconetcong Valleys likely have significant untapped ground water, particularly where fine-grained lake-bottom deposits (units Qpql and Qwrl) overlie sand and gravel (units Qpqf and Qis).

Hydraulic conductivities of the surficial deposits in the quadrangle can be estimated from statewide glacial aquifer-test data on file at the N. J. Geological Survey (Mennel and Canace, 2001) and published data summarized by Stanford and Witte (in press). Sand and gravel deposits are highly permeable (estimated hydraulic conductivity ranges from 100 to 1300 feet per day [ft/d]). Their outcrops may be recharge areas where they overlie glacial or bedrock aquifers. Sandy till is also permeable (estimated hydraulic conductivity ranges from 0.3 to 100 ft/d) and transmits water to underlying aquifers. Sandy silt till, weathered bedrock, and colluvium, are moderately permeable (estimated hydraulic conductivity ranges from 10^{-2} to 10^{-1} ft/d). Lake-bottom sediment is of low permeability and retards ground-water flow, particularly where clay is abundant (estimated hydraulic conductivity of silty-clayey sediment is 10^{-3} to 10^{-5} ft/d; silty-sandy sediment is generally 10^{-2} to 10^{-1} ft/d).

Sand and gravel have been extensively mined from the Waterloo Valley deposits, and, to a lesser extent, from the Pequest Valley and Bear Creek Valley deposits and sandy till of the terminal moraine. The location and extent of these mining operations are shown by pit and excavation-scarp symbols on the map. Most of the pits in the Pequest Valley and Bear Creek Valley deposits were inactive at the time of mapping (1996). Two large pits in the Waterloo Valley deposits were active. Much of the sand in these pits is mined from below the water table by dragline.

Peat and loose, organic-rich sand, silt and clay in units Qs and Qal are of low strength and therefore generally unsuitable supports for structures. They are also subject to frequent flooding and a high water table. Unit Qpql and low-lying parts of unit Qst also may have a high water table and are subject to occasional flooding. They may also contain poorly consolidated, saturated silt, clay, and fine sand of low strength. Areas of bedrock outcrop (unit "r") and thin till (Qnt and Qkt) have little or no soil cover overlying fresh bedrock. The use of septic systems may be severely limited in these areas, and blasting may be required for foundation excavation and road grading.

DESCRIPTION OF MAP UNITS

Postglacial Deposits--Artificial fill and natural sediment deposited along streams, in lakes and wetlands, and at the base of cliffs. These deposits have been accumulating since retreat of the late Wisconsinan glacier. Postglacial lake deposits in Francis Lake (about 1 mile west of Greendell) yielded radiocarbon dates of 18,570±250 (SI-5273), 16,480±430 (SI-5274), 13,510±335 (SI-5300), and 11,220±110 (SI-5301) years before present (yrs BP) from depths of 30, 27, 24, and 20 feet, respectively (Cotter and others, 1986). Similar deposits in Allamuchy Pond just south of Allamuchy yielded dates of 12,260±220 (RIDDL-1238), 10,740±420 (RIDDL-1273), and 9230±160 (RIDDL-1236) yrs BP from depths of 30, 28, and 26 feet, respectively (Peteet and others, 1993).

ARTIFICIAL FILL--Excavated till, sand, gravel, and rock; also, construction debris, cinders, and slag. In highway and railroad embankments, dams, and filled land. As much as 100 feet thick in large railroad embankments but generally less than 20 feet thick. Small areas of fill in urban areas are not mapped.

Qal — ALLUVIUM--Silt, sand, clay, and pebble-to-cobble gravel. Contains variable amounts of organic matter. Color of matrix sediment is gray, brown, and yellowish brown. As much as 15 feet thick. Silt, sand, and clay are deposited as overbank material on floodplains and are most abundant along low-gradient stream reaches. Gravel and sand are deposited in stream channels and are most abundant in higher-gradient stream reaches. Gravel and sand composition is similar to that of surficial deposits in the drainage basin.

Qst — STREAM TERRACE DEPOSITS--Sand, very pale-brown to light-gray, and pebble gravel in terraces with surfaces as much as 15 feet above the modern floodplain. As much as 15 feet thick (estimated).

Qaf — ALLUVIAL FAN DEPOSITS--Cobble-to-boulder gravel and very pale-brown to light-gray sand forming fans where streams enter lowlands. As much as 25 feet thick.

Qs — SWAMP DEPOSITS--Gray silt and clay with organic matter, overlain by dark-brown to black peat. May include fine-grained alluvium in places adjacent to unit Qal. As much as 40 feet thick at Budd Lake (Harmon, 1968) but generally less than 10 feet thick elsewhere (estimated). In the lowlands along the Pequest River, Bear Creek, and Trout Brook in Warren County, swamp deposits are mapped where they are more than 3 feet thick. Surface organic deposits less than 3 feet thick also cover parts of units Qal, Qst, and Qpql. Spot thicknesses for these deposits are indicated by filled triangles on the map. Glacial lake-bottom deposits may also underlie swamp deposits outside these lowlands, particularly in large swamps. Possible occurrences of these underlying lake-bottom deposits are shown in purple on figure 1.

Qta — TALUS--Angular boulders and blocks of gray gneiss (on Allamuchy Mountain) and gray dolomite (near Mud Pond), with little or no matrix material, forming steep aprons at the base of cliffs. Maximum thickness 20 feet (estimated). Many small talus deposits are not mapped.

Glacial Deposits--These include stratified glacial-lake and glacial-stream deposits, and till. They were laid down during the Illinoian and late Wisconsinan glaciations. Illinoian ice advanced to a terminal position about 3 miles south of the south edge of the quadrangle. It reached its maximum extent about 150,000 years ago, based on correlation to the marine oxygen-isotope record (oxygen-isotope stage 6). This correlation is based on comparison of glacial ice volumes and oxygen-isotope values, but has not been confirmed by dates from the deposits. Late Wisconsinan ice advanced to a terminal position along the southern edge of the quadrangle, marked by a prominent terminal moraine (fig. 1; unit Qnm). It began to melt back from this position about 20,000 years ago, based on radiocarbon dating of organic material in the bottom of postglacial bogs and lakes at several locations in northwestern New Jersey and adjacent Pennsylvania, including basal dates of 18,570±250 (SI-5273) and 18,390±260 (SI-4923) years before present (yrs BP) from a depth of 30 feet in Francis Lake one mile west of Greendell (dates on map) (Cotter and others, 1986).

Harmon (1968) analyzed pollen and obtained two radiocarbon dates from a 60-foot core recovered from the floating bog along the west shore of Budd Lake (shown on map). A date of 12,290±570 yrs BP (GXO 330) was obtained on organic clay at a depth of 27 feet, at the transition from pine-spruce to oak-hemlock forest, and a date of 22,870±720 yrs BP (I-2845) was obtained from an organic clay at a depth of 37 feet, within a predominantly spruce-pine interval about 5 feet below the level of maximum cold marked by spruce and sedge pollen. Harmon (1968) rejected both dates as too old, based on correlation of the pollen zones to other deglaciation pollen records in the northeast. However, if the dates are on uncontaminated material and if a precursor to Budd Lake existed before the late Wisconsinan glaciation, as is suggested by buried Illinoian lacustrine sediments in the valley fill at and north of Budd Lake (Stanford and others, 1996), then the lower date may be a maximum age for the arrival of late Wisconsinan ice at the terminal moraine.

Illinoian deposits include till (Qit) and probable glaciolacustrine sediment (Qis). The till crops out in two patches on gently-sloping terrain south of the late Wisconsinan terminal moraine. MacClintock (1940) informally termed this till the "Budd Lake drift" and, based on the degree of clast weathering, suggested it was of early Wisconsinan age. Evidence for early Wisconsin glaciation in the New Jersey-eastern Pennsylvania region has been questioned (Ridge and others, 1990) and an Illinoian age is more likely. The glaciolacustrine sediment occurs in the valley fill beneath late Wisconsinan sediment in the Musconetcong Valley (sections A-A', C-C'), as inferred from well logs. Some of it may be till. The glaciolacustrine sediments here indicate that a glacial lake filled this reach of the Musconetcong Valley during the Illinoian glaciation. This lake in part occupied a glacially overdeepened trough in the carbonate bedrock flooring the valley because well logs in the valley just south of the quadrangle in the Hackettstown area indicate that the 500-foot bedrock-surface contour is closed. Additional closure of the basin is indicated by the occurrence of the glaciolacustrine deposits up to an elevation of about 580 feet (section C-C'). This additional closure may have been provided by a moraine or head-of-outwash dam across the valley at, or north of, the Illinoian terminal position south of Hackettstown. However, because little evidence of such a dam survives, the position of the spillway and elevation of the lake surface are unknown. The direction of Illinoian ice flow was probably similar to late Wisconsinan ice flow because gravel in Illinoian till is similar to that in late Wisconsinan till, and the terminal positions of the two glaciations are parallel.

The orientation of striations and the distribution of erratics indicate that the late Wisconsinan glacier advanced generally southward across the quadrangle, with a slight westerly component in the western half. Gravel clasts in till also indicate southerly to slightly west-of-south ice flow. Till in the northwestern part of the quadrangle contains as much as 10 percent (table 1, sites 6 and 26) quartzite from the Shawangunk Formation. Reconstruction of glacial flowlines suggests that these clasts came from outcrops on Kittatinny Mountain north of the Culvers Gap area, about 15 miles north of the quadrangle (Witte, 1988, 1991). Till on the southern slope of Allamuchy Mountain in the quadrangle contains a high percentage of carbonate pebbles (table 1, sites 15, 17, 20, 23, 24) indicating southerly and southwesterly transport of these clasts from carbonate outcrops in the Pequest Valley.

The glacier deposited till (Qk, Qn) in continuous sheets on hillslopes and valley walls facing the advancing ice (north- or northwest-facing slopes). Locally, till was deposited on overridden zones of weathered bedrock (exposures indicated by inverted triangle symbol on map; see also well logs 42-49 at Lake Tranquility and 83, 84, 89, 94, 97-100, 108, 117, 120 around Petersburg). In the Musconetcong Valley between Waterloo and Hackettstown, till covers glaciolacustrine deposits (Qwr1, Qwrl) laid down in lakes ponded in front of the advancing ice (sections A-A', C-C'). This relationship is exposed in the several large pits in the valley, where 10 to 20 feet of till overlie sand that is locally deformed into large recumbent folds by overriding ice. Most of the overlying till has been removed by excavation. Two boring logs outside the pits also record this stratigraphy (wells 151, 162).

In other areas till deposition was discontinuous and the glacier eroded bedrock. Large erosional features include scoured basins in carbonate rock beneath the Bear Creek Valley (below the 450-foot bedrock-surface contour) and Pequest Valley (below the 400-foot bedrock-surface contour). Well and seismic data in these valleys southwest of the map area indicate that these contours are closed (Witte and Stanford, 1995). Numerous smaller scoured or plucked basins also occur in carbonate and gneiss bedrock on uplands. Many of these basins now contain swamps, for example, the swamp around Mud Pond near Johnsonburg and the swamps on Allamuchy Mountain near Cranberry Lake. On northwest- or north-facing slopes that faced advancing ice, glacial abrasion formed gently-sloping ledges. On southeast- or south-facing slopes that faced away from advancing ice, glacial quarrying formed cliffs. Examples of such cliffs include High Rocks (in carbonate rock near Mud Pond) and the cliffs in gneiss in Panther Valley east of Alphano and on Allamuchy Mountain just northeast of Waterloo. Slopes with oblique orientations to ice flow were alternately abraded and quarried, and thus display both ledge and cliff outcrops.

The terminal moraine (Qnm) is a belt of till with ridge-and-basin topography deposited as the ice margin stood at and receded from its southernmost position. The major landform features of the moraine, shown by special symbols on the map, are ridges, knolls, basins, and plateaus. Many of the basins are swales between ridges built by ice-front deposition rather than kettles formed by melting of ice blocks. The ridges include flowtill aprons with gentle north slopes and steeper apron-like south slopes. These ridges form the front of the moraine on the ridge east of Petersburg (near well 116). They also occur within the moraine in places. Asymmetric ridges with gentle north slopes and steeper south slopes occur along the front of the moraine east of Stephens State Park and within the moraine, either singly or as several parallel ridges. They may represent push or overriding of till by active ice. Also common are roughly symmetrical ridges with parallel or, in places, polygonal map patterns that may represent ice-channel or subglacial ice-cavity fills. The plateaus and knolls may represent deposition in ice-walled basins or subglacial cavities. Nonmorainic till occurs within the moraine belt on steep bedrock slopes where deposition was limited or where morainic landforms were destroyed by slope erosion.

Deposition of stratified drift in Waterloo Valley (Qwr1, Qwr2, Qwrl) occurred shortly before (Qwr1, Qwrl) and shortly after (Qwr2) deposition of the moraine. As the ice front retreated northward from the moraine, stratified drift was deposited in, or on grade to, glacial Lake Pequest (Qpq4-Qpq6, Qpqf, Qpql, Qbc1); in smaller, slightly higher glacial lakes dammed by previously-deposited drift in the Bear Creek and Pequest Valleys (Qbc2, Qbc3, Qpq7-10, Qbcl, some Qpql); and in a few small lakes on uplands above the main valleys (Qsu). As the valleys filled with sediment, and as the level of glacial Lake Pequest lowered during erosion of its moraine dam, meltwater from ice margins to the north of the quadrangle cut channels into the earlier sediments and deposited terrace sand (Qmt). Similarly, after ice withdrew from the Musconetcong Valley, meltwater from upstream ice margins deposited both fluvial and underlying lacustrine sediment there (Qmc).

The ice-contact slopes of stratified deposits, and the distribution of coarse gravel within the stratified deposits indicating proximity to the ice margin, permit an approximate reconstruction of recessional ice margins. In the quadrangle these margins (fig. 1) trend generally east-west. Details of glacial-lake levels and spillways, and glacial-stream drainage, are provided in the map unit descriptions.

Glacial-Lake Deposits--These are stratified and generally well sorted. They include sand and gravel laid down in deltas and lacustrine fans; and clay, silt, and fine sand laid down on lake-bottom plains and in the lower parts of deltas. Bedding in the deltas includes inclined foreset beds of sand, pebbly sand, and minor pebble-to-cobble gravel, overlain at the surface of some deltas by thin, horizontal topset beds of sand and pebble-to-cobble gravel. Lacustrine fans contain gently dipping beds of sand, pebble gravel, and cobble gravel. Bedding in both deltas and lacustrine fans may be deformed locally by collapse, slumping, or pushing by glacial ice. Bedding in lake-bottom deposits is generally horizontal, laminated to thin-bedded, and undeformed. Lake-bottom deposits consist chiefly of silt and clay away from deltas and fans, and include gently inclined bottomset beds of silt and fine sand, with minor clay, beneath or adjacent to deltas. Nongravel sediment is very pale brown to light gray. Sand composition is chiefly quartz, feldspar, and fragments of carbonate rock, gneiss, mudstone, sandstone, and quartzite, with variable but minor amounts of mica and heavy minerals. Gravel consists chiefly of clasts of local bedrock or clasts eroded from the local till. Gravel in the Waterloo Valley deposits consists chiefly of gneiss and carbonate rock (table 1, sites 5, 44, 45, 47) from local subglacial sources. Gravel in unit Qwr2 (site 5) is dominantly gneiss, suggesting that this unit, which is a recessional deposit laid down on top of the terminal moraine, was supplied by meltwater draining from Allamuchy Mountain, or by the reworking of the local carbonate-poor till of the moraine. Gravel in the Bear Creek Valley and Pequest Valley deposits consists chiefly of carbonate rock and gray and brown mudstone and sandstone, with minor amounts of gneiss, quartzite, and red shale. Within these two valleys, deposits rich in gray shale (sites 1-3, 10, 11, 25, 37, 38) occur on, or adjacent to, outcrop areas of gray shale of the Martinsburg Formation, or on shale-rich till. Likewise, deposits rich in carbonate rock (sites 4, 7, 9, 13, 14, 16, 19, 21, 29, 30-32, 34, 35) occur on outcrops of carbonate rock of the Kittatinny Supergroup.

PEQUEST VALLEY DEPOSITS--Deltaic (Qpq4-10), lacustrine-fan (Qpqf), and lake-bottom (Qpql) sediment deposited in glacial Lake Pequest and smaller successor lakes in the Pequest and Trout Brook Valleys (Ridge, 1983; Witte, 1988, 1991). Qpq1-3 are south and west of the quadrangle (Ridge, 1983). Lake Pequest occupied the Pequest and Bear Creek lowland in Warren County. It was dammed by the terminal moraine between Great Meadows and Townsbury, about 4 miles southwest of Alphano. The spillway across the moraine was progressively lowered by erosion from 565 to 535 feet and the level of Lake Pequest thus declined as the ice margin retreated (Witte, 1988). A second spillway at 585 feet at Glovers Pond, about a mile southwest of Johnsonburg, may have discharged for a time before further erosion of the moraine at Townsbury, depending on the amount and direction of isostatic depression in the area. In the Tranquility quadrangle the level of Lake Pequest, adjusting for rebound, thus lowered from about 585 feet near Alphano to 575 feet near Tranquility (Witte, 1988). Units Qpq4, Qpq5, Qpq6, Qpqf, and most of Qpql were deposited in Lake Pequest. The other Pequest Valley deposits include deltaic and overlying fluvial sediments, and some lake-bottom sediment, that filled smaller lake basins dammed by Qpq6 and successive deposits.

Qpq10 — **Pebbly sand**--As much as 50 feet thick (estimated). Spillway was at an elevation of about 560 feet across Qpq8 at Huntsville. Overlies Qpql.

Qpq9 — **Cobble-to-pebble gravel and sand**--As much as 50 feet thick (estimated). Spillway was at an elevation of about 580 feet across Qpq8 at Huntsville. May overlie Qpql.

Qpq8 — **Cobble-to-pebble gravel and sand**--Cobble gravel and sand, with some beds of diamicton, near Brighton and Huntsville grading southwesterly to pebbly sand. As much as 100 feet thick. Spillway was at an elevation of about 570 feet across Qpq6 at Tranquility.

Qpq7 — **Cobble-to-pebble gravel and sand**--Cobble gravel and sand near Turtle Pond grading southward to pebble gravel and pebbly sand. As much as 70 feet thick. Spillway was at an elevation of about 580-590 feet across Qpq6 at Tranquility or at the south end of Lake Tranquility or across the rock upland east of Tranquility. Overlies Qpql in the Lake Tranquility-Buckmire Pond area.

Qpq6 — **Pebbly sand and cobble-to-pebble gravel**--Cobble-to-pebble gravel and sand near Tranquility; sand to pebbly sand elsewhere. As much as 50 feet thick. Overlies Qpql in the plains around Tranquility Church.

Qpq5 — **Cobble-to-pebble gravel and pebbly sand**--Includes some boulder gravel east of Quaker Church. As much as 100 feet thick (estimated).

Qpq4 — **Cobble-to-pebble gravel, sand, and pebbly sand**--As much as 100 feet thick.

Qpql — **Silt, clay, fine sand**--As much as 200 feet thick.

Qpqf — **Cobble-to-pebble gravel and sand**--Includes some pebbly sand. As much as 120 feet thick.

BEAR CREEK VALLEY DEPOSITS--Deltaic (Qbc1, Qbc2, Qbc3) and lake-bottom (Qbcl) sediment deposited in glacial Lake Pequest and smaller successor lakes in the Bear Creek Valley (Witte, 1988, 1991). Unit Qbc1 includes deltaic sediment near Johnsonburg and chiefly fluvial sediment upvalley from the Lackawanna Railroad. It was deposited in, and on grade to, Lake Pequest. Units Qbc2 and Qbc3 were deposited in smaller lakes dammed by sediments of Qbc1.

Qbc3 — **Cobble-to-pebble gravel and sand**--Includes minor boulder gravel. As much as 40 feet thick (estimated). Spillway was at an elevation of about 615 feet across deposits of Qbc1.

Qbc2 — **Cobble-to-pebble gravel, pebbly sand, and sand**--As much as 50 feet thick (estimated). Spillway was either across deposits of Qbc1 or through the low bedrock upland west of Qbc2, at an elevation of about 640 feet.

Qbc1 — **Cobble-to-pebble gravel and pebbly sand**--Cobble-to-pebble gravel near Huntsburg grading southwesterly to pebbly sand near Johnsonburg. As much as 50 feet thick. Overlies Qpql in the Johnsonburg area, and Qbcl locally south of Huntsburg. Likely deposited from more than one ice margin position (fig. 1).

Qbcl — **Silt, fine sand, clay**--As much as 50 feet thick (estimated). Locally underlies Qbc1 and probably underlies swamp deposits in the Big Springs swamp east of deposits Qbc2 and Qbc3.

WATERLOO VALLEY DEPOSITS--Deltaic (Qwr1, Qwr2) and lake-bottom (Qwrl) sediment deposited in glacial lakes in the Musconetcong Valley between Hackettstown and Waterloo. Qwr1 and Qwrl underlie till of the terminal moraine (Qnm) and were deposited in a lake basin in front of advancing ice. This lake may have formed when ice crossing the narrow part of Allamuchy Mountain in the southwestern part of the quadrangle dammed the Musconetcong Valley near Hackettstown, just south of the quadrangle. Ice crossing the broad part of Allamuchy Mountain to the northeast may have been delayed, allowing a lake to fill in the valley north of Hackettstown before arrival of ice there. Qwr2 was deposited in a small lake dammed by the moraine during ice-margin retreat from the valley.

Qwr2 — **Pebbly sand and cobble-to-pebble gravel**--As much as 40 feet thick. Spillway was at an elevation of about 630 feet across the moraine along the route of the present Musconetcong River.

Qwr1 — **Sand and pebbly sand**--As much as 70 feet thick. Locally deformed into isoclinal recumbent folds by overriding ice.

Qwrl — **Silt, fine sand, and clay**--As much as 100 feet thick. In subsurface only (sections AA', CC'), beneath Qwr1.

UPLAND LACUSTRINE DEPOSITS--Deltaic and lacustrine-fan sediment deposited in small ice-dammed lake basins in upland areas.

Qsu — **Cobble-to-pebble gravel and sand**--As much as 40 feet thick. Spillways and ice-margin positions for these deposits are shown on figure 1.

ILLINOIAN GLACIAL-LAKE DEPOSITS--Deltaic and lacustrine-fan sand and gravel (Qis) deposited in an Illinoian glacial lake in the Musconetcong Valley. Spillway location and elevation are uncertain but may have been positioned across an Illinoian sediment dam to the south, now eroded or buried by terminal moraine deposits. In subsurface only, beneath late Wisconsinan deposits (sections A-A', C-C').

Qis — **Sand and gravel**--Minor silt and clay. May include some till (unit Qit). As much as 100 feet thick (estimated).

Glacial-Stream Deposits--Stratified, generally well-sorted sand and gravel forming valley-bottom plains and terraces. Bedding is generally horizontal; varying from massive, thick beds in cobble-to-boulder gravel; to cross-beds and thin horizontal beds in sand to pebbly sand. Nongravel sediment is very pale brown, brown, and light gray. Sand is chiefly quartz, feldspar, and fragments of carbonate rock, gneiss, mudstone, sandstone, and quartzite, with minor mica and heavy minerals. Gravel in the Musconetcong deposits is chiefly gneiss, with some gray to brown mudstone and sandstone and a little gray carbonate rock (table 1, sites 40-43). This composition is noticeably depleted in carbonate rock compared to the adjacent Waterloo Valley deposits, reflecting supply from upstream in the Musconetcong basin where carbonate rocks are rare and carbonate-rock content of the till low. Gravel in the Qm and Qmf deposits is chiefly gneiss, with minor quartzite and carbonate rock. Gravel in unit Qmt is similar to that in the Pequest Valley deposits.

Qmc — MUSCONETCONG DEPOSIT--**Cobble gravel, cobble-to-pebble gravel, and sand**--As much as 80 feet thick near Waterloo, where it includes deltaic sand in the subsurface; elsewhere generally less than 20 feet thick (estimated). Deposited primarily by meltwater from ice margins upstream in the Musconetcong Valley. The deltaic sediment near Waterloo was deposited in a ponded segment of the valley dammed by the terminal moraine during ice-front retreat.

Qm — MIXED MELTWATER AND ALLUVIAL DEPOSITS--**Cobble-to-boulder gravel, sand, silt**--Includes some boulder lag. As much as 10 feet thick (estimated). Deposited by both meltwater and postglacial streams in three small valleys in front of the terminal moraine west of Budd Lake.

Qmf — MELTWATER FAN DEPOSITS--**Cobble-to-boulder gravel and sand**--As much as 20 feet thick. Forms fans where meltwater channels enter valleys. The two fans near Allamuchy are 20 to 40 feet above postglacial alluvial fans on the valley floor, suggesting that they were deposited against the edge of ice filling the valley bottom.

Qmt — MELTWATER TERRACE DEPOSITS--**Sand, pebbly sand, minor pebble gravel**--As much as 50 feet thick but generally less than 20 feet thick. Forms terraces with surfaces below the surfaces of ice-marginal deltaic and fluvial deposits but above the surfaces of postglacial deposits, indicating deposition by meltwater from upvalley ice margins. The deposit south of Quaker Church is shallow-water deltaic sand laid down in a low stage of glacial Lake Pequest.

Till and Related Deposits--Poorly-sorted, nonstratified sediment deposited by glacial ice or by flow of sediment from the glacier surface. Occur in drumlins and moraines, and as a discontinuous layer on the bedrock surface.

Qn, Qnt — NETCONG TILL--Yellow, yellowish-brown, very pale-brown (oxidized) to light-gray and brownish-gray (unoxidized) silty sand to sand with many (10 to 40 percent by volume) subrounded to subangular pebbles and cobbles, and some (5 to 10 percent 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 is chiefly gneiss, some gray carbonate rock and gray-to-brown mudstone and sandstone, and a trace of white-to-gray quartzite. Boulders are chiefly gneiss, with some scattered carbonate rock and quartzite. Unit Qn is as much as 120 feet thick in till sheets but is generally less than 40 feet thick elsewhere. Well records and exposures indicate that the till sheets between Lake Tranquility and Allamuchy and around Petersburg overlie thick zones of weathered gneiss. Several exposures near Allamuchy show that basal parts of Qn here consist largely of weathered gneiss fragments. Unit Qnt delineates areas of scattered bedrock outcrop where the till is discontinuous and generally less than 20 feet thick. Contacts with units Qk and Qkt are gradational.

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.

Qna — NETCONG TILL, ABLATION PHASE--Very pale-brown to light-gray sand to slightly silty sand with many subangular to subrounded pebbles and cobbles and few to some boulders. As much as 30 feet thick. Noncompact. Includes some sand and gravel. Gravel is enriched in carbonate rock and gray mudstone compared to adjacent Qn. Forms hummocky topography in the deep valley northeast of Petersburg. Here, ice may have become separated from the main glacier as the melting ice lowered across the high ridge to the north. Melting of this stagnant ice released the till as an ablation deposit.

Qk, Qkt — KITTATINNY TILL--Very pale-brown and yellowish-brown (oxidized) to grayish-brown and light olive-brown (unoxidized) sandy silt to silt with some to many subrounded to subangular pebbles and cobbles and a few (0 to 5 percent by volume) to some subrounded boulders. Depth of oxidation ranges from 5 to 15 feet. Till matrix is generally compact, slightly plastic, slightly sticky, nonjointed, with moderately developed subhorizontal fissility. Gravel includes chiefly gray-to-white carbonate rock and gray mudstone and sandstone, with some white-to-gray quartzite and a trace of red shale. Boulders are chiefly carbonate rock, with some quartzite. Unit Qk is as much as 150 feet thick (estimated) in the drumlin at Allamuchy but is generally less than 40 feet thick elsewhere. Unit Qkt delineates areas of scattered bedrock outcrop where till is discontinuous and generally less than 20 feet thick. Contacts with units Qn and Qnt are gradational.

Qit — ILLINOIAN TILL--Brown, brownish-yellow, and very pale-brown silty sand to sandy silt with some to many subrounded to subangular pebbles and cobbles and few to some subrounded boulders. Till matrix is generally compact, nonplastic, nonsticky, nonjointed, but may have a weak to moderate subhorizontal fissility. Gravel is chiefly gneiss, and a little gray mudstone, sandstone, chert, carbonate rock, and white-to-gray quartzite. Boulders are chiefly gneiss, with few to some white-to-gray quartzite. Carbonate clasts are fully decomposed to depths of more than 20 feet; gneiss clasts have weathered rinds generally greater than 0.25 inch thick. Some mudstone clasts are also deeply weathered or decomposed. As much as 20 feet thick. Crops out south of the terminal moraine in the southeast corner of the quadrangle, and may underlie late Wisconsinan deposits in places beneath the terminal moraine in the Musconetcong valley fill.

Hillslope Deposits and Weathered Bedrock Material--Poorly stratified and poorly sorted sediment formed by downslope movement of material on hillslopes and by mechanical and chemical decomposition of bedrock.

Qct — TILL COLLUVIUM--Material as in unit Qn, except noncompact and nonfissile, forming aprons or flow-lobes on hillslopes. As much as 20 feet thick (estimated). Includes a flowtill apron in front of the terminal moraine on the 1180-foot hill east of Petersburg, and possible ice-walled debris-flow lobes composed of remobilized till on steeply-sloping parts of the terminal moraine east of Saxton Falls.

Qctg — MIXED TILL AND GNEISS COLLUVIUM--Material as in unit Qct, with the addition of some angular cobbles, pebbles, and boulders of gneiss derived from bedrock outcrops upslope. As much as 20 feet thick. Forms aprons along the base of steep slopes on the west side of the Musconetcong Valley between Waterloo and Saxton Falls. Deposited by downslope movement of till and underlying fractured gneiss.

Qcg — GNEISS COLLUVIUM--Yellowish-brown to reddish-brown silty sand to sandy silt with many angular pebbles and cobbles of gneiss; 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. Upper blocky colluvium is derived from downslope movement of fractured, weathered bedrock; lower, layered colluvium is derived from downslope movement of saprolite. Total thickness as much as 40 feet (estimated). Forms aprons along the base of hillslopes south of the terminal moraine.

Qcal — COLLUVIUM AND ALLUVIUM, UNDIVIDED--Interbedded colluvium as in unit Qcg and dark-brown to yellowish-brown silty sand and pebble-to-cobble gravel alluvium forming valley-bottom fills on uplands south of the terminal moraine. As much as 20 feet thick (estimated).

Qgw — WEATHERED GNEISS--Yellow, very pale-brown, white, pink, clayey sand to gravelly sand with some to many angular pebbles and cobbles of gneiss. Texture and structure vary from massive, blocky fractured-rock rubble to saprolite that preserves rock structure. Most material is a mix of rock rubble and saprolite-derived massive clayey, silty sand. As much as 100 feet thick, but thickness varies greatly within short distances. Includes some patchy gneiss colluvium generally less than 10 feet thick.

MAP SYMBOLS

Contact--Dashed where featheredged, dotted where concealed by water, or where removed by excavation. Contacts of postglacial deposits, stratified glacial deposits, and moraines generally are sharp and well-defined by landforms. Contacts between units Qn, Qnt, Qk, Qkt, Qit, Qgw, Qcg, Qctg, Qct, and bedrock outcrop areas ("r") generally are gradational or featheredged.

Area of extensive bedrock outcrop--Surficial material generally absent.

Striation--Observation at dot. Arrow shows inferred direction of ice flow. Flagged striations are from Ridge (1983).

Drumlin--Line on crest, symbol at summit.

Meltwater channel--Line in channel bottom, arrow shows inferred direction of meltwater flow.

Spillway for glacial lake--Symbol in spillway area. Arrow shows drainage direction. Lettering indicates associated deposit.

Scarp cut by postglacial streams--Line at top of scarp, symbols on slope.

Scarp cut by meltwater--Line at top of scarp, ticks on slope.

Man-made excavation scarp--Line at top of scarp, ticks on slope.

Sand and gravel pit--Line through symbol indicates pit inactive in 1996.

Surface accumulation of boulders--On till, created by meltwater washing.

Exposure of weathered gneiss underlying late Wisconsinan till

Shallow topographic basin--Occurs chiefly in areas of high water table where thin terrace sand overlies clay. May have formed by melting of ground-ice lenses.

(Qnm)/Qwr1 — **Unit formerly present**--Unit in parentheses to left of slash covered unit to right of slash before excavation. Shows former extent of units Qnm, Qmc, and Qmf in the large pits in the Musconetcong Valley where Qwr1 is now exposed.

Thickness of peat--In feet, over unit Qal or Qst. Penetrated by 6-foot hand-auger hole.

Thickness of Qst or Qal--In feet, over unit Qpql. Exposed in excavation or penetrated by 6-foot hand-auger hole.

Well or boring with log in Appendix 1--Location accurate to within 100 feet.

Well or boring with log in Appendix 1--Location accurate to within 500 feet.

Site of pebble lithology count--Data in table 1.

Elevation of bedrock surface--Contour interval 50 feet. Shown only in lowlands.

Radiocarbon date--Age, in radiocarbon years before present, for oldest date in core. Laboratory number in parentheses. References in text.

Topographic features of the terminal moraine:

Asymmetric ridge--Line at crest, barbs on gentler 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--Symbol on summit, line around base.

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

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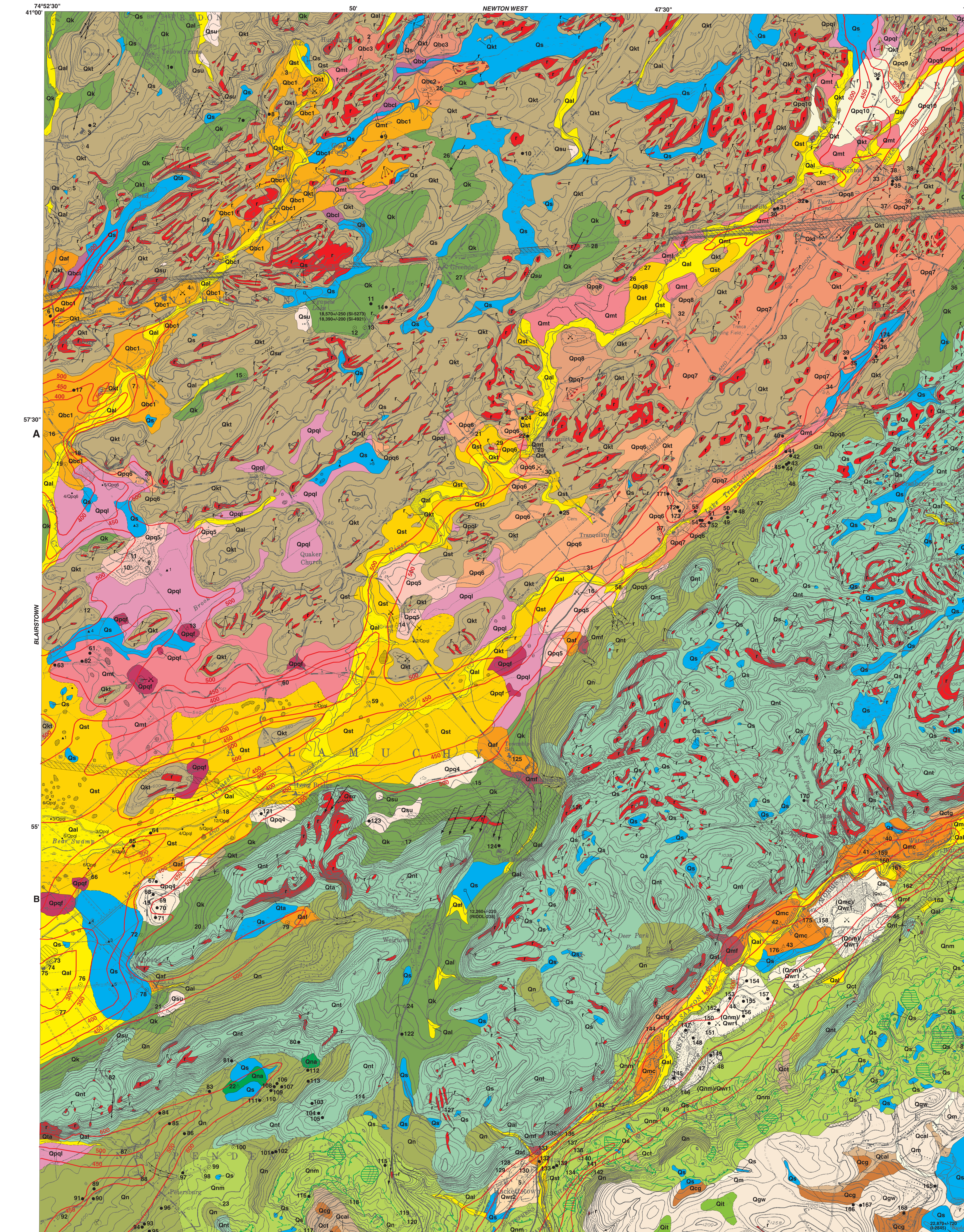


Base from U. S. Geological Survey, 1954
Photorevised 1971

Geology mapped 1983, 1989, 1992-93, 1996

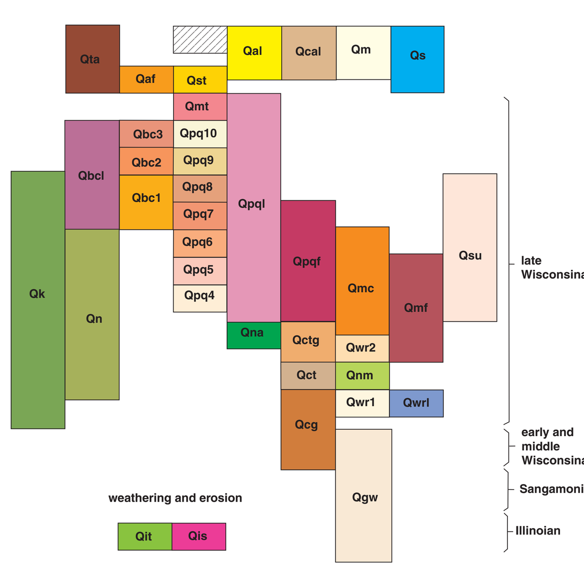
SCALE 1:24 000

APPROXIMATE MEAN DECLINATION, 1971

SURFICIAL GEOLOGY OF THE TRANQUILITY QUADRANGLE, WARREN, SUSSEX, AND MORRIS COUNTIES, NEW JERSEY

by
Scott D. Stanford and Ron W. Witte
2002

CORRELATION OF MAP UNITS



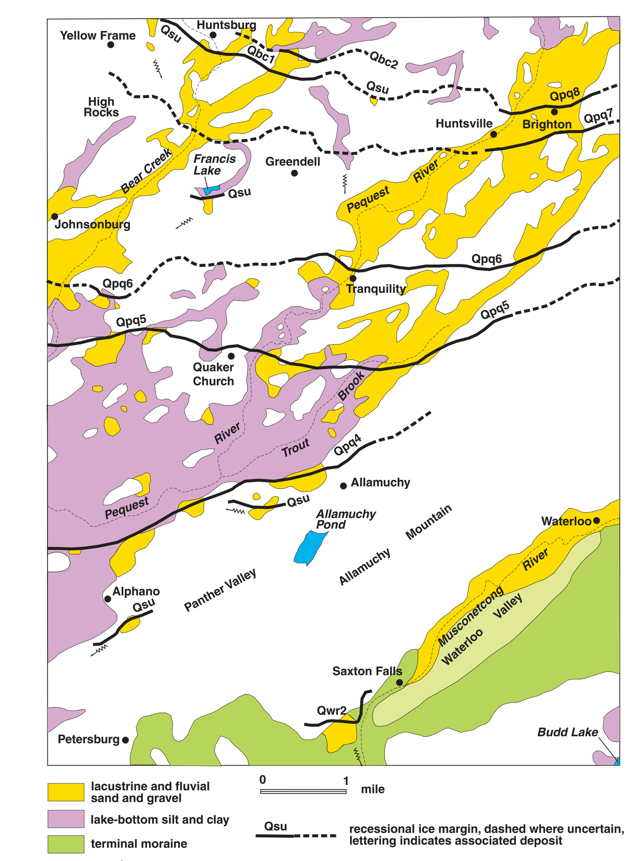
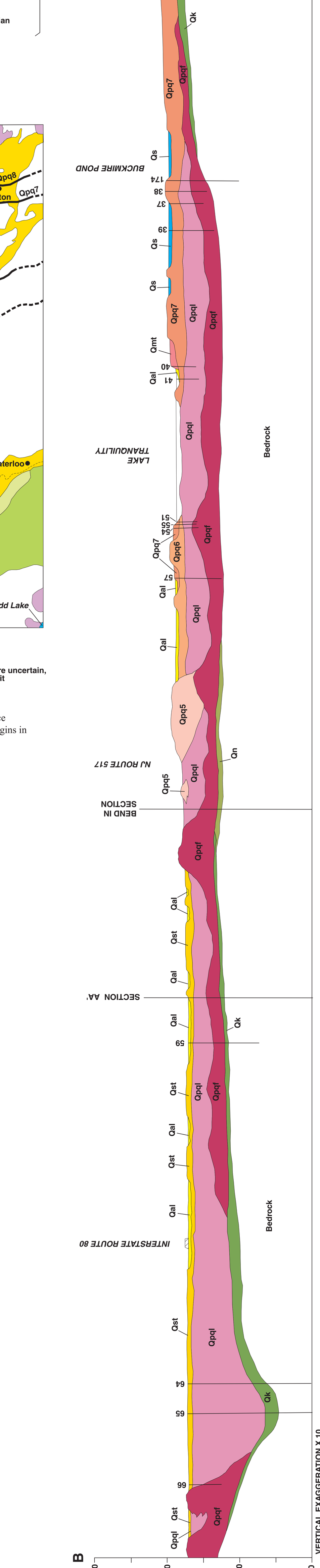


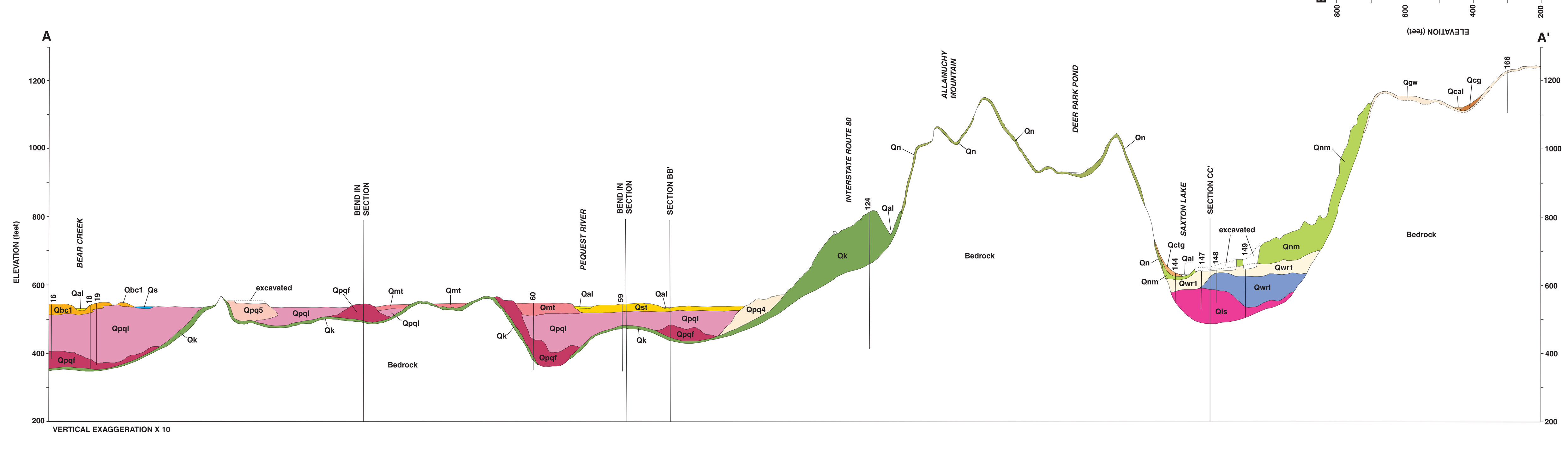
Figure 1.--Terminal moraine, stratified deposits, glacial-lake spillways, recessional ice margins, and places named in text in the Tranquility quadrangle. Recessional ice margins in the Pequest and Bear Creek valleys are from Ridge (1983) and Witte (1988, 1991).

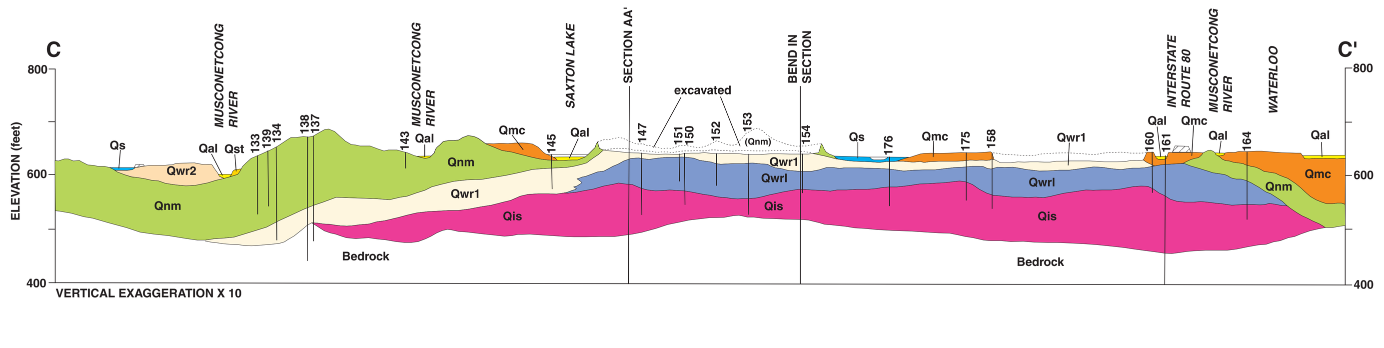
Table 1.--Composition of pebbles in surficial units

Site[1]	Unit	Number of pebbles	gneiss	gray shale	carbonate rock	quartzite	red shale
1	Qbc1	125	0	95	0	5	0
2	Qbc2	125	0	98	1	1	0
3	Qbc1	125	0	95	1	4	0
4	Qpq6	125	0	18	78	4	0
5	Qwr2	109	92	8	0	0	0
6	Qk	211	0	28	60	10	2
7	Qbcl	108	0	5	93	0	0
8	Qwr1	112	89	10	0	1	0
9	Qpq6	115	0	10	87	3	0
10	Qpq7	135	0	45	50	4	1
11	Qpql	123	0	45	51	3	1
12	Qk	121	0	44	53	3	0
13	Qpql	106	0	5	94	1	0
14	Qpq7	124	0	8	88	4	0
15	Qk	111	1	2	95	2	0
16	Qpq2	116	8	6	86	0	0
17	Qk	122	0	11	84	1	0
18	Qst	145	7	48	39	6	0
19	Qpq8	133	1	3	95	1	0
20	Qk	125	0	5	92	3	0
21	Qst	137	8	8	84	0	0
22	Qmc	90	44	47	9	0	0
23	Qmc	120	12	12	76	0	0
24	Qk	136	13	31	55	1	0
25	Qk	125	0	97	3	0	0
26-48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[1]Counts at sites marked by an asterisk are from Ridge (1983).
[2]Gneiss includes all crystalline rocks of Precambrian age. Gray shale includes gray and brown shale, sandstone, slate, and mudstone; these rocks are chiefly from the Martinsburg Formation. Carbonate rock includes dolomite and limestone, and a small percentage of chert and vein quartz, from the Kittatinny Supergroup and Jacksonburg Limestone. Quartzite includes quartzite and conglomerate of the Shawangunk Formation and, locally in the southeastern half of the map area, a small percentage of the same lithologies from the Hardyston Formation. Red shale includes red shale, mudstone, and sandstone chiefly from the Bloomsburg Formation.
[3]Includes 15 percent vein quartz.
[4]Includes 3 percent marble from the Franklin Marble.







Surficial Geology of the Tranquility Quadrangle,
Warren, Sussex, and Morris Counties, New Jersey

New Jersey Geological Survey
Open-File Map 51
2002

text to accompany map

Appendix 1.--Selected Well Logs

Well	Identifier[1]	Geologic Log[2] Depth[3]	Description
1	21-6579	0-40	clay and gravel (Qk)
		40-275	limestone
2	21-678	0-42	cased (no description of surficial material, Qk to 42 feet?)
		42-270	slate
3	BWA files	0-9	clay overburden (Qk)
		9-195	black shale
4	21-6162	0-50	overburden (Qk)
		50-150	shale
5	21-5148	0-10	clay and shale (Qk)
		10-140	shale
6	21-4465	0-40	sand, gravel (Qbc1)
		40-85	clay (Qbcl)
7	21-6665	0-65	sand and gravel (Qk)
		65-275	limestone
8	21-4018	0-30	clay and gravel (Qbc1)
		30-60	clay and sand (Qbcl)
		60-100	limestone
9	21-4384	0-50	overburden, boulders (Qbc1)
		50-87	limestone
10	21-6520	0-30	sand, clay, gravel overburden (Qk)
		30-150	slate
11	21-5990	0-25	overburden (Qk)
		25-110	clay (Qk or weathered dolomite)
		110-150	limestone
12	21-6134	0-73	overburden (Qk and weathered dolomite)
		73-100	limestone
13	21-6664	0-55	clay (Qk and weathered dolomite)
		55-200	limestone
14	21-5675	0-23	overburden (Qk)
		23-100	boulders and clay (Qk? and weathered dolomite)
		100-200	limestone and shale

15	21-4002	0-40	overburden (Qk)
		40-127	black shale
16	21-5635	0-160	sand, gray clay, gravel (Qbc1 over Qpql over Qpqf?)
		cased to 160 feet, yield >20 gpm	
17	NJGS files	0-50	brown-gray fine sand, little silt (Qbc1)
18	21-4453	0-157	clay (Qbc1 over Qpql over weathered dolomite?)
		157-182	slate
19	21-6880	0-4	clay (Qbc1)
		4-180	clay and gray sand (Qbc1 and Qpql)
		180-183	brown sand and gravel (Qpqf)
		yield 70 gpm	
20	21-4979	0-30	gravel, water (Qpq6)
		30-50	large gravel (Qpqf)
		cased to 50 feet, yield >150 gpm	
21	21-5127	0-20	sand (Qpq6)
		20-50	clay and gravel (Qpq6 or Qk)
		50-100	limestone
22	21-6723	0-20	sandy gravel (Qst over Qpq6)
		20-45	quick sand (Qpq6)
		45-208	limestone
23	21-6845	0-22	sand, clay, gravel (Qk)
		22-298	limestone
24	21-5202	0-25	sandy gravel (Qst)
		25-205	limestone
25	21-4511	0-46	overburden (Qk and weathered dolomite)
		46-78	limestone
		78-97	rotten limestone
26	21-5712	0-11	gravel (Qpq8)
		11-50	silt (Qpq8 or weathered dolomite)
		50-325	limestone
27	21-5640	0-37	clay and gravel overburden (Qst over Qpq8)
		37-200	lime rock
28	21-6633	0-10	sandy loam (Qk)
		10-60	limestone with muddy seams
		60-166	limestone
29	21-6632	0-40	sandy loam (Qk)
		40-125	limestone
30	21-5301	0-77	sand and gravel (Qpq8)
		77-123	limestone
31	21-5302	0-74	sand and gravel (Qpq8)
		74-115	limestone
32	21-4941	0-20	big dry gravel (Qpq8)
		20-58	fine sand, gravel, no water (Qpq8)
		58-80	sand (Qpq8)
		80-82	gravel, water (Qpqf)
		cased to 80 feet, yield 20 gpm	

33	21-3562	0-40	clay and gravel (Qpq8)
		40-45	boulders (Qpq8)
		45-50	clay and gravel (Qpq8)
		50-60	boulders (Qpq8)
		60-65	gravel, water (Qpq8)
		cased to 63 feet, yield 15 gpm	
34	22-24291	0-20	sand and gravel (Qpq8)
		20-39	limestone
35	22-24292	0-22	sand and gravel (Qpq8)
		22-50	limestone
36	22-26124	0-42	sand (Qpq10)
		42-49	clay (Qpql)
		49-140	gray silt (Qpql)
		140-150	limestone
37	22-17654	0-74	brown clay, rotten lime, gravel (Qpq7 over weathered dolomite)
		74-90	rotten lime (weathered dolomite)
38	22-8829	0-32	sand and gravel (Qpq7)
		32-71	fine brown sand (Qpql)
		71-72	gravel (Qpqf)
		72-116	gray sand (Qpqf)
		116-120	sand, gravel (Qpqf)
		cased to 119 feet, yield >20 gpm	
39	21-5581	0-32	clay, gravel, sand (Qpq7)
		32-122	limestone
40	21-4024	0-70	sand and gravel (Qpq7)
		cased to 64 feet, yield >20 gpm	
41	21-5941	0-15	sand, boulders (Qpq6)
		15-56	clay (Qpql)
		56-58	granite
42	21-2387	0-12	overburden (Qn)
		12-108	sand, stone (Qgw)
		108-111	soft seam (Qgw)
		111-123	green granite
43	21-2404	0-25	overburden (Qn)
		25-63	sand, stone (Qgw)
		63-70	white sand, stone (Qgw)
		70-120	brown granite
44	21-2405	0-30	overburden (Qn)
		30-69	soft sand, stone (Qgw)
		69-150	white sand, stone (Qgw)
		150-169	green granite
45	21-2350	0-30	overburden (Qn)
		30-80	soft sandstone (Qgw)
		80-147	hard sandstone (gneiss or quartzite)
		147-151	seam (Qgw)
		151-173	hard sandstone (gneiss or quartzite)
46	21-3049	0-11	overburden (Qn)
		11-40	rotten granite, water (Qgw)
		40-198	granite
47	21-2426	0-20	overburden (Qn)

		20-173	granite
48	21-2351	0-66	sand, gravel, boulders (Qn, possibly over Qgw)
		66-68	soft seam, 25 gpm (Qgw)
		68-72	soft granite (Qgw)
49	21-2347	0-8	overburden (Qn)
		8-20	soft brown granite (Qgw)
		20-123	granite
50	21-6576	0-4	fill
		4-40	sandy clay (Qpq7)
		40-60	sandstone (possibly Qgw)
		60-88	granite
51	21-5949	0-62	overburden (Qpq7)
		62-200	granite
52	21-3702	0-30	gravel and overburden (Qpq7)
		30-60	sand (Qpq7 or Qpql)
		60-145	granite
53	21-2654	0-60	overburden, with sand and gravel (Qpq7 over Qpqf)
		cased to 60 feet, yield >20 gpm	
54	21-2566	0-10	overburden (Qpq7)
		10-50	sand (Qpq7 or Qpql)
		50-65	gravel (Qpqf)
		cased to 60 feet, yield 20 gpm	
55	21-5835	0-16	boulders (Qpq7)
		16-35	clay (Qpql)
		35-60	sand, gravel (Qpqf)
		cased to 60 feet, yield 30 gpm	
56	21-2445	0-40	overburden (Qk)
		40-247	limestone
57	21-2307	0-25	sand and gravel (Qpq6)
		25-85	dirty sand and clay (Qpql)
		85-129	gravel (Qpqf)
		screened 110-129, yield 284 gpm	
58	21-4130	0-35	overburden (Qpq5 or Qn)
		35-45	sand, gravel (Qpq5 or Qn)
		45-85	limestone
		85-102	sand (weathered rock or collapsed glacial sediment)
59	24-12159	0-68	sand, gravel, and boulders (Qst over Qpqf or Qk)
		68-198	limestone
60	24-260	0-55	gravel and sand (Qmt)
		55-90	fine sand and blue and gray clay, mixed (Qpql)
		90-195	blue and gray sticky clay (Qpql)
		195-200	coarse gravel (Qpqf)
		yield 30 gpm	
61	24-14148	0-5	overburden (Qmt)
		5-27	sand, clay, gravel (Qmt, possibly over Qpql or Qk)
		27-93	limestone
62	24-21562	0-30	sand (Qmt)
		30-125	limestone
63	24-21563	0-29	sand, water (Qmt)

		29-75	limestone
64	24-11199	0-1	sand and gravel fill
		1-3	soft mucky clay (Qal)
		3-6	gray clay (Qal or Qst)
		6-39	sand with clay (Qst over Qpql)
		39-149	gray clay with sand layers (Qpql)
		149-155	sand and gravel hardpan (Qpqf or Qk)
		155-177	granite hardpan (Qk or weathered rock)
		177-502	limestone
65	24-6895	0-10	black swamp muck (Qal)
		10-205	gray clay (Qpql)
		205-215	hard fine sand and clay (Qpql)
		215-217	clay (Qpql)
		214-242	dirty gravel and clay (Qk)
		242-243	yellow clay (weathered dolomite)
		243-495	limestone
66	24-19450	0-90	clay, gravel, silt (Qst over Qpql over Qpqf?)
		cased to 88 feet, yield 100 gpm	
67	24-15535	0-73	sand and gravel (Qpq4)
		yield 80 gpm	
68	24-18724	0-73	gravel (Qpq4)
		cased to 73 feet, yield 40 gpm	
69	24-13906	0-10	overburden (Qpq4)
		10-65	sand and gravel (Qpq4)
		yield 20 gpm	
70	24-13178	0-40	sand and gravel (Qpq4)
		40-91	fine sand (Qpq4)
		91-105	hardpan and clay gravel (Qk)
		105-240	limestone
		240-280	red limestone and shale
		280-405	granite
71	24-15216	0-30	sand and gravel (Qpq4)
		30-50	gravel (Qpq4)
		50-66	fine sand (Qpq4)
		66-68	boulder (Qk)
		68-113	gravel (Qk)
		113-115	boulder (Qk)
		115-175	brown clay--looks like soft limestone with clay (weathered dolomite)
		cased to 92 feet, yield 25 gpm	
72	24-17350	0-55	sand, brown clay, gravel (Qk)
		55-123	granite
73	24-2059	0-4	bog material and fill (Qal)
		4-8	clay and sand (Qal)
		8-126	brown clay and layers of fine sand (Qpql)
74	24-14597	0-12	sand, silt (Qal)
75	24-2656	log by F. J. Markewicz, NJGS, abbreviated here	
		0-4	fill
		4-200	light- to dark-gray calcareous varved silty clay (thin Qal over Qpql)
		200-232	light-gray calcareous clayey silty very fine sand (Qpql)
		232-236	angular fragments of dolomitic limestone (Qk)
		236-395	bluish-gray dolomitic limestone

76	24-2059	0-168	stratified drift (Qal over Qpql, probably over Qpqf)
		flowing well, screened 151-168 feet, yield 200 gpm	
77	24-15150	0-15	sand (Qal)
		15-205	gray clay (Qpql)
		205-214	sand, large gravel (Qpqf)
		cased to 212 feet, yield >300 gpm	
78	24-15144	0-70	sand and gravel (thin Qs over Qpqf?)
		cased to 70 feet, yield 94 gpm	
79	24-6111	0-18	fill and small boulders (Qaf)
		18-24	rock or big boulders (Qaf)
		24-48	dirt and small boulders (Qn)
		48-54	ledge of rock, granite (boulder in Qn)
		54-84	gravel and clay (Qn or Qgw)
		84-105	dirty sand and gravel (Qn or pre-advance stratified drift or Qgw)
		at 105	hit hard rock
		screened 86-106 feet, yield 133 gpm	
80	24-19183	0-11	sandy hardpan (Qn)
		11-398	granite
81	24-22109	0-17	stony hardpan (Qn)
		17-398	granite
82	24-15110	0-12	stony hardpan (Qn)
		12-122	granite
83	24-17501	0-85	sand, clay (Qn)
		85-100	sandstone (Qgw?)
		100-148	granite
84	24-15981	0-140	clay, broken sandstone (Qn over Qgw?)
		140-168	sandstone (Qgw?)
85	24-22958	0-45	overburden (Qn)
		45-148	sand, gravel, boulders (Qn)
		148-150	gravel (Qn)
		yield 12 gpm	
86	24-21678	0-15	clay and boulders (Qn)
		15-119	clay and gravel (Qn)
		yield 30 gpm	
87	24-12766	0-30	fine sand (Qn)
		30-55	sand, clay, gravel (Qn)
		55-65	limestone
88	24-3352	0-193	sand, clay, boulders, hardpan (Qn)
		193-215	sandstone rock
89	24-21481	0-30	clay and gravel (Qn)
		30-40	sand and gravel (Qn)
		40-78	clay (weathered dolomite?)
		78-100	soft limestone
90	24-19843	0-69	sand, clay (Qn)
		69-105	limestone
91	24-19228	0-120	clay and boulders (Qn)
		120-150	limestone

92	24-4191	0-88	clay and hardpan, boulders (Qn)
		88-110	granite
93	24-19068	0-75	sand and stone (Qn)
		75-125	granite rock
94	24-18883	0-92	clay, sand, gravel (Qn)
		92-100	gravel (Qn or Qgw)
		flowing well, cased to 92 feet, yield >50 gpm	
95	24-21181	0-100	sand and gravel (Qn)
		yield 10 gpm	
96	24-22135	0-65	clay, boulders (Qn)
		65-72	granite
97	24-15218	0-50	mud and gravel (Qnm)
		50-100	clay and gravel (Qnm or Qgw)
		100-150	clay mixed with gravel (Qnm or Qgw)
		150-175	clay (Qgw?)
		175-194	clay, gravel, large gravel mixed (Qgw?)
		194-220	clay, gravel, water (Qgw?)
		cased to 194 feet, yield 7 gpm	
98	24-563	0-250	clay and soft sandstone (Qnm over Qgw)
		well finished in gravel at 165 feet (Qgw?), yield 5 gpm	
99	24-6497	0-64	overburden, gray silt (Qnm)
		64-66	gray clay, boulder (Qnm)
		66-115	clay (Qgw?)
		115-183	clay, small rock seams (Qgw)
		183-200	brown hard clay (Qgw)
		200-204	hard clay (Qgw)
		204-241	rock
		241-287	clay (Qgw)
		287-294	water, rock, seam
		294-297	clay (Qgw)
100	24-8174	0-60	clay and boulders (Qnm)
		60-101	clay, gravel, boulders (Qnm over Qgw)
		101-140	clay and gravel (Qgw)
		140-145	red clay (Qgw)
		145-162	clay and gravel (Qgw)
101	24-17554	0-40	sandy clay (Qn)
		40-45	sandstone
		45-148	granite
102	24-20285	0-63	clay, sand, gravel (Qn)
		63-198	granite
103	24-22754	0-22	sand, clay, gravel overburden (Qn)
		22-200	granite
104	24-20913	0-18	sand, clay, gravel overburden (Qn)
		18-125	granite
105	24-22772	0-10	sand, clay, gravel overburden (Qn)
		10-125	granite
106	24-13885	0-110	sand, clay, gravel (Qn)
		110-147	gray granite
107	24-20428	0-50	overburden (Qn)
		50-130	granite

108	24-13884	0-36	gray clay and gravel (Qn)
		36-88	yellow clay (weathered rock)
		88-145	yellow clay and sand (weathered rock)
		145-253	gray granite
109	24-16230	0-110	clay, sand, gravel (Qn)
		110-148	soft brown limestone
110	24-12966	0-89	clay hardpan (Qn)
		89-105	sandstone
		105-148	granite
111	24-20284	0-143	sand, clay, gravel (Qn)
		143-148	limestone and water
112	24-20910	0-25	sand, clay, gravel overburden (Qn)
		25-125	granite
113	24-18721	0-28	hardpan and gravel (Qn)
		28-198	granite
114	24-21611	0-23	overburden
		23-150	granite
115	24-11351	0-10	dirt (Qnm)
		10-20	sand, gravel (Qnm)
		20-30	hard gray (sic) (Qnm)
		30-45	sand, gravel (Qnm)
		45-55	hard (sic) (Qnm)
		55-60	sand, gravel (Qnm)
		60-100	hard (sic) (Qnm or gneiss)
116	24-14224	0-76	clay, large gravel (Qnm)
		76-225	granite
117	24-7184	0-40	overburden with boulders (Qnm)
		40-90	gravel, lime stone (probably Qgw)
		90-173	granite
118	24-9211	0-62	sand, heavy gravel, boulders (Qnm)
		62-155	granite
119	24-15151	0-53	clay, large gravel, sand (Qnm)
		53-146	granite
120	24-15094	0-52	clay, sand, gravel (Qnm)
		52-60	soft granite (Qgw)
		60-248	granite
121	24-15	0-67	clay and gravel (Qpq4 over Qk)
		67-111	limestone and clay seams
		111-137	limestone
122	24-13256	0-18	overburden (Qk)
		18-148	limestone
123	24-15529	0-35	overburden (Qsu over Qk)
		35-50	soft limestone
		50-265	hard limestone
		265-280	soft limestone
		280-298	hard limestone
124	24-15594	0-18	clay overburden (Qk)
		18-21	boulder (Qk)

		21-145	clay and gravel (Qk)
		145-147	sand and gravel (Qk)
		147-280	clay and gravel (Qk, possibly over weathered rock)
		280-395	rock and soft rock
125	24-23549		abbreviated log
		0-27	brown fine-to-coarse sand and fine-to-coarse gravel, trace silt (Qaf)
126	24-7987	0-21	boulders and sand (Qn)
		21-215	granite
127	24-13077	0-12	overburden (Qn)
		12-171	granite
128	24-3152	0-43	boulders, sand, clay (Qwr2 over Qn)
		43-235	blue and gray granite, very seamy
129	24-1978	0-57	clay and sand mixed and hardpan (Qwr2 over Qn)
		57-120	sandstone and iron ore mixed
130	24-3043	0-77	boulders, sand, hardpan (Qwr2 over Qnm)
		77-240	gray and blue granite
131	24-15075	0-15	clay, boulders (Qmf)
		15-45	sand (Qwr2)
		45-55	clay, sand (Qwr2)
		55-60	sand, gravel (Qwr2)
		yield 25 gpm	
132	24-15848	0-80	clay, sand, gravel (Qaf over Qwr2 over Qnm?)
		cased to 80 feet, yield >20 gpm	
133	24-24248	0-98	sand, gravel (Qnm)
		98-112	clay and gravel (Qnm)
134	24-4130	0-160	glacier formation--boulders, sand, hardpan (Qnm)
		160-172	coarse gravel (Qwr1 or Qnm)
135	NJGS files	abbreviated log	
	boring MD1	0-25	brown silty sand with boulders and cobbles (Qn)
		25-65	gneiss
136	NJGS files	abbreviated log	
	boring MD1A	0-20	brown silty sand and small gravel (Qal)
		20-70	brown to gray silty sand with some clay and angular to subrounded dolomite and gneiss rock fragments (Qnm)
		70-145	weathered gneiss fragments with yellow, red, and gray clay (Qgw)
		145-196	gneiss
137	NJGS files	abbreviated log	
	boring MD2	0-150	brown to gray poorly sorted fine-to-coarse sand with silt and clay and much angular to subrounded gravel and large boulders (Qnm)
		150-200	dolomite
138	NJGS files	abbreviated log	
	boring MD3	0-154	brown to gray fine-to-coarse silty sand with angular to subangular gneiss, dolomite, and quartzite gravel and boulders (Qnm)
		154-225	dolomite
139	24-20222	0-102	sand and gravel, silt (Qnm over Qwr1)
		cased to 100 feet, yield >30 gpm	

140	NJGS files	abbreviated log	
	boring MD4	0-100	brown to gray-brown fine-to-coarse silty sand with dolomite and gneiss gravel and boulders (Qnm)
141	NJGS files	abbreviated log	
	boring MD5	0-208	brown silty fine sand with dolomite and gneiss gravel and boulders (Qnm)
		208-268	dolomite
142	NJGS files	abbreviated log	
	boring MD6	0-110	brown fine silty sand with subangular to subrounded dolomite and gneiss gravel and boulders (Qnm)
		110-151	weathered granite and phyllonite
143	24-15451	abbreviated log	
		0-25	brown silty sand with gravel and boulders (Qnm)
144	24-6373	0-15	sand, boulders (Qctg)
		15-81	sand and gravel, hard-packed (Qnm over Qwr1)
145	NJGS files	abbreviated log	
	boring TH35	0-55	gravel, grit, sand (Qwr1)
146	BWA files	0-119	sand and clay (Qwr1 over Qwrl)
147	NJGS files	abbreviated log	
	boring TH37	0-113	coarse sand and gravel (Qwr1 over Qis)
148	NJGS files	abbreviated log	
	boring TH33	0-35	clay (Qwrl)
		35-55	no gravel, 95% waste (silt and fine sand, Qwrl)
		55-85	gravel, grit, coarse sand (Qis)
		85-90	boulder
149	NJGS files	abbreviated log	
	boring TH34	0-20	coarse sand, gravel (Qwr1)
		20-110	gray clay (Qwrl)
		110-135	gravel, coarse sand (Qis)
		at 138	bedrock
150	NJGS files	abbreviated log	
	boring TH25	0-5	gravel, coarse-to-medium sand (Qwr1)
		5-65	sand, no gravel (Qwr1 or Qwrl)
		65-90	gravel, good sand (Qis)
151	NJGS files	log by F. J. Markewicz, NJGS, abbreviated here	
		0-40	silty sand with angular pebbles of gneiss, limestone, and quartzite (Qnm, now removed by excavation)
		40-90	silt and fine sand (Qwrl)
152	NJGS files	abbreviated log	
	boring TH 21	0-15	gravel, coarse sand (Qwr1)
		15-60	fine sand, silt (Qwrl)
153	NJGS files	abbreviated log	
	boring TH 29	0-80	fine sand, clay (Qwrl)
		80-105	gravel, coarse sand, trace clay (Qis)
154	NJGS files	abbreviated log	
	boring TH 32	0-75	sand and gravel (Qwr1)
		75-100	clay, fine sand (Qwrl)
		100-110	sand, gravel, clay (Qis)
155	NJGS files	abbreviated log	

	boring TH 30	0-80	fine sand, clay (Qwrl)
		80-90	sand, coarse sand (Qis)
		90-95	boulder
156	NJGS files	abbreviated log	
	boring TH 28	0-80	fine sand, clay (Qwrl)
		80-85	fine sand, clay, a little gravel (Qis)
		85-90	gravel, coarse sand (Qis)
157	NJGS files	abbreviated log	
	boring TH 31	0-35	coarse sand, trace gravel (Qwr1)
		35-80	clay, fine sand (Qwrl)
		80-90	gravel, grit, good sand, some clay (Qis)
158	24-34612	0-30	sand and gravel (Qmc over Qwr1)
		30-78	silt (Qwrl)
		78-95	sand and gravel, some big boulders (Qis)
		95-100	cobbles, sand, and silt (Qis or Qit)
		screened 88-98 feet, yield 38 gpm	
159	NJGS files	abbreviated log	
	boring 80-1	0-4	fill
		4-10	silty sand and gravel (Qmc)
		10-85	gray thinly bedded fine sand and silt, occasional clay laminae (Qwrl)
		85-102	sand, gravel, boulders, trace red clay (Qis)
		102-139	gray-brown very compact fine-to-coarse silty sand with angular to subrounded gravel and gneiss and dolomite boulders (Qit)
		139-200	dolomite
160	24-15481	abbreviated log	
		0-30	fine-to-coarse sand and some gravel (Qmc)
		30-60	fine sand, silt, some medium sand (Qwrl)
		60-67	fine-to-medium multicolored sand, gravel and boulders (Qis)
161	NJGS files	abbreviated log	
	boring 80-2	0-7	fill
		7-85	gray to brown fine-to-coarse sand, trace silt, poor recovery (Qal over Qmc over Qwrl?)
		85-150	tan to brown dense fine-to-medium sand with a little silt, some subrounded gravel and cobbles (Qis?)
		150-177	brown sandy silt with dolomite and gneiss gravel and boulders (Qit)
		177-250	dolomite and limestone
162	NJGS files	abbreviated log	
	boring 80-3	0-4	fill
		4-20	gray and brown sandy clayey silt with boulders (Qnm)
		20-50	brown fine-to-coarse sand (Qwr1)
		50-98	brown very fine-to-fine silty sand (Qwrl)
		98-110	brown fine-to-coarse sand with large subrounded gravel, some boulders and cobbles (Qis)
		110-160	brown and yellow clayey silt with some angular to subangular gravel and little sand (Qit)
		160-161	dolomite
163	NJGS files	abbreviated log	
	boring 80-4	0-52	brown-gray silty fine sand with some gneiss and dolomite pebbles, cobbles and boulders (Qnm)
		52-59	brown to yellow-brown cohesive silty clayey sand (Qgw)
		59-100	gneiss

164	25-26070	0-10	overburden (Qmc)
		10-121	sand, clay, gravel (Qmc over Qwrl?)
165	25-16048	0-10	overburden (Qgw)
		10-11	boulder (Qgw)
		11-60	dirt, gravel, water (Qgw)
		60-64	rotten granite (Qgw)
		64-200	granite
166	25-20965	0-5	sand, clay, boulders (Qgw)
		5-125	sandstone and granite
167	25-20963	0-42	sand, clay, boulders (Qgw)
		42-125	granite
168	25-18178	0-5	overburden and boulders (Qcg)
		5-62	sand, gravel, clay (Qcg over Qgw)
		62-74	rotten gravel (Qgw)
		74-123	granite
169	22-10152	0-25	overburden (Qpq7 over Qk)
		25-73	limestone
170	24-116	0-10	clay and boulders (Qn)
		10-142	rock
171	21-2156	0-5	overburden (Qpq6)
		5-20	gravel (Qpq6)
		20-45	fine sand (Qpq6)
		45-49	gravel (Qpq6)
		49-79	fine sand, clay (Qpql)
		79-85	sand, gravel (Qpqf)
		cased to 81 feet, yield 15-20 gpm	
172	21-2473	0-36	overburden with gravel and boulders (Qpq6)
		36-70	limestone
173	21-2618	0-35	overburden with sand, gravel, boulders (Qpq6)
		35-135	limestone
		135-140	brown clay with water (weathered dolomite)
174	21-5205	0-25	sandy gravel (Qpq7)
		25-205	limestone
175	NJGS files boring TW-1-2	0-52	brown very fine silty sand to sandy silt (Qmc over Qwrl)
		52-70	gray fine-to-medium sand and gravel with angular to subangular rock fragments (Qis?)
		70-85	gray silty sand (Qis?)
176	NJGS files boring TW-5-1	abbreviated log	
		0-57	gray-brown very fine silty sand (Qmc over Qwrl)
		57-76	brown very fine-to-medium sand, a little gravel (Qis)
		76-90	brown-gray very fine-to-fine silty sand and medium-to-coarse gravel with angular to subrounded rock fragments of gneiss and dolomite (Qis or Qit)

[1]Numbers of the form xx-xxxx (for example, 21-5205) are well permit numbers issued by the N. J. Department of Environmental Protection, Bureau of Water Allocation. The notation "NJGS files" indicates records of wells or borings on file at the N. J. Geological Survey. Borings prefixed by "MD", "80", or "TW" were drilled in 1981 for the Hackettstown Reservoir project. Logs for these borings are from Dames and Moore (1981a, b). Borings prefixed by "TH" are test holes drilled for the Saxton Falls Sand and Gravel Company in

1988 (Richard H. Schindelar and Associates, 1988). The notation "BWA files" indicates records of wells in the Bureau of Water Allocation well record file that do not have permit numbers.

[2]All descriptions are as they appear in the original source, except for minor format, punctuation, and spelling changes. Most logs are drillers' reports; a few are reports of geologists or engineers. Inferred map units and comments by authors are in parentheses. Logs identified as "abbreviated" have been condensed for brevity. For wells completed in surficial material, the screened interval in feet below land surface (if reported) and yield in gallons per minute (gpm) are provided below the geologic log. Greater-than symbol (>) indicates yield is greater than indicated value.

[3]In feet below land surface.