DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF SCIENCE AND RESEARCH
NEW JERSEY GEOLOGICAL SURVEY

ENVIRONMENTAL GEOLOGY OF WARREN COUNTY, NEW JERSEY: SURFICIAL GEOLOGY AND EARTH MATERIAL RESOURCES

PLATE 1

by

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DESCRIPTION OF MAP UNITS

Map units denote unconsolidated materials more than 5 feet thick. Color designations, based on Munsell Color Company (1975), were determined from naturally moist samples. Elsewhere, only the most pronounced colors are listed for sediments of highly variable colorration. Deposits are listed by age, youngest to oldest; within age groups, deposits similar in origin are listed together.

Holocene

af — **ARTIFICIAL FILL** - Rock waste, gravel, sand, some silt, and manufactured materials emplaced by man; as much as 90 feet thick. Not shown in urban areas, or beneath roads, and railroads if it is less than 10 feet thick.

am — **MINE AND QUARRY TAILINGS** - Rock waste, and minor sand and gravel consisting of crushed or pulverized rock emplaced by man; as much as 50 feet thick.

Qal — **ALLUVIUM** - Stratified, moderately- to poorly-sorted, gray to brown sand, gravel, silt, minor clay and organic material, locally bouldery; as much as 25 feet thick. Includes planar- to cross-bedded gravel and sand in channel deposits, and cross-bedded rippled sand, massive and parallel-laminated fine sand, and silt, in flood-plain deposits. In places, is overbain by, and interbedded with, thin layers of organic material and colluvium.

Late Wisconsinan and Holocene

Qat — **STREAM-TERRACE DEPOSITS** - Stratified, well- to moderately-sorted light-brown to yellowish-brown, gray sand, cobble-pebble and pebble gravel, and silt in terraces flanking present-day or former stream courses; as much as 25 feet thick. Includes planar- to cross-bedded sand and gravel in stream-channel deposits, and massive to laminated fine sand and silt in overbank deposits.

Qs — **SWAMP DEPOSITS** - Black to dark brown peat, chiefly of reed, sedge, and woody origin, and muck, underlain by laminated dark-gray to light-gray organic-rich silt and clay; as much as 25 feet thick, but generally less than 10 feet thick. Locally interbedded with alluvium and thin colluvium. In areas underlain by limestone and dolostone, marl is as much as 20 feet thick, and underlies peat and muck.

Qta — **TALUS** - Angular boulders, cobbles, and smaller rock fragments that accumulate at the base of bedrock cliffs and steep hillslopes; as much as 20 feet thick.

Late Wisconsinan

Qwfv — **VALLEY-OUTWASH DEPOSITS** - Stratified, moderately- to poorly-sorted, brown to yellowish-brown, gray sand, boulder-cobble to pebble gravel, and minor silt; as much as 100 feet thick. The near-glacier part of these deposits includes massive to horizontally-bedded and imbricated coarse gravel and sand, and planar to tabular and trough crossbedded fine gravel and sand in bars and channel-lag deposits with minor cross-bedded sand in channel-fill deposits. Downstream, clasts generally are smaller, and sand is more abundant; trough and planar cross-bedding, and graded beds are more common. Overbank deposits of massive to laminated fine sand and silt are rare.

Qwfl — **MELTWATER-TERRACE DEPOSITS** - Stratified, well- to moderately-sorted, gray to brown sand, cobble-pebble to pebble gravel, and minor silt; as much as 45 feet thick. Sediment and bedforms similar to the downstream part of valley-outwash deposits. Includes bouldery-lag deposits formed on till.

Qwld — **GLACIAL-LAKE DELTAIC DEPOSITS** - Stratified, well- to moderately-sorted, gray to brown sand, gravel, and silt. Includes moderately- to poorly-sorted sand and boulder-cobble to pebble gravel in glaciofluvial topset beds as much as 45 feet thick. Bedding is similar to valley-outwash deposits. Topset beds overlie and grade into foreset beds that dip 20° to 35° basinward and consist of well- to moderately-sorted, rhythmically-bedded cobble-pebble and pebble gravel and sand. These beds grade downward and outward into ripple cross-laminated and parallel-laminated, sand, silt, and pebble gravel that dip less than 20°. Lower foreset beds grade into gently inclined bottomset beds of rhythmically-bedded, ripple cross-laminated to graded-laminated fine sand and silt with minor clay drapes. Thickness may be as much as 100 feet.

Qwlf — **GLACIAL LACUSTRINE-FAN DEPOSITS** - Stratified, gray to brown sand, gravel, and silt; as much as 60 feet thick. Includes well- to modenetely-sorted sand and gravel in massive- to rythmically-bedded steeply to gently dipping foreset beds that gnade basinward into ripple cross-laminated to parallel-laminated foreset beds of sand, fine gravel and silt. Foreset beds gnade outward into or overlap gently inclined bottomset beds that consist of rhythmically-bedded, ripple cross-laminated and parallel-laminated fine sand and silt with minor drapes of silty clay.

Qwlb — **GLACIAL LAKE-BOTTOM DEPOSITS** - Parallel-laminated, irregularly to rhythmically-bedded, dark-gray to light-gray, olive-brown silt, sand, and clay; and minor cross-laminated silt, sand, and minor clay; as much as 200 feet thick.

Qwtg, Qwtgu — **HIGHLANDS TILL** - Compact, unstratified, poorly sorted light-gray (10YR 7/2), pale-brown (10YR 6/3) to brown (10YR 5/3) silty sand that typically contains 10 to 20 percent gravel; as much as 80 feet thick. Locally overlain by thin, discontinuous, noncompact to slightly compact, poorly sorted, poorly layered dark yellowish-brown (10YR 4/4) to brown (10YR 5/3) silty sand, and sand that contains as much as 35 percent gravel, and minor thin beds of well- to moderately-sorted sand and gravel; as much as 10 feet thick. Clasts consist of unweathered gneiss, foliated granite, and marble; also minor quartzite, sandstone, and carbonate rock. Matrix is a varied mixture of gneiss and granite fragments, quartz, feldspar, mica, heavy minerals, and silt; minor constituents may include fragments of sandstone, siltstone, quartzite, carbonate rock; and clay. Near the late Wisconsinan terminal mornine also contains weathered gneiss, foliated granite, leached carbonate clasts, and weathered matrix material. Derived chiefly from gneiss and foliated granite, and their weathering products. Subscript "r" denotes areas of thin till; less than 15 feet thick, scattered bedrock outcrops, and minor colluvium.

Qwts, Qwtsu — **KITTATINNY VALLEY TILL** - Compact, unstratified, poorly sorted light yellowish-brown (2.5Y 6/4), light olive-brown (2.5Y 5/4) to grayish-brown (2.5Y 5/2), gray (5Y 5/1) to olive-gray (5Y 5/2) noncalcareous to calcareous silt and sandy silt that typically contains 5 to 15 percent gravel; as much as 100 feet thick. Locally overlain by thin, discontinuous, noncompact to slightly compact, poorly sorted, poorly layered yellowish-brown (10YR 5/6-8), light yellowish-brown (10YR 6/4) sandy silt that contains as much as 30 percent gravel, and minor thin beds of well- to modenitely sorted sand, gravel, and silt; as much as 10 feet thick. Clasts chiefly are unweathered slate, siltstone and sandstone, dolomite, limestone, chert, minor quartzite, and quartz-pebble conglomerate. Matrix is a varied mixture of nonweathered quartz, rock fragments, and silt; minor constituents include feldspar and clay. Contains weathered carbonate and sandstone clasts near the terminal momine. Derived chiefly from slate, greywacke, dolomite, and minor limestone. On the northwest flank of the New Jersey Highlands, additional minor constituents include gneiss, granite, mica, and heavy minerals. Subscript "r" denotes areas of thin till; less than 15 feet thick, scattered bedrock outcrops, and minor colluvium.

Qwm — **MORAINAL DEPOSITS** - Unstratified to poorly stratified sand, gravel, and silt; as much as 150 feet thick. Consists of poorly compact, stony till, silty-sandy compact till, and minor lenses and layers of water-laid sand, gravel, silt, and glacially-trnasported substrate in discontinuous, bouldery, chiefly cross-valley ridges that mark former glacier margins. Till in momines in Kittatinny Valley is chiefly unit Qwts, and on Jenny Jump Mountain and the New Jersey Highlands is chiefly unit Qwtg.

Qwic — **CREVASSE-FILL OR ICE-SINK DEPOSITS** - Stratified, well- to poorly-sorted, gray to brown sand, gravel, silt and interbedded flowtill; as much as 50 feet thick. Attitude of bedding is highly variable, and beds are typically collapsed.

Early Wisconsinan

Qoal — **OLDER ALLUVIUM** - Stratified, modentely- to poorly-sorted sand, gravel and minor silt; as much as 30 feet thick. In subsurface only (sections C-C' and E-E')

Wisconsinan

Qaf — **ALLUVIAL-FAN DEPOSITS** - Stratified, modentely- to poorly sorted, brown to yellowish-brown, gray sand, gravel, and silt in fan-shaped deposit; as much as 35 feet thick. Includes massive to planar-bedded sand and gravel and minor cross-bedded channel-fill sand. Bedding dips as much as 30° toward the trunk valley. Locally interlayered with unstratified, poorly sorted, sandy-silty to sandy gravel.

Qac — **ALLUVIUM AND COLLUVIUM, UNDIFFERENTIATED** - Stratified, poorly to modernately sorted, brown to yellowish-brown, gray sand, silt and minor gravel; as much as 20 feet thick. Interlayered with or overlying, massive to crudely layered, poorly sorted sand, silt, and minor gravel.

Middle Pleistocene to Holocene

Qwcg — **GNEISSIC AND GRANITIC COLLUVIUM** - Massive to crudely layered, slightly compact, poorly sorted yellowish-brown (10YR 5/4-8) to dark yellowish-brown (10YR 4/4), brown (10YR 5/3), strong brown (7.5YR 5/6) silty sand and sandy silt, containing as much as 60 percent lightly to modernately weathered angular to subangular cobbles, pebbles, and boulders of gneiss and foliated granite; as much as 50 feet thick. Matrix consists of a varied mixture of quartz sand, weathered feldspar, mica, amphibole, heavy minerals, silt, and clay.

Qwcs — **SLATE, SILTSTONE, AND SANDSTONE COLLUVIUM** - Crudely to modentely layered, noncompact, poorly sorted light yellowish-brown (10YR 6/4) to brownish-yellow (10YR 6/6) or light olive-brown (2.5Y 5/4) silty sand and clayey silt, containing as much as 80 percent lightly to modernately weathered angular to subangular slate chips, tabular pebbles and cobbles of siltstone and sandstone; as much as 30 feet thick. Matrix consists of a varied mixture of rock fragments, quartz sand, silt, and clay.

Qwcc — **CARBONATE ROCK COLLUVIUM** - Massive to crudely layered, slightly compact, poorly sorted dark yellowish-brown (10YR 4/4) to yellowish-brown (10YR 5/4), reddish-yellow (7.5YR 6/8) to strong-brown (7.5YR 5/6-8) clayey silt containing as much as 5 percent angular to subangular fragments and pebbles of leached carbonate rock, chert, and minor quartzite; as much as 20 feet thick. Matrix consists of a varied mixture of clay, quartz sand, rock fragments, and silt.

Qwcu — **UNDIFFERENTIATED COLLUVIUM** - Mixture of weathered bedrock and till; as much as 10 feet thick.

Pre-Wisconsinan

Qoc — **OLDER COLLUVIUM** - Massive to crudely layered, slightly compact, poorly sorted red (2.5YR 4/8), strong-brown (7.5YR 5/6) clayey silt to sandy silt; as much as 25 feet thick (estimated). Contains as much as 20 percent angular to subangular clasts of weathered gneiss and granite and minor subangular to rounded weathered carbonate rock, sandstone, and quartzite. Matrix is typically a mixture of quartz, clay, silt, rock fragments, minor mica, and heavy minerals. In subsurface only; typically underlies Wisconsinan colluvium, particularly unit Qwcg. In subsurface only (sections A-A', B-B', C-C', and F-F').

Illinoian

Qif — **VALLEY-OUTWASH AND MELTWATER-TERRACE DEPOSITS** - Stratified, well- to modentely-sorted, reddish-brown to brown, gray sand, cobble-pebble to pebble gravel, and minor silt; as much as 50 feet thick. Contains subrounded to well-rounded pebbles and cobbles of gneiss, granite, quartzite, sandstone, carbonate rock, and chert. Gneiss and granite clasts generally have thick weathering rinds, quartzite and sandstone clasts exhibit iron stains, and carbonate rock clasts are completely decomposed to depths of at least 15 feet. In Delaware valley, some clasts are reddish due to a thin coating of iron oxide.

Qil — **GLACIAL-LAKE DELTAIC DEPOSITS** - Stratified, well- to modentely-sorted, reddish-brown to brown, gray sand, gravel and minor silt laid down by meltwater streams in proglacial lakes; as much as 100 feet thick. Lithology and weathering similar to that of unit Qif

Qit — **TILL** - Massive, compact, poorly sorted strong-brown (7.5YR 5/6), pale-brown (10YR 6/3), yellow (10YR 7/6) to yellowish-brown (10YR 5/4-6) clayey silt and sandy silt that typically contains 5 to 15 percent gravel; as much as 60 feet thick. Locally reddish in till rich in weathered carbonate rock. Clasts consist of gneiss, foliated granite, quartzite, quartz-pebble conglomente, slate, sandstone, chert, and carbonate rock. Crystalline clasts have thick to thin weathering rinds (0.5 in.); carbonate clasts are generally decomposed to depths exceeding 10 feet. Other clasts have thin weathering rinds (0.1 in.), and pitted surfaces. Matrix is a varied mixtun of quartz, rock fragments, silt, clay, weathered feldspar; minor mica, and heavy minerals. Subvertical joints modentely developed to depths of at least 10 feet. Iron and iron-manganese stain the surface of clasts, sand grains, and joints to depths of at least 10 feet. In Delaware Valley some clasts are reddish due to a thin coating of iron oxide.

Qim — **MORAINAL DEPOSITS** - Sandy silty to silty sandy compact till, stony noncompact sandy till, and minor well- to modentely-sorted sand and gravel in broad cross-valley ridge; as much as 65 feet thick.

Pre-Illinoian

Qps — **UNDIFFERENTIATED MELTWATER DEPOSITS** - Deeply weathered, stratified, modentely- to poorly-sorted reddish-yellow (7.5YR 6/6-8) to strong-brown (7.5YR 5/6-8) sand, cobble-pebble to pebble-gravel, silt, and clay; as much as 25 feet thick. Contains subrounded to well rounded pebbles and small cobbles of quartzite, chert, sandstone, gneiss, and granite. Carbonate rock, gneiss, and granite clasts typically are fully decomposed; sandstone and quartzite clasts have thin weathering rinds and pitted surfaces. Red iron and black iron-manganese oxide coat the surface of some clasts and sand grains. Typically underlies a round-stone clayey-silty diamict that may be as much as 6 feet thick; presumably a thick soil.

Qpt — **TILL** - Deeply weathered, compact, massive to crudely layered reddish-yellow (7.5YR 6/6-8) to strong-brown (7.5YR 5/6-8) to yellowish-brown (10YR 5/6-8), or reddish-brown (5YR 4/3) to weak-red (2.5YR 4/3) sandy silt and clayey silt that typically contains 2 to 5 percent gravel; as much as 30 feet thick. Gnvel consists of pebbles and cobbles of quartzite, gneiss, sandstone, shale, chert, carbonate rock, and a few boulders of quartzite and gneiss. Gneiss clasts have thick weathering rinds or are completely decomposed; carbonate clasts are fully decomposed. Quartzite, sandstone, and chert pebbles and cobbles have pitted surfaces and thin weathering rinds. Matrix contains clay, quartz, weathered rock fragments, minor weathered mica, and few heavy minerals. Subvertical joints are poorly to modentely developed to depths exceeding 10 feet. Clasts and joints are commonly coated with red iron and black iron-manganese oxide.

Tertiary (?) to Quaternary

Qgw — **WEATHERED BEDROCK DERIVED FROM GNEISS, FOLIATED GRANITE, AND MINOR SYENITE** - Massive to layered, noncompact to compact brown (10YR 5/3), yellowish-brown (10YR 5/6-8), strong-brown (7.5YR 5/6), white (5YR 8/1), and red (2.5YR 5/8) silty sand to clayey silt saprolite consisting of clay, quartz, minor mica and heavy minerals; and sandy, blocky rock rubble. As much as 100 feet thick. Includes thin stony and blocky colluvium on hillslopes, and bouldery to cobbly mantle of angular to subangular gneiss and granite on very gentle hillslopes; as much as 10 feet thick. Weathered zone grades downward through a bouldery zone of joint blocks into underlying unweathered bedrock, and extends deeply along joints, fractures, and bedrock layers. Joint blocks and rock rubble typically have thick weathering rinds.

Qsw — **WEATHERED BEDROCK DERIVED FROM SLATE, SILTSTONE, AND SANDSTONE** - Massive to layered, noncompact to slightly compact reddish-brown (5YR 4/3-2.5YR 4/4) silty clay or sandy silt decomposition residuum of clay, quartz, and rock fragments; and slate-clay gravel containing flat pebbles of slate, tabular pebbles of siltstone, and sandstone; as much as 30 feet thick. Locally includes thin shaley colluvium on hillslopes; as much as 10 feet thick. Weathered zone typically grades downward through a zone of fractured rock into underlying unweathered bedrock.

Qcw — **WEATHERED BEDROCK DERIVED FROM DOLOSTONE AND LIMESTONE** - Massive, compact light-red (2.5YR 6/6) to red (2.5YR 5/6), reddish-yellow (7.5YR 7/8) to strong-brown (7.5YR 5/6) to yellowish-brown (10YR 5/6), or yellow (10YR 7/6), locally highly variegated, clay and silty-clay solution residuum of clay, quartz, and iron oxide; generally containing less than 5 percent chert, vein quartz, and minor quartzite; thickness is highly variable, typically less than 15 feet, but locally as much as 100 feet. Locally includes thin colluvium as much as 5 feet thick on gentle hillslopes. Also may include sand, gravel, silt, and clay washed into sinkholes and solution cavities from overlying colluvial, alluvial, and glacial sediment. Weathered zone typically ends at an abrupt, very irregular contact with unweathered bedrock and also extends deeply along joints and fractures.

SCALE 1:48,000

2 1 0 2 MILES

2000 0 2000 4000 6000 8000 10000 12000 14000 FEET

2 1 0 2 KILOMETERS

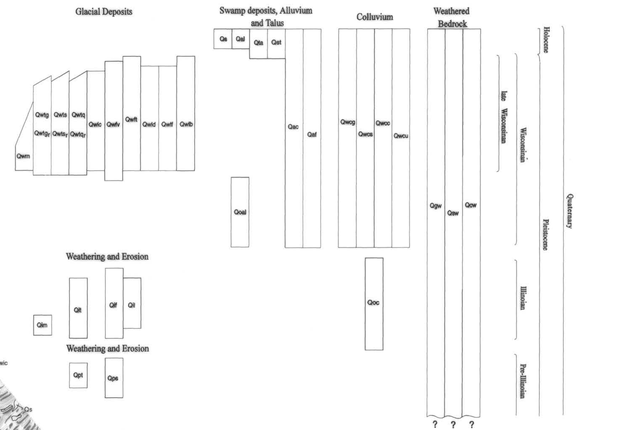
CONTOUR INTERVAL 20 FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

Map Symbols

- Contacts, dashed where approximated, dotted where concealed.
- Erosional scarp cut by postglacial streams.
- Areas of extensive bedrock outcrops; minor very thin till, colluvium, and erratics.
- Terminal moraine.
- Thick, extensive till of late Wisconsinan age.
- Active sand and gravel pit.
- Inactive sand and gravel pit.

Correlation of Map Units



Purpose

Industrial, commercial, and residential expansion in New Jersey has promoted the increased use of geologic data for land-use planning, identification of aquifers, management and protection of ground water resources, siting for solid waste disposal, development of geologic aggregate and construction materials, contaminant remediation, and delineation of natural geologic hazards. Geologic maps and reports are the most widely used means of disseminating earth science data to government agencies, geotechnical consulting firms, and the general public.

The purpose of this report is to describe the surficial geologic materials of Warren County, their distribution and history, in a way that informs and educates the increasingly diverse group of people using geologic maps. The Warren County surficial geology map depicts a varied assemblage of earth materials based on a mapping scheme that emphasizes physical characteristics. Additional plates show the elevation of the deeply buried bedrock surface, geologic sections, and block diagrams that illustrate typical glacial valley-fill settings. There is also a supplemental listing of well records, grain size, and mineralogic data.

Introduction

Warren County is located in northwestern New Jersey where it borders on Sussex, Morris, and Hunterdon Counties. Northampton County, Pennsylvania lies to the west across the Delaware River. The county is largely rural and covers an area of approximately 360 square miles, of which 38 percent is used for agriculture, and 10 percent, including numerous lakes, is classified as recreational (Fletcher, 1979). The highest point in the county is the summit of Kittatinny Mountain, approximately 1605 feet above sea level; the lowest point is at the confluence of the Delaware and Musconetcong Rivers, approximately 135 feet above sea level. U.S. Geological Survey 7 1/2-minute topographic quadrangles that cover the county are shown in figure 1.

The population of Warren County according to the 1990 census was 91,607; Phillipsburg is the largest town, and Belvidere is the county seat. The climate is seasonal; winters are generally cold, with an average temperature of 30°F, and summers are warm, with an average temperature of 71°F. Total average annual precipitation as measured at Belvidere from 1951 to 1973 is 44.97 inches (Fletcher, 1979). Flooding is chiefly caused by extended periods of precipitation during the early spring, by heavy downpours accompanying thunderstorms, and by occasional tropical storms.

Surficial geologic materials in the county include: 1) weathered bedrock, 2) till and meltwater sediment deposited during three glaciations, and 3) nonglacial stream sediment, hillslope sediment, and swamp deposits laid down in interglacial and postglacial time. These materials are organized and depicted on the map on the basis of their physical characteristics, and readily distinguishable boundaries. They are the parent material on which soils form, and they exhibit an extremely wide range of physical characteristics. Cumulative thickness is as much 250 feet for glacial and alluvial sediment, and as much as 300 feet for weathered bedrock. The bedrock formations are described by Monteverde and others (1994), and the soils are described by Fletcher (1979).

Previous investigations

The surficial deposits in Warren County were first discussed by Cook (1877, 1878, and 1880), and studied more thoroughly by Salisbury (1902). A surficial geologic map of part of the county was published by Bayley and others (1914), and Wasd (1938) discussed the glacial geology of the Delaware Valley. Ridge (1983), Cotter (1983), and Witte (1988) traced the most recent glacial history of the county.

In a program to update the surficial and bedrock geology of New Jersey, the N.J. Geological Survey conducted on a cooperative study with the U.S. Geological Survey to map the entire state (1985-1993). The surficial geology of the glaciated part of New Jersey, which includes Warren County, was mapped at 1:24,000 scale, making available a comprehensive geological data base.

Methods of investigation

Surficial materials were examined in sand and gravel pits, excavations, and banks along streams and roads. A shovel or hand auger was used where exposures were not available. Surficial deposits, geologic contacts, and areas of extensive bedrock outcrops were marked on 7 1/2-minute topographic maps in the field, and completed by viewing colored stereographic air photos, scale 1:12,000, on file at the N.J. Geological Survey, Trenton, New Jersey. Subsurface data (table 1) were obtained from: 1) records of domestic and municipal wells, 2) N.J. Department of Transportation soil borings, and 3) soil borings on file at the N.J. Geological Survey, Trenton, New Jersey. A seismic-refraction study in the Great Meadows area by Jeff Waldner, David Hall, and Don Jagel (N.J. Geological Survey, written communication, 1992) provided data on depth to bedrock. Tentuml information is based on sieve analyses from Rogers and Leader (1952), and Minard and others (1954a, b). Pebble-count data (table 2) are chiefly from Ridge (1983).

Physiography and bedrock geology

Warren County is loated in the glaciated section of the the Appalachian-Valley-and-Ridge physiogmphic province; and the New Jersey Highlands, which is part of the southern extension of the New England physiographic province (fig. 1). Major physiogmphic features include the New Jersey Highlands, Kittatinny Mountain, Kittatinny Valley, and smaller valleys drained by the Delaware River and its tributaries: Paulins Kill, Pequest River, Lopatcong Creek, Pohatcong Creek, and Musconetcong River (fig. 1).

The New Jersey Highlands is chiefly underlain by gneiss and foliated granite of Proterozoic age (more than 570 million years old), and forms a mountainous area on the southeast side of the county. It if an area of modernte to rugged topography, made up of narmow- to broad-crested ridges and hills, and narrow valleys; relief here is as much as 600 feet. Ridge crests generally parallel bedrock layering, although discordant trends are common. The many small valleys have been cut by small streams as they erode headward into the Highlands. The resulting landscape has a highly dissected appearance.

Musconetcong River, Pohatcong Creek, and parts of the Delaware and Pequest River valleys are within the New Jersey Highlands. They are typically underlain by carbonate rock, slate, and sandstone of Cambrian and Ordovician age (570 to 438 million years old). Relief is generally less than 200 feet. In areas underlain by slate and sandstone the land surface is marked by rolling hills, ridges, and deep narrow valleys. In areas underlain by carbonate rock, the land surface forms a poorly-drained plateau marked by shallow depressions.

Kittatinny Valley is a broad northeast-trending lowland underlain by dolostone, limestone, slate, sandstone, and minor quartzite of Cambrian and Ordovician age. Carbonate rock chiefly underlies river valleys of the Pequest River and Paulins Kill. Relief here is as much as 200 feet; the rock surface has been deeply scoured by glacial erosion forming an irregular surface marked by ridges, pinnacles, and depressions. Slate and sandstone generally underlie the uplands between river valleys and foothills below Kittatinny Mountain; relief here is as much as 500 feet. The rock surface is irregular, marked by rolling hills, and ridges.

Kittatinny Mountain is underlain by quartzite, quartz-pebble-conglomerate, red sandstone and shale; all of Silurian age (438 to 408 million years old). Except for a few water gaps, it forms a continuous narrow upland, extending southwestward from the Shawangunk Mountains in New York through New Jersey into Pennsylvania. Relief here is rugged, the land surface typically marked by steep-sided ridges and hills.

Geomorphic Evolution

The present-day landscape of Warren County has its beginnings in the Tertiary period which began about 65 million years ago. Initially, ancestral streams flowed southeast on a cover of unconsolidated coastal plain sediments of Cretaceous age. Following a lengthy interval of erosion the underlying folded and faulted rocks of the Appalachians and Highlands were exposed (Fenneman, 1938). Present-day water gaps and wind gaps through Kittatinny Mountain and the New Jersey Highlands are places where early streams first encountered resistant rocks and cut down into them. Erosion continued into the late Tertiary period (5.3 million years ago); the land worn down to a gently-dipping surface of low relief (Johnson, 1931). The summits on Kittatinny Mountain and the New Jersey Highlands are possible remnants of this erosion surface. During this time period many reaches of southeast-flowing streams adjusted their courses to the southwest, eroding belts of weaker rock. A renewed period of erosion and valley cutting, presumably related to uplift, commenced during the latter part of the Tertiary period (5.3 to 1.6 million years ago). Streams cut down in the old erosional surface, further adjusting their courses along belts of weaker rock and deepening water gaps. It was during this time that the largest uplands and valleys were formed. During the Pleistocene epoch (1.6 million to 10,000 years ago), glacial deposits and glacial ice blocked or filled river valleys, diverting some streams into new courses.

Quaternary geology

The distribution of glacial drift in Warren County, and wide differences in extent of its weathering and preservation, indicate that continental ice sheets reached the county at least 3 times (fig. 2). Each ice sheet modified the landscape; valleys underlain by weathered rock were deeply scoured; bedrock ridges, hills, and slopes were worn down and streamlined; and most preglacial surficial materials were eroded. Material entrained by the ice sheets was redeposited as till and meltwater sediment. The weight of each ice sheet also depressed the Earth's crust.

Terrestrial and oceanic records indicate that the growth and decay of continental ice sheets in the northern hemisphere during the Pleistocene was cyclic. In addition to the three recognized glaciations, there have been at least 8 other glaciations of a magnitude sufficient to bring continental ice sheets near New Jersey (Braun, 1989). In response to the growth and decay of the ice cap in the northern hemisphere, the climate varied from boreal in glacial times to temperate or subtropical in interglacial ones. During cold intervals bedrock was more easily broken up by freeze and thaw, and surficial materials moved more easily downslope owing to sparse and shallow-rooted vegetative cover and enhanced mass movement of slope material. Ridge and others (1992) indicate weathering during interglacial periods results in the formation of thick soil and saprolite.

The oldest glacial deposits (the Jerseyan of Bayley and others, 1914), which are currently considered to be the pre-Illinoian Port Murray Formation (Stone and others, 1989), at one time covered all of the county. Their age is uncertain, but recent evidence (Braun, 1989) suggests that they were laid down during one or more glaciations in the early to middle Pleistocene (850,000 to 450,000 years old). In Warren County till and stmtified deposits of pre-Illinoian age are deeply weathered, overlie weathered bedrock, are extensively colluviated, and are at least 60 feet above the floor of stream valleys. They remain only where protected from hillslope and stream erosion, and their original forms are rarely preserved.

The second ice sheet covered about half of Warren County, 130,000 years ago during the Illinoian stage (fig. 2). Its deposits, represented by the Lamington and Flanders Formations (Stone and others, 1989), are modernely weathered and overlie unweathered to modernely weathered bedrock. These deposits lie in stream valleys and their original forms are preserved, although subdued. Till remains on many hillslopes.

The difference in distribution between the Illinoian and pre-Illinoian drift suggests that regional base level was lowered by uplift of the land or drop in sea level prior to the Illinoian glaciation. The Delaware River and its tributaries adjusted by downcutting as much as 100 feet. The narrow floor and steep rock-walled valleys of the Delaware River, Musconetcong River, and Pohatcong Creek provide supporting evidence.

The most recent ice sheet dates from the late Wisconsinan substage of the Wisconsinan stage; approximately 22,000 years ago (Cotter and others, 1986). Its furthest southern advance is generally marked by a terminal momine (fig. 2); the course of which indicates the margin of the ice sheet was lobate. Its major lobes are called here the Kittatinny, and Minisink Valley lobes. The glacial deposits, represented by the Rockaway, Kittatinny Mountain, and Netcong formations (Stone and others , 1989), are lightly weathered, overlie unweathered bedrock, and floor stream valleys. Depositional forms are well preserved, and the drift covers most of the land surface.

During late Wisconsinan deglaciation, the outer part of the ice sheet thinned and its flow, largely independent of topography where it was thicker, became much more constrained by the northeast-southwest trend of the large valleys (fig. 2). During glacial retreat, meltwater sediment was laid down chiefly in glacial lakes (fig. 2) that occupied valleys now drained by the Pequest River, Paulins Kill, and Delaware River; and in small upland basins and valleys (Ridge, 1983; Witte, 1988). All these former lake basins were dammed by meltwater deposits, momines, and/or stagnant blocks of ice, or by the margin of the ice lobe. Ridge (1983) and Witte (1988, 1991) indicate that deglaciation preceded from the Terminal Momine systematically northeastward and varied from stagnation-zone retreat (Koteff and Pessl, 1981) to retreat of an active ice margin. Accordingly, deglaciation of Warren County involved the systematic northeastward retreat of the Kittatinny Valley and Minisink Valley ice lobes (fig. 2). This interpretation is chiefly based on the distribution of meltwater deposits and momines, and correlative relationships among elevations of delta topset-foreset contacts, former glacial-lake-water plains, and glacial- lake spillways.

Postglacial history

Warren County was uncovered by ice before 18,500 years ago, based on a radiocarbon date of the oldest organic material cored from Princis Lake in Frelinghuysen Township (Cotter, 1983). Meltwater continued to flow down the Delaware Valley until the glacier margin retreated from the Delaware River drainage basin to the Susquehanna River drainage basin about 15,000 years ago (Ozvath and Coates, 1986). Initially, cold, wet conditions, and sparse vegetative cover enhanced erosion of hillslope material by solifluction, soil creep, and slope wash. Mechanical disintegration of rock outcrops by freeze and thaw provided additional sediment. Gndually as the climate warmed, vegetation spread, and was succeeded by types that further limited erosion. Between 14,250 and 11,250 years ago (Cotter, 1983) lake sediments which had largely consisted of rock and mineral material became rich in organic material. The climate warmed enough to sustain subaquatic vegetation, and land vegetation changed from boreal species to those requiring milder conditions, such as spruce and hemlock. Based on the pollen record oak and mixed hardwood forests started to dominate the landscape around 9700 years ago (Cotter, 1983)

The glacial and postglacial fluvial history of the study area is well preserved in the Minisink Valley where events can be divided in 4 phases. Phase 1 is an interval of valley filling where glacial lake and glacial stream deposits were laid down at the margin of the Minisink Valley lobe. At times the margin of the glacier remained stationary and outwash built up in front of the glacier and extended many miles downstream. The valley-outwash deposits in the Minisink Valley are relict features of these events. Downvalley, the surfaces of older valley outwash deposits were eroded as the proglacial river adjusted to its longer course. Phase 2 marks an interval of deep incision in the valley and formation of meltwater-terrace deposits. Meltwater from a distant ice margin cut a deep narrow channel in the glacial valley fill. The terraces are chiefly erosional, and their sediment, at least their gravel fraction, was eroded from local valley fill. Phase 3 marks the onset of stream-terrace deposition and starts when the ice sheet retreated from the Delaware River drainage basin about 15,000 years ago and stream discharge diminished substantially. This promoted an interval of extensive lateml erosion on the valley floor and formation of stream-terrace deposits which lie 25 to 40 feet above the modern channel floor. Phase 4 marks renewed downcutting and formation of the modern valley floor. This interval appears related to 2 events during the latter part of the late Wisconsinan (14,000 to 10,000 years ago). They are: 1) rebound of the Earth's crust from isostatic depression caused by the weight of the ice sheet, and 2) the onset of warmer climate such that deeper rooted and more extensive vegetation reduced sediment load in the drainage basin.

Location of Warren County, and physiographic provinces in New Jersey

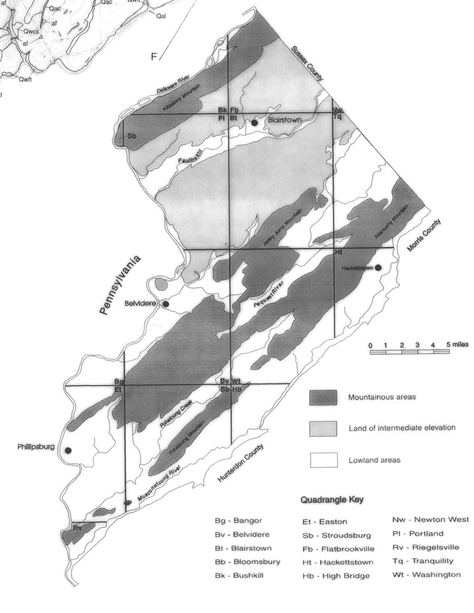


Figure 1. Physiography of Warren County, New Jersey, and coverage of U.S. Geological Survey 7 1/2-minute quadrangles.

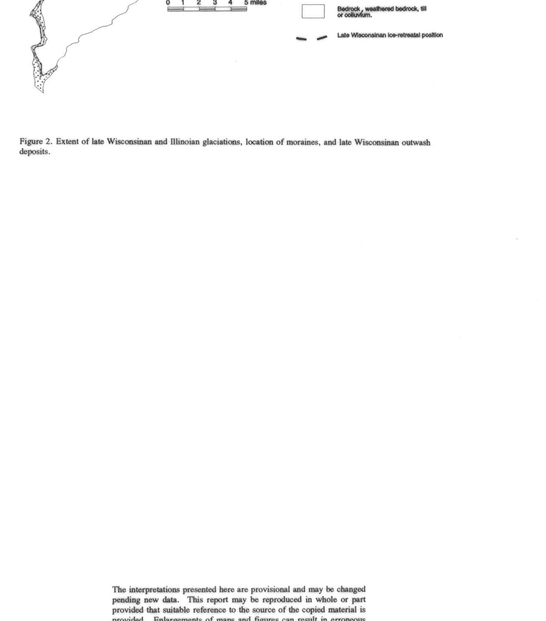


Figure 2. Extent of late Wisconsinan and Illinoian glaciations, location of moraines, and late Wisconsinan outwash deposits.

Mapping Credits (areas listed refer to U.S. Geological Survey, 7 1/2 minute topographic quadrangles)

Ron W. Witte [1] - Bangor, Belvidere, Blairstown, Bloomsbury, Bushkill, Easton, Stroudsburg, Flatbrookville, High Bridge, Portland, and Washington (1990 - 1994).

Scott D. Stanford [1] - Hackettstown, Newton West, Riegelsville, and Tranquility (1990 - 1994).

John C. Ridge [2] - Belvidere (north of Pequest River), and Blairstown (Jenny Jump Mountain) from Ridge (1983).

[1] New Jersey Geological Survey, Trenton, New Jersey.

[2] Tufts University, Medford, Massachusetts.

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ENVIRONMENTAL GEOLOGY OF WARREN COUNTY, NEW JERSEY: SURFICIAL GEOLOGY AND EARTH MATERIAL RESOURCES

PLATE 2

by

Ron W. Witte and Scott D. Stanford

1995

Surficial deposits

Nonglacial materials

Alluvium (Qal) is chiefly late Holocene in age (less than 5000 years old) and includes both channel and overbank sediment laid down by streams as sheet-like deposits on the floors of modern valleys. Its sediment, chiefly derived from local surficial materials, is of highly variable composition. Channels, channel scarps and levees are commonly preserved on flood plains. Alluvium floors all modern stream valleys and is thickest in the Delaware River valley.

Stream-terrace deposits (Qst) also include both channel and overbank sediment. They lie 5 to 25 feet above the modern flood plain and below the level of meltwater-terrace deposits. They are of highly variable composition, and are typically derived from reworked glacial outwash. Based on radiocarbon dates (McNett and McMillian, 1977) and topographic position, they are post-glacial, late Wisconsinan to early Holocene in age. Channels, channel scarps and minor levees are preserved on some terraces. In the Delaware River valley, topographic profiles of stream-terrace deposits, and meander scrolls preserved on some terraces, indicate they are erosional terraces cut by a postglacial stream. As rebound of the Earth's crust commenced about 14,000 years ago (Koteff and Larsen, 1989) the river began to cut a channel to its present level. Older alluvial deposits (Qoal) observed in the Delaware River valley by Ridge and others (1992) overlie Illinoian outwash and pre-Wisconsinan colluvium.

Alluvial-fan deposits (Qaf) are scattered throughout the county; most are south of the late Wisconsinan border in the Delaware, Musconetcong, and Pohatcong Valleys. They form fan-shaped deposits that lie near the base of hillslopes at the mouths of gullies, ravines, and tributary valleys. Their sediment is highly variable in composition, and is derived chiefly from local surficial material laid down by intermittent and perennial streams draining adjacent uplands. The surface of most alluvial fans is entrenched by modern streams. This suggests that fan building is cyclic, presumably influenced chiefly by climate and its effects on weathering, sediment supply, and amount and type of hillslope vegetation.

Swamp and bog deposits (Qs) are numerous north of the late Wisconsinan border. They formed in scoured bedrock basins, in kettles that previously contained shallow lakes or ponds, in glacial lakes that persisted into the Holocene, and in abandoned stream channels on alluvial plains. These deposits principally consist of peat, muck, marl, and minor loose rock and mineral material. Peat is largely the remains of plants which grew in shallow bodies of water. In Kittatinny Valley, peat is largely of the reed and sedge type and where the local bedrock is limestone or dolostone, it is underlain by calcareous marl (Waksman and others, 1943). Peat deposits on Kittatinny Mountain and those northwest of Paulins Kill valley are generally of the forest type, whereas those in the Highlands are typically a mixture of reeds, sedges, and alluvium. Unlike peat, muck is finely divided organic matter, lacking recognizable plant remains. It contains some silt and clay washed in from adjacent soils (Waksman, 1942).

Hillslope deposits include colluvium, undifferentiated alluvium-colluvium, and talus. They originate from hillslope and cliff material that has been transported downslope by soil creep, solifluction, earth or debris flows, and rockfall.

Colluvium (Qwcg, Qwcs, Qwc) is very widespread south of the late Wisconsinan limit, especially on the flanks of mountainous areas underlain by gneiss and granite. It is derived chiefly from weathered bedrock. Sediment typically ranges from silty sand and sand with pebbles, cobbles, and boulders on steep upper slopes to silty sand with pebbles downslope, and includes thin beds and lenses of sorted, stratified sheet- and rill-wash sand and gravel. Colluvium mantles most hillslopes and forms thick aprons on their lower parts. It also collects in small amphitheater-shaped basins at the heads of drainages in upland areas. Near the surface, colluvium is typically stony and clasts are lightly weathered. In places this upper material overlies a truncated red soil that formed on older colluvium and on colluviated pre-Wisconsinan till (Qoc).

Undifferentiated alluvium-colluvium (Qac) makes up thin sheet-like deposits on the floors of narrow valleys, and in first-order drainage basins in areas of rugged relief. These deposits are laid down by small streams, sheet and rill wash, and mass movements.

Talus (Qta) is rock rubble that collects at the base of bedrock cliffs, and on steep slopes below extensive rock outcrops It is chiefly the product of physical weathering, principally frost shattering, and it moves downslope by rockfall, and later by creep. Thick talus lies on the southeast-facing flank of Kittatinny Mountain where it forms an extensive apron of quartzite and quartz-pebble conglomerate boulders. Elsewhere, thick talus lies beneath small cliffs in the New Jersey Highlands, where it consists mainly of boulders of gneiss and granite.

Glacial materials

Till

Till is a poorly sorted, nonstratified to very poorly stratified mixture of clay- to boulder-sized material laid down at the base of a glacier. It also includes poorly stratified sediment that has flowed off or has melted out of a glacier. Where till is thin, the topographic form of the bedrock surface shows through. Thicker till subdues the bedrock surface forms and may completely mask them. Very thick till forms drumlins, aprons on some north-facing hillslopes, and ground moraine. It may also fill narrow valleys; especially those oriented transverse to glacier flow.

Till of late Wisconsinan age (Qwtg, Qwts, Qwtq) consists of three varieties, each reflecting a different group of source rocks (fig. 3). Unit Qwts is chiefly derived from slate, gray siltstone, gray sandstone, dolostone, and limestone underlying Kittatinny Valley. It chiefly lies in the valley, but also extends uphill on the northwest facing flank of the New Jersey Highlands where it is mixed with gneiss and granite. Unit Qwtq is chiefly made from quartzite, quartz-pebble conglomerate, red sandstone, and red shale that underlie Kittatinny Mountain. It lies on the mountain and extends into Kittatinny Valley along its western side. Unit Qwtg is chiefly derived from gneiss and foliated granite of the New Jersey Highlands. Its distribution here is restricted because the glacier did not flow across the Highlands into Kittatinny Valley. Lithologic changes in till sheets are generally gradational so contacts on the map are approximations based on field observations, pebble counts (table 2), and reconstruction of glacier flow.

Till of Illinoian age (Qit) crops out along a narrow belt south of the late Wisconsinan terminal moraine (fig. 3). It lies on many hillslopes and valley floors. In places it has been buried by Wisconsinan colluvium and late Wisconsinan glacial drift. Two moraines are preserved, one in the Pohatcong Valley near Washington, the other in the Pequest Valley. Typically, clasts and matrix material near the surface are moderately weathered. Limestone and dolostone clasts are conspicuously absent, removed from the landscape by extensive chemical weathering during the Sangamon interglacial, which lasted from 130,000 to 75,000 years ago.

Till of pre-Illinoian age (Qpt) is preserved only where protected from stream and hillslope erosion. It lies scattered throughout the Pohatcong, Musconetcong, and Delaware Valleys where it is at least 60 feet above the floor of modern stream valleys. Only a few scant deposits remain in the Highlands where most of it has been eroded. Clasts and matrix material are extensively weathered and the underlying bedrock is deeply weathered. In many places in the Delaware Valley (fig. 3), a gravel lag of quartzite, quartzose sandstone, and chert is all that remains. The lag is the weathering product of till originally rich in limestone and dolostone.

Meltwater deposits

Stratified gravel, sand, and silt was chiefly laid down in valley-outwash deposits, and glacial-lake deltas at and beyond the glacier margin. The sediments are of late Wisconsinan, Illinoian, and in a few places, pre-Illinoian age. Most of the sediment was transported by meltwater through glacial tunnels to the glacier margin (Gustavson and Boothroyd, 1987), and by meltwater streams draining ice-free upland areas adjacent to the valley (Evenson and Clinch, 1987; Witte, 1988; Witte and Evenson, 1989). Sources of stratified material include debris from the base of the glacier, and till and reworked outwash in upland areas. Debris carried to the margin of the ice sheet by direct glacial action was minor.

Glacial stream deposits were laid down in **valley-outwash** (Qwfv, Qifv, Qpv), **meltwater-terrace deposits** (Qwft) and **topset beds of deltas** (Qwld, Qild) (figs. 4a and 4b). These sediments include cobbles, pebbles, sand, and minor boulders deposited in stream channels; and sand, silt, and minor pebbly sand in overbank deposits. Sediment laid down near the glacier margin typically includes massive, imbricated, and horizontally-bedded coarse gravel and minor channel-fill deposits of cross-stratified sand. Downstream, sand typically is more abundant and trough and planar-crossbedding and graded beds are more common.

Glacial lake sediments were laid down in **deltas** (Qwld, Qild), **lacustrine-fan** (Qwlf) and **lake-bottom deposits** (Qwlb) (fig. 4a) by meltwater streams flowing into proglacial lakes. Deltas consist of coarse gravel and sand topset beds overlying fine gravel and sand foreset beds (fig. 4a).Near the former position of the meltwater feeder stream, foreset beds typically dip 25° to 35° , and consist of rhythmically-bedded fine gravel and sand. Farther out into the lake basin these sediments grade into less steeply dipping foreset beds of graded, ripple cross-laminated, parallel-laminated sand and fine gravel with minor silt drapes. These beds in turn grade basinward into gently dipping bottomset beds of ripple-cross-laminated, parallel-laminated sand and silt with clay drapes.

Typically, deltas consist of individual lobes that built out from the delta front over the lake floor, thinning and widening with distance. Because many glacial lake basins were very small or narrow, deltaic deposits commonly filled the basin and were subsequently covered by a thick wedge of gravel and sand laid down by meltwater streams (fig. 4b).

Unlike deltas, lacustrine-fan deposits (Qwlf) lack topset beds; they were deposited at the mouth of glacial tunnels which generally exited the glacier near the floor of the lake basin (fig. 4a). Lacustrine fans also become progressively finer grained basinward. However, near the former tunnel mouth, sediments may be coarser grained and less sorted because of high sedimentation rates and little chance for sorting. Typically, lacustrine-fan deposits are buried beneath lake-bottom deposits. However, if the tunnel remained open and the ice front remained stationary, the fan might build up to lake level.

Lake-bottom deposits (Qwlb) consist of laminated, rhythmically bedded fine sand, silt, and clay that progressively settled out from suspension to the lake floor, and coarse sand and silt carried by density currents. These deposits grade laterally into bottomset beds of deltas and lacustrine-fan deposits.

Ice-marginal deposits

In Warren County stratified ice-marginal sediments lie in heads-of-outwash of ice-marginal deltas, the ice-marginal parts of the lacustrine-fan deposits, and a few ice-sink and crevasse-fill deposits. Only ice-sink and crevasse-fill deposits are mapped separately. Typically these deposits are collapsed, and sediments consist of a varied mixture of stratified materials interlayered with debris-flow deposits. Most of the unstratified to poorly stratified material was released from ice by melting, and subsequently transported and redeposited by meltwater or mass flows.

Moraines in the county mark the lobate edge of former ice sheets. They were chiefly formed by the glacier as it pushed debris and debris-rich ice at its margin. The moraine in the Pohatcong Creek valley marks the Illinoian terminal position and the one in the Pequest River valley marks an Illinoian recessional position. Both consist largely of till, and exhibit subdued knob and kettle topography. The late Wisconsinan terminal moraine and Franklin Grove recessional moraine consist of bouldery, cross-valley ridges consisting of compact silty-sandy till, poorly compact sandy till, and minor layers of stratified sand, gravel, and silt. Their surface is highly irregular; marked by ridge-and-kettle, and knob-and-kettle topography and their cross-sectional profiles are asymmetric with the outermost slopes the steepest. In places where moraines cross river valleys, meltwater and postglacial streams have eroded them.

Weathered bedrock

Weathered bedrock (Qgw, Qsw, Qcw) in Warren County is the product of chemical and mechanical weathering of: 1) gneiss, foliated granite, and minor syenite, 2) slate, siltstone, and minor sandstone, and 3) dolostone, limestone, and marble. It forms a layer of highly variable thickness that covers large areas in the southern part of the county. Most of this material is probably of middle Pleistocene age or younger. Except where protected from erosion, older weathered bedrock has been removed by glacial, mass movement, and stream action. Unweathered and lightly weathered bedrock that lies north of the late Wisconsinan border is in marked contrast to deeply weathered rock that lies to the south. Also, north of the border bedrock outcrops are extensive, but south of it they are sparse.

Gneiss, foliated granite, and syenite weather to saprolite, and rock rubble. Saprolite is the product of chemical weathering of crystalline rocks in which the structure of the parent bedrock is generally preserved. Its texture varies from sandy to clayey, depending on the relative abundance of quartz, which is resistant to weathering, to aluminosilicate minerals which weather to clay. Saprolite extends deeply into bedrock along foliation, joints, and fractures, and is generally thickest in areas of gentle slope. Rock rubble is the product of mechanical weathering and it forms a discontinuous mantle on the land surface.

Slate, gray siltstone, and gray sandstone weather to decomposition residuum (Richmond and others, 1991), and slate-chip rubble. Decomposition residuum is the product of chemical weathering of clastic rocks. Its texture is inherited from the mineralogy of its parent bedrock. Slate and siltstone typically weather to a clayey residuum whereas sandstone, if it is enriched in quartz, is more sandy. Bedrock does not generally crop out; and where it is close to the surface, it tends to be covered by a mixture of soil and slate chips or flagstone.

Limestone. dolostone, and marble weather to solution residuum (Richmond and others, 1991). Solution residuum is the product of chemical weathering of carbonate rock. It typically forms a clayey material that contains varying amounts of chert and quartz. This material extends deeply in the subsurface along fractures, joints and bedding planes which have been widened by dissolution. In many places it alternates in the subsurface with unweathered bedrock. Bedrock outcrops are few and widely scattered; the rock surface is highly irregular and pinnacles of rock are typical. Material mapped as weathered carbonate rock also includes sorted and unsorted sand, gravel, silt, and clay from overlying colluvial, alluvial, and glacial sediment deposited in sink holes and solution cavities.

Glacial Valley Fill

Meltwater deposits in the county occupy three valley-fill settings. The first includes deposits that did not completely fill the lake basins (fig. 4a). Typically these basins were large, and at least 100 feet deep. Their deltas and lacustrine-fan deposits are generally separated by extensive areas of lake-bottom sediment. Glacial Lakes Pequest, and Oxford illustrate this environment.

The second setting includes deposits that nearly or completely filled the lake basins (fig. 4b). Typically these basins are small and/or narrow, and topset beds may have been extensively built up. Deltas and lacustrine-fan deposits commonly coalesce and form the floor of an entire lake basin. Lacustrine-fan deposits may also underlie younger deltaic and lake-bottom deposits. Typically these fans overlie till or bedrock at the bottom of the former lake basin. Paulins Kill, parts of the Pequest and Beaver Brook, and the Delaware Valley north of Foul Rift illustrate this environment.

The third setting includes valley-outwash and meltwater-terrace deposits in valleys that drained away from the glacier margin. Valley-outwash deposits form the highest terrace in the valley and generally flank the valley walls. Meltwater-terrace deposits form lower paired and unpaired erosional terraces cut down into the upper outwash surface. Delaware Valley south of Foul Rift, Buckhorn Creek valley, and parts of Beaver Brook, Blairs Creek, and Van Campens Creek valleys exhibit this valley-fill and -cut environment. In the Delaware Valley, south of Foul Rift,, outwash overlies older alluvium or early Wisconsinan outwash (Ridge and others, 1992).

Buried-bedrock topography

The buried and partly buried valleys in Warren County (pl. 3) chiefly lie north of the Illinoian glacial border in the Delaware, Paulins Kill, Pequest, and Musconetcong Valleys. Their distribution and gradient indicate that earlier they were eroded by streams, and later, deeply scoured by glacial ice during the Illinoian and late Wisconsinan glaciations. Closed depressions on the buried-bed rock surface are common; they are products of glacial erosion in areas of weak, soft, and weathered rock. A projection of the valley's bedrock gradient upstream from the Chestnut Hill - Marble Mountain water gap indicates that glacial erosion has lowered the valley floor by as much as 150 feet since pre-Illinoian time.

These buried and partly-buried valleys now contain deposits of glacial sediment that are as much as 250 feet thick. The deposits are chiefly meltwater sediment of late Wisconsinan age. Stratified deposits include valley-outwash, meltwater-termce, deltaic, lacustrine-fan, and lake-bottom deposits.

Economic resources

The most valuable geologic resource in Warren County, other than ground water, is sand and gravel. It is used extensively in construction as aggregate, subbase material, and fill. A large part of the county's ground-water supply also is in this material. Most sand and gravel is excavated from valley-outwash (Qwfv), meltwater-termce (Qwft), and deltaic deposits (Qwld) of late Wisconsinan age. These deposits chiefly lie in the Delaware River, Pequest River, Paulins Kill, and Beaver Brook valleys. Commercial sand and gravel opentions are active in the Delaware Valley downstream from Belvidere, and the Pequest Valley downstream from Great Meadows. Elsewhere, inactive sand and gravel pits in glacial materials are common. Generally, valley-outwash deposits contain more gravel than deltaic deposits of comparable area because valley outwash consists of sand and gravel to its base, whereas deltaic deposits contain abundant sand and silt in their lower parts.

Peat is primarily used as a soil conditioner, and is widespread in the many swamps north of the late Wisconsinan border. Most of it is of the reed and sedge type with organic content varying between 60 and 96 percent (Waksman and others, 1943). It was formerly extracted in the Great Meadows area, but no commercial opentions are currently active.

Other surficial materials of some limited economic importance include clay and marl. Clay is obtained from lake-bottom deposits, deeply weathered older till, and weathered bedrock; it is made into bricks, ceramic material, and impervious liners for ponds and landfills. Marl, which is principally calcium carbonate produced by the chemical activity of aquatic plants, generally underlies peat deposits in areas underlain by limestone and dolostone. It has been used in the past for agricultural lime.

Pebble Composition of Glacial Materials

Ridge (1983) and Witte (1988) indicate that regional ice flow was nearly due south, across the southwest trend of Kittatinny Valley. During deglaciation, thinning near the margin of the ice sheet realigned ice flow southwestward, parallel to the valley. The composition of the pebble fraction of till (table 2) supports this interpretation. Quartzite, quartz-pebble conglomerate, red sandstone and shale, all derived from Kittatinny Mountain, are conspicuous in most of the samples. These pebbles could have been transported only by glacier ice that flowed southward over Kittatinny Mountain, and through the Delaware Water Gap. Limestone, dolostone, slate, gmy siltstone, gray sandstone pebbles, all derived from Kittatinny Valley, are prominent in till that lies on the northwest-facing flank of the New Jersey Highlands. Their distribution also indicates ice flowed southward across Kittatinny Valley. However, divergent flow at the eastern margin of the Kittatinny Valley lobe could also have carried these pebbles onto the Highlands. The lack of gneiss and granite pebbles in till of Kittatinny Valley indicates ice never flowed from the Highlands into the valley.

Meltwater sediment in Kittatinny Valley was chiefly derived from: 1) till beneath the glacier, 2) debris from the glacier's base, and 3) material from adjacent ice-covered and deglaciated uplands (Witte, 1988; Witte and Evenson, 1989). Table 2 shows that the 7 drainage basins in this study fall into 3 groups, each with a distinctive pebble suite (fig. 5). Group 1 includes outwash in the Delaware River valley downstream from Belvidere, Beaver Brook, and Buckhorn Creek valleys. These deposits consist chiefly of a mixture of limestone, dolostone, slate, gray siltstone, gmy sandstone, secondary quartzite, quartz-pebble conglomerate, and minor gneiss and foliated granite. Group 2 includes outwash in the lower and upper Pequest Valley. These deposits contain limestone, dolostone, secondary slate, sandstone, and lesser quartzite, and gneiss. The downstream part of Pequest Valley contains significantly more gneiss due to its proximity to Jenny Jump Mountain and the northwest flank of the Highlands. Group 3 includes outwash in the Paulins Kill Valley and the Delaware River valley above Belvidere. These deposits are enriched in quartzite, quartz-pebble-conglomerate, red sandstone, and red shale.

Texture of glacial materials

Textural information is based on sieve analyses from Rogers and Leuder (1952), and Minard and others (1954a, 1954b). Their samples have been correlated to map units in this report, based on their location, similarities in material, and geologic setting. Ternary diagrams (fig. 6) show weight percent of gmvel, sand, and fines (silt and clay) of till. Till of late Wisconsinan age typically has a silty-sand matrix. Qwtg, derived from gneiss and granite, and Qwtq, from quartzite and sandstone, are both sandier than Qwts, which originated largely from slate, siltstone, dolostone, and limestone. Older till contains proportionally more silt and clay, a characteristic of more prolonged weathering.

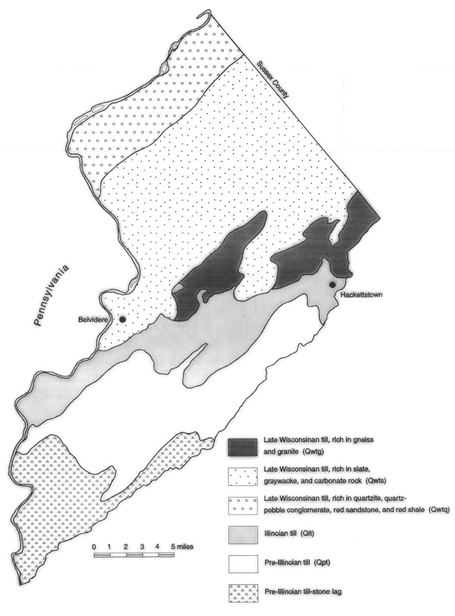


Figure 3. Surface limit of till in Warren County, New Jersey. Includes areas of bedrock outcrop, and places where till has been eroded or covered by younger surficial material. Till-stone lag consists chiefly of cobbles and pebbles of quartzite, quartzose sandstone, and chert derived from highly weathered pre-Illinoian till that was formerly rich in carbonate rock.

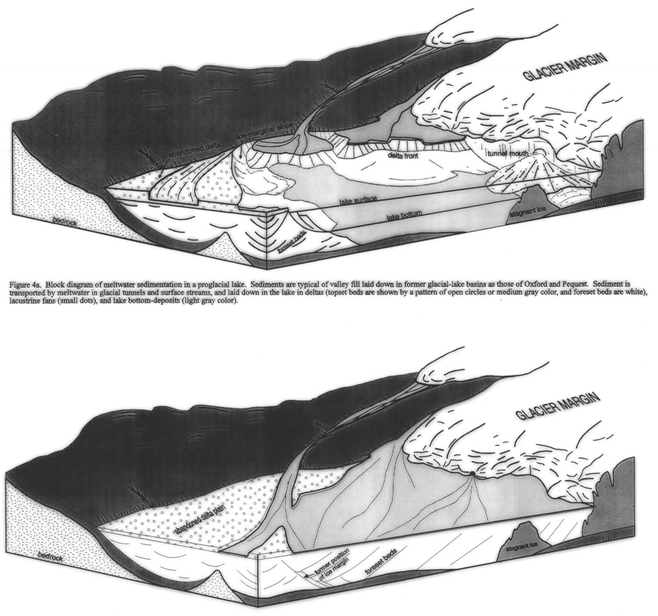


Figure 4a. Block diagram of meltwater sedimentation in a proglacial lake. Sediments are typical of valley fill laid down in former glacial-lake basins as those of Oxford and Pequest. Sediment is transported by meltwater in glacial tunnels and surface streams, and laid down in the lake in deltas (topset beds are shown by a pattern of open circles or medium gray color, and foreset beds are white), lacustrine fans (small dots), and lake bottom-deposits (light gray color).

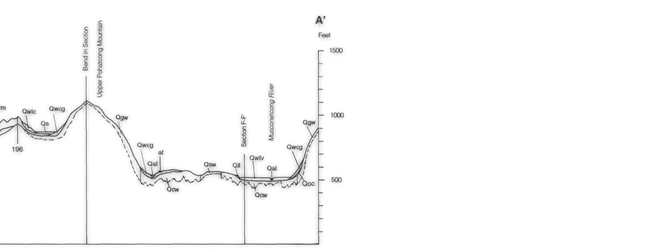


Figure 4b. Block diagram of meltwater sedimentation in a filled glacial-lake basin. Sediments are typical of valley fill laid down in Delaware River, Paulins Kill, Beaver Brook, and Pequest River valleys. Lake basins in this setting are generally small or narrow, and typically become filled with deltaic and lake-bottom sediment. Continued sedimentation may form a thick wedge of fluvial sand and gravel on top of the delta topset beds (circular pattern). Retreat of the glaciers margin forms a new glacial-lake basin and the cycle of sedimentation is renewed; the former delta plain is typically incised by later meltwater streams.

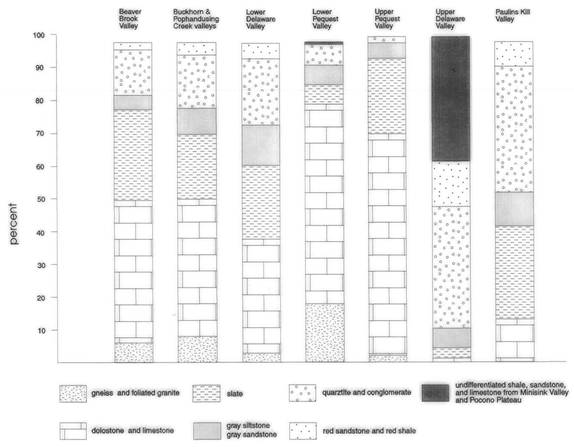


Figure 5. Composition of pebbles in glacial outwash in Warren County, New Jersey. Values are averages for each valley. Modified from Witte (1988) and Ridge (1983); sample sites are shown on plate 3.

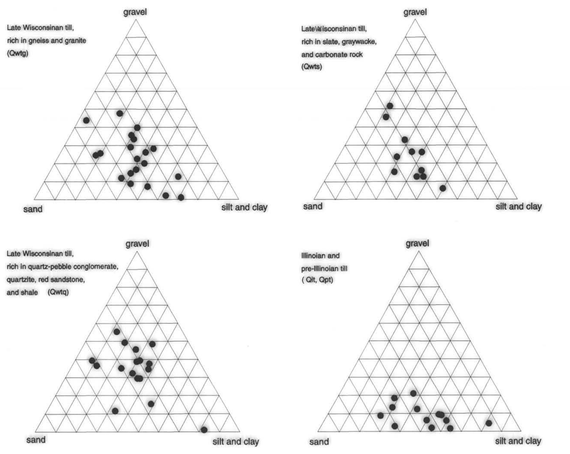
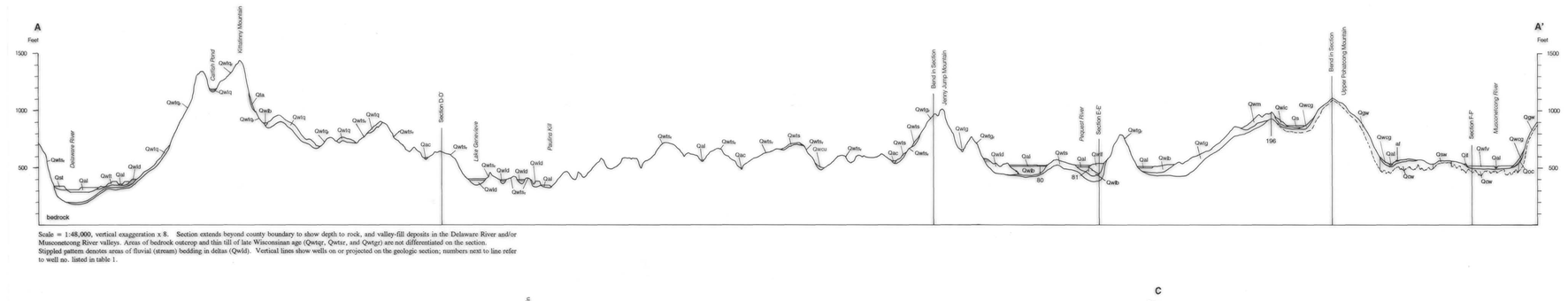
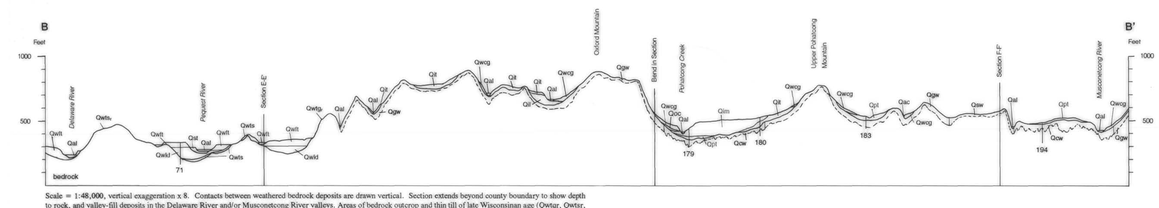


Figure 6. Weight percent of gravel, sand, and fines (silt and clay) of till in northwest New Jersey. Data modified from Minard and others (1954a, 1954b).



Scale = 1:48,000, vertical exaggeration x 8. Section extends beyond county boundary to show depth to rock, and valley-fill deposits in the Delaware River and/or Musconetcong River valleys. Areas of bedrock outcrop and thin till of late Wisconsinan age (Qwtgr, Qwtsr, and Qwtgr) are not differentiated on the section.
Stippled pattern denotes areas of fluvial (stream) bedding in deltas (Qwld). Vertical lines show wells on or projected on the geologic section; numbers next to line refer to well no. listed in table 1.



Scale = 1:48,000, vertical exaggeration x 8. Contacts between weathered bedrock deposits are drawn vertical. Section extends beyond county boundary to show depth to rock, and valley-fill deposits in the Delaware River and/or Musconetcong River valleys. Areas of bedrock outcrop and thin till of late Wisconsinan age (Qwtgr, Qwtsr, and Qwtgr) are not differentiated on the section.
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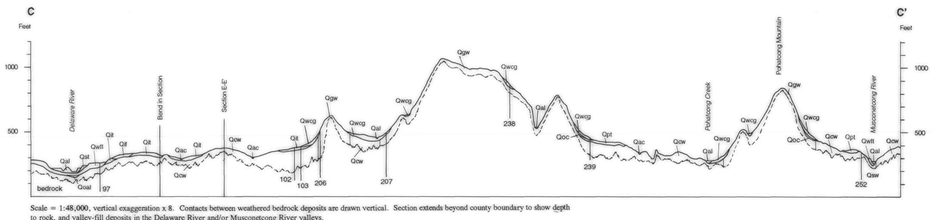

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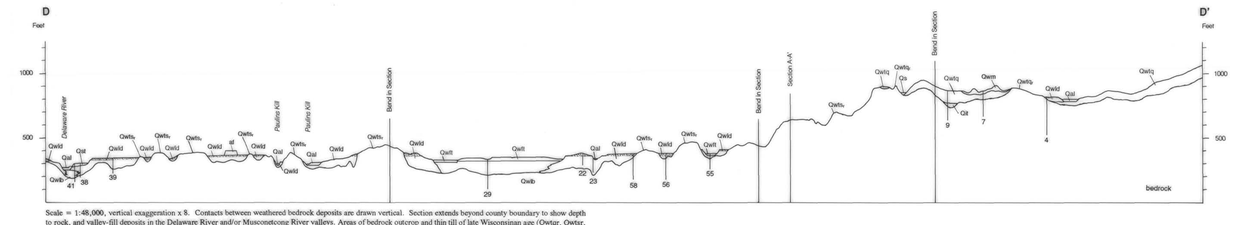

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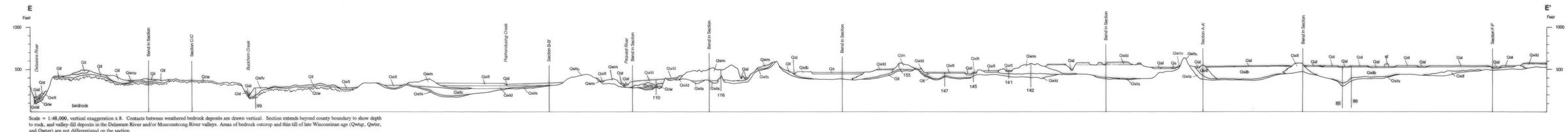

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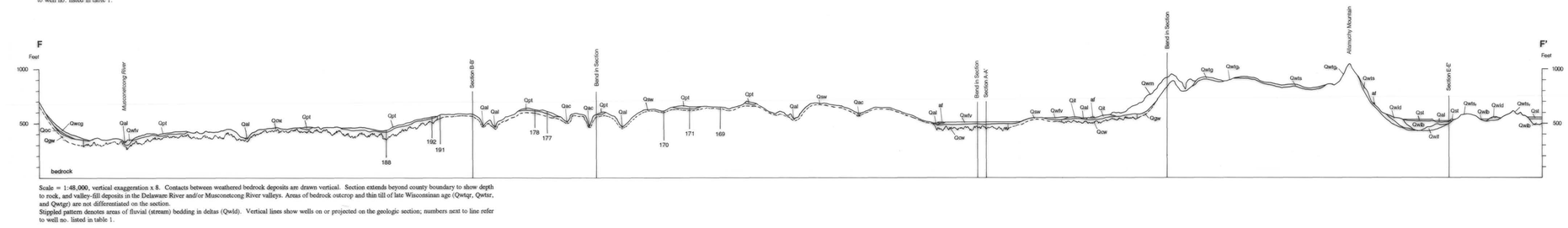

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The interpretations presented here are provisional and may be changed pending new data. This report may be reproduced in whole or part provided that suitable reference to the source of the copied material is provided. Enlargements of maps and figures can result in erroneous interpretations.

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DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF SCIENCE AND RESEARCH
NEW JERSEY GEOLOGICAL SURVEY

ENVIRONMENTAL GEOLOGY OF WARREN COUNTY, NEW JERSEY:

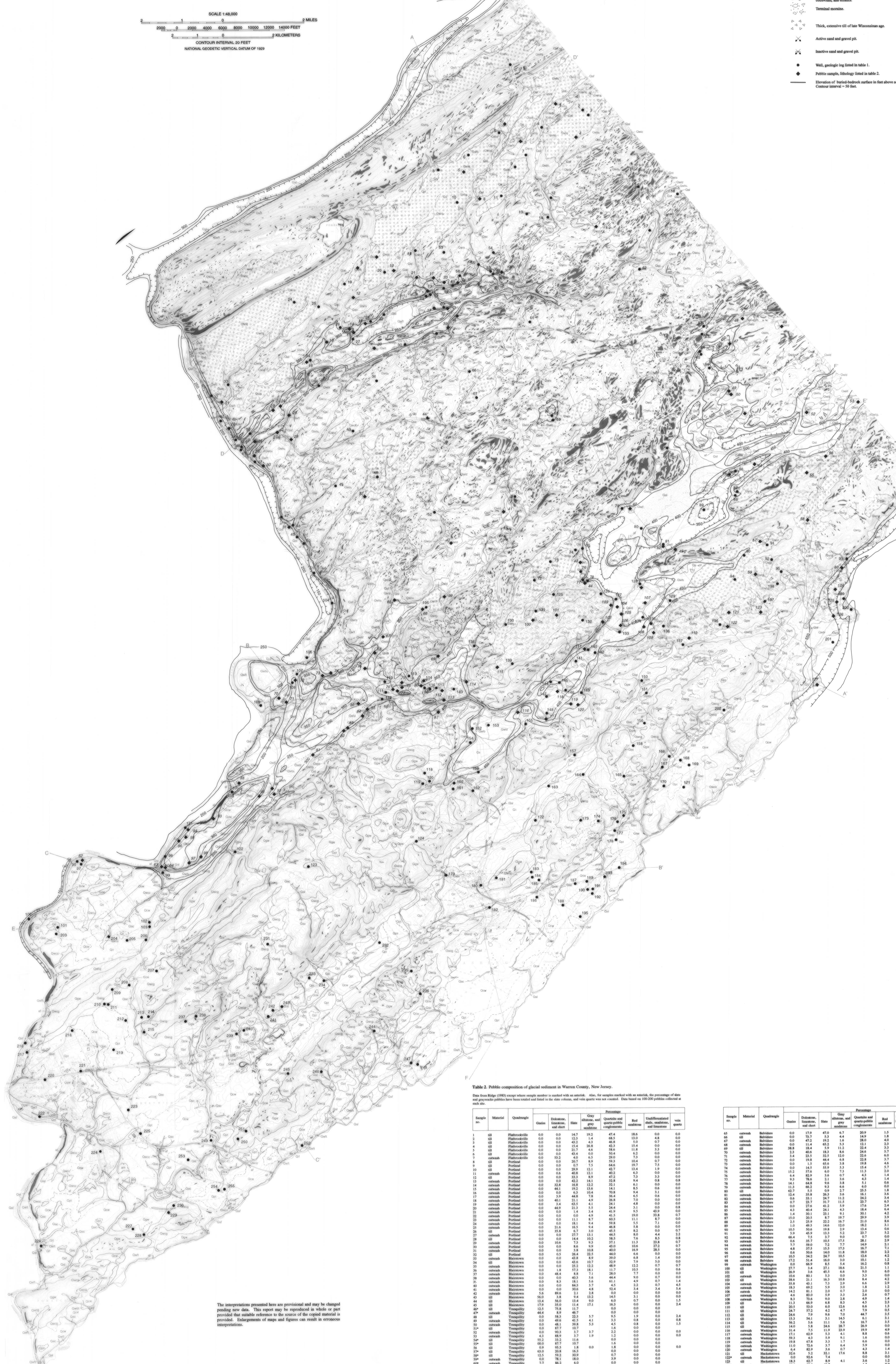
SURFICIAL GEOLOGY AND EARTH MATERIAL RESOURCES

PLATE 3

by

Ron W. Witte and Scott D. Stanford

1995



Map Symbols

- Contacts, dashed where approximated, dotted where concealed.
- Erosional scarp cut by postglacial streams.
- Areas of extensive bedrock outcrops; minor very thin till, colluvium, and erratics.
- Terminal moraine.
- Thick, extensive till of late Wisconsinan age.
- Active sand and gravel pit.
- Inactive sand and gravel pit.
- Well, geologic log listed in table 1.
- Pebble sample, lithology listed in table 2.
- Elevation of buried-bedrock surface in feet above sea level. Contour interval = 50 feet.

Table 1. Records of selected wells in Warren County, New Jersey.

The listed wells were drilled for private and public water supply, exploration, and ground water monitoring. Wells listed with a NJDEP permit number are from the files of the Bureau of Water Allocation, Division of Water Resources, N.J. Department of Environmental Protection, Trenton, New Jersey. If the NJDEP permit number is not listed the well record is from a soil boring on file at N.J. Geological Survey, Trenton, New Jersey. Well locations are shown on plate 3. Discharge is listed as gallons per minute (gpm), and depth in feet is below land surface. Well locations are based on property maps; generally within 500 feet of actual location.

Well no.	NJDEP Permit number	U.S. Geological Survey Quadrangle	Discharge reported by drillers in gpm	Depth in feet	Driller's log
1	21-264	Flatbrookville	10	0-55 55-71	dirt, clay red shale
2	21-8205	Flatbrookville	20	0-90 90-200	overburden shale
3	21-5631	Flatbrookville	12	0-148 148-150	sand, clay, gravel gravel & sand
4	21-7241	Flatbrookville	6	0-7 7-298	clay gray slate
5	21-8389	Flatbrookville	30	0-51 51-200	sand, clay, gravel overburden shale
6	21-8098	Flatbrookville	20	0-65 65-113 113-125 125-158 158-323	gray clay, large gravel pink clay, gravel pink sandstone brown clay, shale slate
7	21-8021	Flatbrookville	10	0-20 20-68 68-77 77-202	boulders hardpan rotten shale shale
8	21-3273	Flatbrookville	12	0-180 180-188	clay, gravel, boulders small gravel
9	21-4661	Flatbrookville	5.5	0-133 133-222	gray clay, dense gravel gray shale
10	21-7336	Flatbrookville	15	0-90 90-250	overburden, layers of clay, gravel shale
11	21-7767	Flatbrookville	4	0-4 4-67 67-87 87-497	clay sandy clay, gravel red sandstone rock gray shale
12	21-7940	Flatbrookville	8	0-50 50-475	sand, clay, gravel overburden slate
13	21-8105	Flatbrookville	4.5	0-10 10-19 19-25 25-50 50-295 295-490	sandy clay, boulders gravel, boulders clay, gravel red rock, slate slate limestone
14	21-7712	Flatbrookville	25	0-10 10-20 20-30 30-58 58-96 96-125	boulder, gravel sandy clay, gravel sandy clay fractured limestone limestone fractured limestone, water
15	21-7813	Flatbrookville	11	0-28 28-198	clay, gravel limestone rock
16	21-6049	Flatbrookville	20	0-3 3-15 15-115 115-125	soil gravel, sand clay, gravel mix water bearing gravel
17	21-8353	Flatbrookville	none reported	0-3 3-47 47-122	topsoil sand, gravel blue limestone
18	21-4296	Portland	15	0-90	sand, clay, gravel
19	21-7819	Portland	8	0-15 15-30 36-248	clay hard red clay blue slate
20	21-5749	Portland	6	0-16 16-480	overburden shale
21	21-3375	Portland	12	0-134	hardpan, gravel
22	21-278	Portland	11	0-6 6-24 24-76 76-84	clay gravel gravel, sand gravel
23	21-7678	Portland	18	0-2 2-23 23-115 115-120	clay clay, gravel sand, gravel gravel bed
24	21-2883	Portland	15	0-122 122-195	clay, gravel gray shale
25	21-6899	Portland	30	0-20 20-255	cobbles with clay shale
26	21-7132	Portland	5	0-2 2-18 18-25 25-500	overburden gravel sand limestone
27	21-2950	Portland	6	0-6 6-58 58-112 112-116 116-120 120-130	overburden limestone brown clay and gravel dense gravel, clay, silt boulder clay, gravel
28	21-6440	Portland	15	0-30 30-325	sandy overburden limestone, shale
29	21-3878	Portland	60	0-11 11-101 101-117 117-120	gravel soft blue clay sand, hard gravel limestone
30	21-3595	Portland	4	0-25 25-55 55-70 70-77 77-83	sand hard clay, gravel mixed clay, gravel gravel with boulders limestone
31	21-8063	Portland	2	0-38 38-400	sand, clay, gravel overburden limestone
32	24-12674	Portland	7	0-100 100-161 161-170	clay, gravel gravel gravel, water
33	21-7897	Portland	4	0-15 15-40 40-50 50-395	sandy clay, boulders clay, gravel clay slate
34	21-8095	Portland	20	0-25 25-75 75-87 87-91 91-95	sand, gravel, boulders sand, gravel sand, broken limestone broken limestone (water) broken limestone
35	21-7989	Portland	25	0-25 25-54 54-70	sand, boulders sand, gravel limestone
36	21-7522	Portland	10	0-6 6-150	sand, clay, gravel overburden slate
37	21-2072	Portland	20	0-25 25-35 35-45 45-50 50-84	boulders gravel, boulders fine sand gravel, boulders sand, gravel
38	24-13786	Portland	12	0-30 30-60 60-75	sand, gravel clay clay, limestone
39	24-5211	Portland	8	0-50 50-82 82-115	sand gravel limestone
40	24-17555	Portland	10	0-26 26-64 64-68 68-125	gravel silt limestone rock
41	24-24435	Portland	15	0-11 11-14 14-25 25-40 40-80 80-140	sandy clay boulders gravel sand, gravel gray clay limestone
42	24-16465	Portland	12	0-45 45-128	sand, gravel limestone
43	24-13313	Portland	8	0-69 69-147	overburden shale
44	21-8166	Portland	15	0-6 6-10 10-148	clay, cobbles brown shale slate
45	24-17472	Portland	5	0-25 25-150	clay, gravel shale
46	24-15179	Portland	8	0-30 30-128	clay, sandstone slate
47	24-17102	Portland	8	0-58 58-60	sand, gravel slate
48	24-6464	Portland	3	0-24 24-30 30-40 40-147	sandy clay, gravel boulder gray clay, gravel slate
49	24-14411	Portland	30	0-90 90-135	clay, gravel slate
50	24-14790	Portland	20	0-120 120-131	clay gravel
51	24-14958	Portland	10	0-10 10-55 55-78 78-175	sand sand, gravel gray clay slate
52	24-21508	Portland	none reported	0-20 20-327	clay, gravel, boulders shale
53	21-5237	Blairstown	5	0-45 45-310	overburden shale
54	21-6433	Blairstown	35	0-26 26-275	overburden shale
55	21-4012	Blairstown	5	0-74	clay, gravel
56	21-5096	Blairstown	8	0-28 28-70 70-200	sand, gravel brown soil, rock mixture hard blue rock
57	21-8006	Blairstown	20	0-72 72-150	sand, clay and gravel overburden slate
58	21-6639	Blairstown	20	0-20 20-25 25-125	topsoil, boulders fractured limestone hard limestone
59	21-5881	Blairstown	30	0-58 58-72	sand, clay, gravel limestone
60	21-5875	Blairstown	20	0-115	gravel
61	21-7406	Blairstown	2	0-10 10-500	overburden shale
62	21-8208	Blairstown	6	0-29 29-225	overburden shale
63	21-4839	Blairstown	4	0-2 2-25 25-65 65-90 90-95 95-123	overburden sand, heavy gravel gray sand and clay brown clay soft brown shale shale
64	21-6652	Blairstown	none reported	0-4 4-10 10-60 60-68	clay sandy clay sand gravel
65	21-5632	Blairstown	40	0-8 8-222 222-224	sandy clay gray clay gravel
66	21-8123	Blairstown	8	0-22 22-285 285-400	overburden shale limestone
67	21-7154	Blairstown	6	0-95 95-290	clay, gravel shale
68	21-2055	Blairstown	6	0-55 55-105	sand, clay clay, gravel
69	24-22804	Blairstown	8	0-80 80-85 85-90 90-175	clay gravel clay shale
70	24-19455	Blairstown	20	0-38 38-175	overburden limestone
71	24-18576	Blairstown	15	0-2 2-20 20-98 98-110	topsoil gravel, sand gray clay broken limestone
72	24-19136	Blairstown	7	0-120 120-150 150-268	clay, sand broken sandstone granite
73	24-22108	Blairstown	15	0-25 25-91 91-223	sandy hardpan sandstone granite
74	24-16964	Blairstown	5	0-38 38-50 50-298	clay, hardpan fractured limestone limestone
75	24-14963	Blairstown	60	0-110 110-147	sand, clay, lime gravel rotten yellow limestone
76	24-11998	Blairstown	5	0-18 18-198	clay, boulders, large gravel limestone
77	24-20092	Blairstown	7	0-191 191-248	hardpan, gravel, sand limestone
78	24-13519	Blairstown	25	0-165	sand, clay, gravel
79		Blairstown	none measured	0-5 5-11 11-80 80-82 82-84	peat silt silt, clay fine sand very fine sand
80		Blairstown	none measured	0-11 11-69 69-71	sand silt, clay clay, silt, gravel
81		Blairstown	none measured	0-13 13-14 14-16 16-55	fine sand silt fine sand silt, clay
82		Blairstown	none measured	0-44 44-46	sand, gravel clay, silt, gravel
83	21-4465	Tranquillity	20	0-40 40-85 85-95	sand, gravel clay gravel
84	21-6880	Tranquility	70	0-4 4-180 180-183	clay clay, gray sand brown sand, gravel
85	24-6895	Tranquility	500	0-10 10-205 205-217 217-242 242-243 243-495	black swamp muck gray clay hard fine sand and clay dirty gravel and clay yellow clay limestone
86	24-11199	Tranquility	600	0-1 1-3 3-6 6-39 39-149 149-155 155-177 177-212 212-502	fill soft mucky clay gray clay sand with clay gray clay with sand layers sand, gravel hardpan, granite hardpan limestone with clay seams limestone, various hardness
87	24-13178	Tranquility	20	0-40 40-91 91-105 105-240 240-280 280-405	sand, gravel fine sand hardpan, clay, gravel limestone red limestone, shale granite
88	24-15216	Tranquility	25	0-30 30-50 50-66 66-68 68-113 113-115 115-175	sand, gravel gravel fine sand boulder gravel boulder soft limestone with clay
89	24-2656	Tranquility	548	0-4 4-182 182-232 232-236 236-250 250-395	fill gray clay clay, sand clay, stones soft broken gray rock gray rock
90	24-21678	Tranquility	30	0-15 15-119	clay, boulders clay, gravel
91	24-12966	Tranquility	none reported	0-89 89-105 105-148	clay, hardpan sandstone granite
92	24-20285	Tranquility	30	0-63 63-198	clay, sand, gravel granite
93	24-15075	Tranquility	25	0-15 15-45 45-55 55-60	clay, boulders sand clay, sand sand, gravel
94	24-19068	Tranquility	30	0-75 75-125	sand and stone granite
95	24-14224	Tranquility	33	0-76 76-225	clay, large gravel granite
96	24-13815	Bangor	6	0-2 2-18 18-80 80-625	topsoil yellow clay broken limestone limestone
97	24-14509	Bangor	10	0-32 32-75 75-150	sand, gravel brown clay, rock mix gray limestone
98	24-14899	Bangor	25	0-12 12-20 20-50 50-125	brown soil sand, gravel brown clay granite rock
99	24-16175	Bangor	25	0-80 80-250	overburden limestone
100	24-3581	Bangor	15	0-40	sand and gravel
101	24-11669	Bangor	5	0-4 4-150 150-190 190-423	overburden clay hard rock trap rock and voids
102	24-13862	Bangor	25	0-145 145-175 175-192	clay broken limestone limestone
103	24-21398	Bangor	12	0-50 50-68 68-114 114-125 125-160 160-180	clay, gravel broken limestone clay, silt, gravel broken limestone clay, gravel, broken limestone limestone
104	24-22928	Belvidere	30	0-55 55-100 100-134 134-150	sand, gravel gray clay clay shale
105	24-13378	Belvidere	8	0-90 90-180 180-200 200-248	gray clay, gravel granite brown granite soft sandstone with layers of hardpan
106	24-2844	Belvidere	none reported	0-38 38-39 39-72	brown sand, silt calcareous clay fine to medium sand, some gravel
107		Belvidere	none reported	0-20 20-40 40-90 90-100 100-125	sand, gravel sand sand, gravel sand, fine gravel, some silt and clay gray fine sand, some silt, gray limestone at 125 feet
108		Bangor	none reported	0-10 10-60 60-93 93-122 122-125 125-145	sand, gravel fine sand, silt, some clay, a few pebbles sand, gravel gray clay, silt, some fine sand gravel and clay sand, gravel; end at boulders
109	24-12122	Belvidere	none reported	0-90	sand, gravel
110	24-15502	Belvidere	12	0-82 82-104 104-175	sand and gravel brown clay and rock mix limestone
111	24-5476	Belvidere	20	0-20 20-50	overburden with boulders sand, gravel
112	24-15471	Belvidere	30	0-15 15-51	clay gravel
113	24-17094	Belvidere	18	0-38 38-220	sand, clay, gravel soft yellow and gray limestone
114	24-15789	Belvidere	12	0-15 15-82 82-162	brown soil sand and gravel limestone
115	24-21579	Belvidere	15	0-20 20-120 120-160	topsoil, boulders silt, clay gravel
116	24-16962	Belvidere	10	0-68 68-144	sand and gravel limestone
117	24-6082	Belvidere	10	0-155	hardpan, gravel
118	24-17032	Belvidere	12	0-70 70-132	clay, sand sandstone
119	24-13830	Belvidere	none reported	0-30 30-85	sand, clay granite
120	24-17112	Belvidere	15	0-75 75-100	clay limestone
121	24-9902	Belvidere	24	0-74 74-94 94-105	sand, gravel white clay, gray rock gray rock, limestone
122	24-13013	Belvidere	13	0-60 60-275	sand, loose rock granite
123	24-14955	Belvidere	50	0-20 20-35 35-78	clay sandstone gray granite
124	24-12175	Belvidere	20	0-30 30-40 40-124	overburden, sand rotten granite granite
125	24-6286	Washington	10	0-18 18-61 61-65	clay, gravel very rotten granite rotten granite
126	24-12547	Washington	10	0-68 68-69 69-110 110-123	overburden, sand stone quartz, rotten stone granite
127	24-16306	Washington	none reported	0-98 98-498	sand granite
128	24-18802	Washington	30	0-105	clay, sand, gravel
129	24-12545	Washington	none reported	0-74 74-80 80-92	overburden, sand, clay, gravel brown limestone limestone with water
130	24-15669	Washington	5	0-15 15-180 180-225	overburden sand, clay, gravel brown, white granite
131	24-21677	Washington	30	0-105 105-120	clay, gravel sand, gravel
132	24-15419	Washington	none reported	0-45 45-100	clay, sand, gravel, water granite
133		Washington	none reported	0-15 15-34 34-38 38-40	sand, silt, trace of gravel sand, gravel, trace of silt boulders sand, gravel, trace of silt
134	24-18577	Washington	70	0-138 138-148	sand, clay, gravel limestone
135	24-14810	Washington	20	0-46 46-70	sand, clay brown sandstone, granite
136	24-13404	Washington	35	0-18 18-56 56-99	hardpan brown sandstone granite
137	24-18248	Washington	12	0-70 70-105 105-248	sand, clay, gravel soft sandstone granite
138	24-6529	Washington	22	0-67 67-98	clay, sand, gravel soft granite
139	24-10896	Washington	14	0-30 30-50 50-100 100-121 121-126 126-133	sand yellow clay clay, gravel hard clay brown granite water
140	24-20443	Washington	10	0-47 47-52 52-125	sand, gravel boulder gravel
141	24-5451	Washington	15	0-135 135-142 142-155	sand, gravel clay gravel
142	24-11549	Washington	8	0-8 8-140	overburden sand, gravel
143	24-14135	Washington	30	0-35 35-91 91-100	hardpan sand, clay, gravel sand, gravel, water
144		Washington	none reported	0-28 28-50 50-91	clay, sand, gravel mix of rock and clay hard rock
145		Washington	none measured	0-28 28-37 37-40 40-68 68-101 101-104	sand and gravel sand, silt and gravel boulder clay, rocks, some sand mix of clay, gravel and rock hard rock
146		Washington	none measured	0-52 52-56 56-78 78-104	sand, gravel light brown clay sand and gravel rock
147		Washington	none measured	0-25 25-50 50-52 52-61 61-600	sand, gravel clay, gravel cobbles soft, sandy yellow rock carbonate rock
148	24-07192	Washington	300	0-147 147-155	silt, gravel, brown silt large gravel, water area
149	24-18319	Washington	20	0-120 120-300	clay brown rock
150	24-13958	Washington	10	0-20 20-55 55-148	clay sand mix of soft and hard granite
151	24-16743	Washington	30	0-50 50-165	clay, sand granite
152	24-14474	Washington	50	0-60 60-200	overburden limestone
153	24-4871	Washington	30	0-58 58-81	clay, sand granite or limestone
154	24-19525	Washington	100	0-60 60-375	overburden limestone
155		Washington	none measured	0-10 10-20 20-25 25-50 50-61	sand, silt sand, silt, gravel sand, silt sand, silt, gravel yellow silt, clay, trace of sand
156	24-16524	Washington	15	0-29 29-125	overburden granite
157	24-15090	Washington	100	0-10 10-20 20-28 28-82	sand, clay gravel clay gravel, broken stone
158	24-17634	Washington	9	0-5 5-20 20-120	clay sandy clay granite
159	24-8554	Washington	25	0-26 26-120	overburden, boulders gray granite
160	24-1562	Washington	10	0-40 40-73	clay, boulders limestone
161	24-19193	Washington	15	0-55 55-75	clay, silt limestone
162	24-18427	Washington	none reported	0-40 40-75 75-165	clay, sand sandstone granite
163	24-5838	Washington	none reported	0-5 5-25 25-50 50-70	overburden sand, gravel clay, mud gravel, rotten shale
164	24-2808	Washington	16	0-126 126-146	clay, boulders, hardpan sandstone rock
165	24-17697	Washington	25	0-15 15-75	clay, boulder granite
166	24-17318	Washington	50	0-10 10-50 50-70	sandy clay, boulders sandy clay brown shale
167	24-18099	Washington	15	0-35 35-91 91-148	sandy hardpan brown shale gray slate
168	24-15931	Washington	6	0-30 30-50 50-325	clay shale slate
169	24-17656	Washington	14	0-69 69-198	clay, shale, sand slate
170	24-11116	Washington	2	0-28 28-260 260 260-273	clay, gravel, mixed gray shale water shale
171	24-13187	Washington	6	0-8 8-165	overburden shale
172	24-15998	Washington	10	0-200 200-250	clay limestone, shale
173	24-17636	Washington	15	0-51 51-145	clay, sand granite
174	24-16554	Washington	3.5	0-54 54-248	yellow hardpan granite
175	24-4158	Washington	2	0-20 20-54 54-230	clay clay, traces of sand rotten limestone
176	24-18389	Washington	20	0-95 95-170	overburden limestone
177	24-16900	Washington	15	0-5 5-15 15-200	soil hardpan shale
178	24-15589	Washington	27	0-45 45-198	clay gray shale
179	24-8679	Washington	20	0-80 80-105	overburden, gravel, water, clay limestone
180	24-11588	Washington	none reported	0-70 70-350	boulders, clay, gravel limestone
181	24-8198	Washington	0 (dry)	0-200	brown granite, gray granite
182	24-8261	Washington	none reported	0-87 87-345	yellow clay, stones limestone
183	24-1718	Washington	4	0-84	yellow clay and boulders, water in gravel
184	24-5945	Washington	15	0-40 40-70 70-240 240-260	yellow clayey micaceous soil buff clay, sand clay and sand mylonite
185	24-1462	Washington	2	0-25 25-44	clay limestone
186	24-15687	Washington	100	0-10 10-12 12-50 50-440	clay with broken boulders boulders boulders, broken rock & clay limestone
187	24-6820	Washington	45	0-32 32-248	overburden limestone
188	24-320	Washington	30	0-90 90-100 100-223 223-240 240-264	clay clay, limestone black rock black rock, mixed with rotten brown rock granite rock
189	24-6807	Washington	30	0-20 20-115	overburden limestone
190	24-11136	Washington	15	0-70 70-260	overburden limestone
191	24-5771	Washington	4.5	0-22 22-262	clay hard limestone
192	24-8275	Washington	9	0-28 28-173 173-178 178-198	overburden limestone soft seam limestone
193	24-15429	Washington	20	0-53 53-60 60-79 79-90	overburden with clay, boulders limestone clay, limestone, void limestone with clay, water
194	24-1570	Washington	2	0-16 16-160	hardpan limestone
195	24-18518	Washington	50	0-10 10-95 95-198	clay broken limestone limestone
196	24-21634	Hackettstown	none reported	0-44 44-166 166-198	brown clay, sand, gravel brown and gray soft sandstone granite
197	24-15866	Hackettstown	22	0-144 144-198	clay, sand, gravel granite
198	24-8063	Hackettstown	none reported	0-35 35-137 137-146 146-149 149-167 167-207	clay, gravel, stumps, some water gray clay, sand, large gravel sandstone clay seam rotten sandstone granite
199	24-05582	Hackettstown	230	0-60 60-80 80-86 86-160 160-173	clay, boulders dirty sand, gravel boulder or ledge rock decayed limestone soft and hard layers of limestone
200	24-13972	Hackettstown	20	0-11 11-25 25-28 28-90 90-95 95-175	overburden, boulders sand, gravel, boulders boulders sand, gravel, boulders rotten limestone, clay limestone
201	24-6997	Hackettstown	400	0-10 10-24 24-30 30-42 42-57 57-58	clay, rocks sand, gravel sand yellow clay with stones rotten limestone hard limestone
202	24-23071	Hackettstown	6	0-130 130-160	clay broken rock, limestone
203	24-16846	Easton	20	0-130 130-361	clay, gravel limestone
204	24-15070	Easton	20	0-8 8-120 120-160 160-195 195-250	brown soil brown rock, soil mix light shattered limestone gray clay light limestone
205	24-18366	Easton	12	0-120 120-235	clay, sand, gravel limestone
206	24-16111	Easton	18	0-200 200-268	clay limestone
207	24-17648	Easton	30	0-80 80-100	clay limestone
208	24-14798	Easton	3	0-30 30-92 92-136 136-350	brown rock, soil mix brown clay gray clay blue granite
209	24-15424	Easton	50	0-35 35-180 180-278 278-310	brown soil brown loam soil mixture gray clay white and gray granite
210	24-17218	Easton	30	0-130 130-200	sand, gravel, clay limestone
211	24-15644	Easton	15	0-22 22-80 80-150 150-225	brown soil brown clay light brown shattered limestone limestone
212	24-16015	Easton	4	0-25 25-400	clay limestone, gray
213	24-15838	Easton	12	0-18 18-205 205-240 240-255	brown soil brown clay brown soil, rock mix light limestone
214	24-15009	Easton	25	0-15 15-22 22-42 42-76 76-150	brown soil sand, gravel brown clay sand, gravel gray granite
215	24-17116	Easton	6	0-50 50-185	clay, sand gravel
216	24-6549	Easton	300	0-10 10-25 25-60 60-84 84-87	boulders, sand, clay sand, silt, coarse gravel, boulders sand, gravel fine to coarse sand sand, clay, stones
217	24-8913	Easton	10	0-5 5-25 25-50 50-60	sandy loam sand, gravel sand, gravel, rock fragments rock
218	24-15149	Easton	10	0-12 12-65 65-82 82-142 142-250	brown soil brown clay light shattered limestone gray clay blue limestone
219	24-15205	Easton	20	0-30 30-90 90-170 170-258	brown clay gray clay mixture rock clay mixture light gray limestone
220	24-21448	Easton	none reported	0-5 5-11 11-50	silty clay, fine sand, fine gravel fractured limestone limestone
221	24-21433	Easton	none reported	0-22 22-65 65-100 100-114 114-152 152-173	clay limestone clay, gravel limestone clay limestone
222	24-15132	Easton	none reported	0-6 6-12 12-41.5	fill medium to fine sand, some medium gravel medium brown sand, gravel
223	24-15616	Easton	20	0-12 12-62 62-105 105-122 122-225	brown soil gray clay soil and rock mixture shattered limestone blue limestone
224	24-17161	Easton	12	0-60 60-200	overburden limestone
225	24-15452	Easton	35	0-80 80-90 90-340	clay broken limestone limestone
226	24-1172	Easton	10	0-87	clay, gravel formation
227	24-13907	Easton	20	0-60 60-110 110-185 185-200 200-208	brown clay brown sand, gravel clay, gray brown sand, gravel brown sandstone
228	24-13341	Easton	30	0-170 170-204	clay broken limestone
229	24-15250	Easton	10	0-150 150-185	clay limestone, shale
230	24-15468	Easton	20	0-6 6-60 60-82 82-175	brown soil brown clay soil, rock mix light limestone
231	24-16287	Bloomsbury	7.5	0-15 15-30 30-205	clay, sand sandstone granite
232	24-15310	Bloomsbury	60	0-35 35-130 130-185	sand, clay broken limestone limestone
233	24-9299	Bloomsbury	6	0-258	yellow clay and limestone
234	24-17383	Bloomsbury	15	0-30 30-60 60-145	gravel broken limestone limestone
235	24-12171	Bloomsbury	12	0-72 72-148	clay, hardpan gray granite
236	24-17715	Bloomsbury	10	0-40 40-75 75-205	sand, clay sandstone granite
237	24-15519	Bloomsbury	5	0-80 80-158 158-225	brown soil, rock sand, soil mix gray granite
238	24-14902	Bloomsbury	1	0-15 15-45 45-325	brown soil mixture brown mixture of clay gray granite
239	24-15375	Bloomsbury	20	0-40 40-140 140-228	clay broken limestone limestone
240	24-17803	Bloomsbury	20	0-30 30-180 180-208	clay broken limestone limestone
241	24-14982	Bloomsbury	20	0-65 65-145 145-197	clay broken limestone limestone
242	24-15417	Bloomsbury	30	0-80 80-150	overburden broken limestone
243	24-16331	Bloomsbury	40	0-75 75-100 100-166	clay broken limestone limestone
244	24-15225	Bloomsbury	10	0-30 30-85 85-118 118-250	light brown loam soil sand, gravel brown clay granite
245	24-17831	Bloomsbury	20	0-80 80-125	clay limestone
246	24-15055	Bloomsbury	10	0-30 30-95 95-188	sand, clay sandstone granite
247	24-17216	Bloomsbury	30	0-100 100-139 139-140	clay sand, gravel decomposed limestone
248	24-8906	Bloomsbury	1.5	0-10 10-500	overburden limestone
249	24-15002	Bloomsbury	50	0-125 125-130	clay, limestone decomposed limestone
250	24-10021	Bloomsbury	10	0-60 60-250	overburden limestone
251	24-14122	Bloomsbury	25	0-50 50-175	sand, clay sandstone
252	24-16634	Bloomsbury	20	0-40 40-200	clay limestone
253	24-15283	Bloomsbury	30	0-100 100-200	clay broken limestone
254	24-8992	Bloomsbury	15	0-75 75-99	clay, limestone limestone
255	24-9071	Bloomsbury	25	0-114	yellow clay-limestone

The interpretations presented here are provisional and may be changed pending new data. This report may be reproduced in whole or part provided that suitable reference to the source of the copied material is provided. Enlargements of maps and figures can result in erroneous interpretations.

Table 2. Pebble composition of glacial sediment in Warren County, New Jersey.

Data from Ridge (1983) except where sample number is marked with an asterisk. Also, for samples marked with an asterisk, the percentage of slate and graywacke pebbles have been totaled and listed in the slate column, and vein quartz was not counted. Data based on 100-200 pebbles collected at each site.

Sample no.	Material	Quadrangle	Percentage: Gneiss	Dolostone, limestone, and chert	Slate	Gray siltstone, and gray sandstone	Quartzite and quartz-pebble conglomerate	Red sandstone	Undifferentiated shale, sandstone, and limestone	vein quartz
1	till	Flatbrookville	0.0	0.0	14.7	19.2	47.4	18.6	0.0	0.0
2	till	Flatbrookville	0.0	0.0	12.3	1.4	68.5	13.0	4.8	0.0
3	till	Flatbrookville	0.0	0.0	43.2	4.3	46.8	5.0	0.7	0.0
4	till	Flatbrookville	0.0	0.0	15.4	26.8	42.3	15.4	0.0	0.0
5	till	Flatbrookville	0.0	0.0	21.7	4.6	58.6	11.8	3.3	0.0
6	till	Flatbrookville	0.0	0.0	43.4	0.0	50.4	6.2	0.0	0.0
7	outwash	Flatbrookville	0.0	53.2	4.0	6.5	29.0	7.3	0.0	0.0
8	till	Portland	0.0	0.0	20.7	8.9	59.3	10.4	0.7	0.0
9	till	Portland	0.0	0.0	0.7	7.5	64.6	19.7	7.5	0.0
10	till	Portland	0.0	0.0	29.9	12.1	42.7	13.4	1.9	0.0
11	outwash	Portland	0.0	0.6	40.8	12.1	40.2	6.3	0.0	0.0
12	till	Portland	0.0	0.0	33.3	8.9	47.2	7.3	3.3	0.0
13	outwash	Portland	0.0	0.0	42.2	14.1	32.8	9.4	0.8	0.8
14	outwash	Portland	0.0	32.8	16.8	12.2	32.1	6.1	0.0	0.0
15	outwash	Portland	0.0	44.1	19.2	13.6	14.1	8.5	0.6	0.0
16	outwash	Portland	0.0	0.0	6.3	10.4	70.8	9.4	3.1	0.0
17	outwash	Portland	0.0	3.9	44.8	7.8	36.4	6.5	0.6	0.0
18	outwash	Portland	0.0	40.1	21.1	4.9	26.8	7.0	0.0	0.0
19	outwash	Portland	0.0	3.4	63.5	4.1	24.1	4.8	0.0	0.0
20	outwash	Portland	0.0	44.9	21.3	5.5	24.4	3.1	0.0	0.8
21	outwash	Portland	0.0	0.0	1.4	3.4	41.9	9.5	43.9	0.0
22	outwash	Portland	0.0	0.0	0.0	4.9	41.5	19.0	33.8	0.7
23	outwash	Portland	0.0	0.0	11.1	8.7	60.3	11.1	8.7	0.0
24	outwash	Portland	0.0	0.0	18.1	9.4	59.8	5.5	7.1	0.0
25	outwash	Portland	0.0	21.6	16.5	9.4	46.8	5.8	0.0	0.0
26	till	Portland	0.0	35.8	6.7	3.0	45.5	8.2	0.0	0.7
27	outwash	Portland	0.0	0.0	27.7	13.1	44.5	8.0	4.4	2.2
28	till	Portland	0.0	0.0	14.4	10.2	58.5	7.6	8.5	0.8
29	outwash	Portland	0.0	10.6	7.3	9.3	37.1	11.3	23.8	0.7
30	outwash	Portland	0.0	0.0	8.6	9.9	43.0	10.6	27.2	0.7
31	outwash	Portland	0.0	0.0	3.8	10.8	40.0	16.9	28.5	0.0
32	till	Portland	0.0	0.5	26.4	22.5	44.0	6.6	0.0	0.0
33	outwash	Blairstown	0.0	0.0	43.8	8.9	39.0	6.8	1.4	0.0
34	till	Blairstown	0.0	0.0	43.6	10.7	32.9	7.9	5.0	0.0
35	outwash	Blairstown	0.0	0.0	25.2	12.2	48.9	12.2	0.7	0.7
36	outwash	Blairstown	0.0	1.8	57.3	18.1	11.7	10.5	0.0	0.6
37	outwash	Blairstown	0.0	48.4	8.8	7.1	28.0	7.7	0.0	0.0
38	outwash	Blairstown	0.0	0.0	40.3	5.6	44.4	9.0	0.7	0.0
39	outwash	Blairstown	0.0	8.3	18.1	5.6	61.1	4.9	0.7	1.4
40	outwash	Blairstown	0.0	0.0	84.3	3.7	4.5	2.2	0.7	4.5
41	outwash	Blairstown	0.0	0.0	30.6	4.8	52.4	3.4	3.4	5.4
42	outwash	Blairstown	5.6	89.6	2.1	2.8	0.0	0.0	0.0	0.0
43	till	Blairstown	56.0	3.8	9.4	13.2	14.5	3.1	0.0	0.0
44	till	Blairstown	13.4	56.0	13.4	9.0	6.0	0.7	0.0	1.5
45	till	Blairstown	17.9	35.0	11.4	17.1	16.3	0.0	0.0	2.4
46*	till	Tranquility	12.5	75.8	11.7		0.0	0.0	0.0	
47*	outwash	Tranquility	44.4	8.9	46.7		0.0	0.0	0.0	
48	till	Tranquility	0.0	58.3	22.3	5.7	9.5	1.9	0.0	2.4
49	outwash	Tranquility	0.0	49.6	41.5	4.1	3.3	0.8	0.0	0.8
50	outwash	Tranquility	0.0	48.1	39.8	5.3	4.5	0.8	0.0	1.5
51*	till	Tranquility	0.0	87.7	10.7		1.6	0.0	0.0	
52	outwash	Tranquility	0.0	90.3	3.7	3.7	2.2	0.0	0.0	0.0
53	outwash	Tranquility	4.3	88.9	3.7	1.9	1.2	0.0	0.0	0.0
54*	till	Tranquility	55.2	33.2	11.6		0.0	0.0	0.0	
55*	till	Tranquility	00.0	87.7	10.7		1.6	0.0	0.0	
56	till	Tranquility	0.9	95.5	1.8	0.0	1.8	0.0	0.0	0.0
57*	till	Tranquility	63.0	20.8	16.3		0.0	0.0	0.0	
58*	till	Tranquility	12.5	59.2	30.9		0.7	0.0	0.0	
59*	outwash	Tranquility	0.0	78.1	18.0		3.9	0.0	0.0	
60*	outwash	Tranquility	7.7	86.2	6.0		0.0	0.0	0.0	
61*	outwash	Tranquility	24.1	22.1	48.3		5.5	0.0	0.0	
62	outwash	Bangor	7.0	41.3	16.1	13.2	15.7	4.1	0.0	2.5
63	outwash	Bangor	10.2	50.5	5.4	14.0	12.4	7.0	0.0	0.5
64	outwash	Bangor	15.8	27.3	15.1	8.6	25.2	3.6	0.7	3.6
65	outwash	Belvidere	0.0	17.9	47.0	6.7	20.9	1.5	0.0	6.0
66	till	Belvidere	0.0	73.7	5.3	4.4	14.9	1.8	0.0	0.0
67	outwash	Belvidere	0.0	47.2	19.2	1.6	28.0	4.0	0.0	0.0
68	outwash	Belvidere	0.0	11.4	65.2	5.3	12.1	2.3	0.0	3.8
69	till	Belvidere	38.8	18.4	5.9	11.2	22.4	3.3	0.0	0.0
70	outwash	Belvidere	2.3	40.6	18.3	8.6	24.6	5.7	0.0	0.0
71	outwash	Belvidere	3.4	23.5	32.5	12.0	22.6	6.0	0.0	0.0
72	outwash	Belvidere	0.0	19.8	44.4	6.8	22.8	3.7	1.2	1.2
73	outwash	Belvidere	0.0	1.5	65.6	3.8	19.8	4.6	2.3	2.3
74	outwash	Belvidere	0.0	14.5	55.9	5.3	15.4	5.7	2.2	0.9
75	outwash	Belvidere	15.2	57.6	6.0	7.3	11.3	2.0	0.0	0.7
76	outwash	Belvidere	6.4	82.9	3.6	0.7	4.3	1.4	0.0	0.7
77	outwash	Belvidere	9.3	78.6	2.1	3.6	4.3	1.4	0.0	0.7
78	outwash	Belvidere	14.1	64.8	9.6	3.8	5.1	0.6	0.0	1.9
79	outwash	Belvidere	11.3	66.2	9.3	6.6	6.0	0.0	0.0	0.7
80	till	Belvidere	62.7	5.5	0.9	2.7	25.5	1.8	0.0	0.9
81	outwash	Belvidere	12.4	35.8	26.3	3.6	16.1	3.6	0.0	2.2
82	outwash	Belvidere	0.6	33.1	24.7	11.2	24.2	3.4	0.6	2.2
83	outwash	Belvidere	0.7	23.7	31.7	11.5	23.7	6.5	0.0	2.2
84	outwash	Belvidere	0.0	27.6	41.2	5.9	17.6	2.4	0.0	5.3
85	outwash	Belvidere	4.3	40.4	24.1	4.3	18.4	6.4	0.0	2.1
86	outwash	Belvidere	1.4	30.1	23.1	9.1	30.1	4.2	0.0	2.1
87	outwash	Belvidere	15.0	20.5	8.7	19.7	29.9	3.9	0.8	1.6
88	outwash	Belvidere	2.5	25.9	22.2	16.7	21.0	8.6	1.2	1.9
89	outwash	Belvidere	1.0	49.5	14.6	12.0	18.2	3.1	1.0	0.5
90	outwash	Belvidere	10.5	50.6	19.8	2.9	13.4	0.6	0.0	2.3
91	outwash	Belvidere	5.9	45.9	13.3	5.2	23.7	5.2	0.0	0.7
92	outwash	Belvidere	66.4	7.5	3.7	9.0	0.7	0.0	0.0	12.7
93	outwash	Belvidere	0.6	35.7	10.5	17.5	28.1	2.9	1.8	2.9
94	outwash	Belvidere	7.7	59.0	7.2	7.7	14.9	2.1	1.0	0.5
95	outwash	Belvidere	4.8	37.5	15.5	17.3	16.7	7.1	0.6	0.6
96	outwash	Belvidere	0.6	50.6	14.0	11.8	18.0	2.2	0.6	2.2
97	outwash	Belvidere	10.5	34.2	24.7	10.5	12.6	4.2	1.1	2.1
98	outwash	Belvidere	17.2	51.4	16.0	3.0	10.1	1.2	0.0	1.2
99	outwash	Washington	0.0	66.9	8.5	5.4	16.2	0.8	0.0	2.3
100	till	Washington	27.7	3.4	27.1	18.6	21.5	1.1	0.0	0.6
101	till	Washington	26.9	3.6	45.5	6.6	9.0	6.0	0.6	1.8
102	outwash	Washington	10.6	80.1	5.3	0.0	3.3	0.0	0.0	0.7
103	till	Washington	38.6	21.1	16.3	10.8	8.4	4.2	0.0	0.6
104	outwash	Washington	35.8	43.1	7.3	2.9	6.6	2.9	0.0	1.5
105	outwash	Washington	18.3	69.2	5.9	3.0	1.8	1.2	0.0	0.6
106	outwsh	Washington	14.2	81.1	2.0	0.7	2.0	0.0	0.0	0.0
107	outwash	Washington	4.6	83.0	5.9	3.3	2.6	0.7	0.0	0.0
108	outwash	Washington	8.3	73.6	9.0	2.8	4.9	1.4	0.0	0.0
109	till	Washington	11.3	66.9	6.8	8.3	4.5	2.3	0.0	0.0
110	till	Washington	20.5	53.0	6.0	12.6	6.6	1.3	0.0	0.0
111	till	Washington	24.7	57.2	4.2	4.7	7.9	0.5	0.0	0.9
112	till	Washington	24.6	7.9	9.6	7.0	44.7	3.5	0.0	2.6
113	till	Washington	15.3	54.1	3.1	14.5	6.1	3.1	0.8	3.1
114	till	Washington	56.2	5.6	11.1	5.6	16.7	3.5	0.0	1.4
115	till	Washington	14.0	5.8	24.6	28.7	26.9	0.0	0.0	0.0
116	outwash	Washington	31.4	7.5	11.9	23.9	19.9	4.9	0.4	0.0
117	outwash	Washington	17.1	62.9	5.3	4.1	8.8	0.6	0.0	1.2
118	outwash	Washington	59.3	4.3	5.9	9.1	1.6	0.0	0.0	19.8
119	outwash	Washington	19.8	67.8	3.3	1.7	6.6	0.0	0.0	0.8
120	outwash	Washington	11.0	72.6	3.7	6.4	5.9	0.0	0.5	0.0
120	outwash	Washington	6.4	82.9	3.6	0.7	4.3	1.4	0.0	0.7
121	till	Hackettstown	32.6	5.2	32.1	17.6	8.8	3.1	0.0	0.5
122*	outwash	Hackettstown	0.0	92.6	7.4		0.0	0.0	0.0	
123	till	Hackettstown	18.3	62.7	8.9	4.1	3.6	1.2	0.0	1.2
124*	outwash	Hackettstown	28.9	28.9	40.7		1.5	0.0	0.0	
125*	outwash	Hackettstown	0.0	87.0	10.4		2.6	0.0	0.0	
126*	outwash	Hackettstown	64.9	24.7	9.0		1.3	0.0	0.0	
127*	outwash	Hackettstown	87.0	2.5	10.4		0.0	0.0	0.0	