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INTRODUCTION

The Lambertville and Pennington quadrangles are in the Newark Basin geologic province in central New Jersey. Bedrock in the map area includes shale, mudstone, and sandstone, and intrusive diabase, of Triassic and Jurassic age. The rocks are faulted, locally folded, and generally dip to the northwest at 10° to 20° (Owens and others, 1998). Surficial sediments include fluvial, hillslope, and windblown deposits and weathered rock material. They are situated in a landscape shaped within the past 10 million years by two main periods of river incision and valley deepening, followed by several periods of cold climate alternating with warm intervals.

The accompanying map and sections show the surface extent and subsurface relations of the surficial deposits. The composition and thickness of the deposits are described in the *Description of Map Units*. Table 1 lists the thickness and stratigraphy of surficial materials as inferred from records of wells and test borings. The chronologic relationships of the deposits and episodes of erosion are shown in the *Correlation of Map Units*. The hydrology and resource potential of the surficial deposits and the history of erosional and depositional events in the quadrangle are briefly described in the two following sections.

RESOURCES AND HYDROLOGIC PROPERTIES

The late Wisconsinan glaciofluvial deposit (unit Qwf), granular coarse sand from weathering of arkose (within Qws), and gravel beds in the Pensauken Formation (Tp), are permeable materials that transmit groundwater. Aquifer-test and laboratory data on similar materials in New Jersey indicate hydraulic conductivities of 10^1 to 10^3 feet/day (ft/d) (Mennel and Canace, 2002). None of these materials are more than 50 feet thick within the map area, and the permeable zones in units Tp and Qws are thin and of small extent. They are not considered aquifers, but they store water for, and transmit water between, bedrock aquifers and surface streams. The other surficial materials in the map area are of low permeability and generally impede infiltration and flow of water. Materials with a silty, clayey silt, or sandy clayey silt matrix likely have hydraulic conductivities of 10^{-5} to 10^{-3} ft/d. In places, however, they may be more permeable than the underlying bedrock. For example, coarser granular zones within weathered diabase (Qwd) and diabase colluvium (Qcd) are more permeable than diabase bedrock. Also, gravels in alluvium (Qal) and lower terrace deposits (Qtl) typically are more permeable than shale and mudstone. Sand beds within the postglacial stream terrace deposit (Qst) are also moderately permeable. These sandier or gravelly materials likely have hydraulic conductivities of 10^{-3} to 10^{-1} ft/d. Although the alluvial and terrace deposits are too thin to store significant volumes of water, they may store and transmit groundwater on top of the bedrock surface, discharging the water in seeps on footslopes and into streams in valley bottoms.

Sand and gravel was formerly dug from unit Qwf in pits south of Lambertville and in New Hope, Pennsylvania. These pits are inactive. Although a large volume of sand and gravel remains, further extraction is impractical due to residential land use on the deposit. Sand and gravel are also available from the Pensauken Formation (Tp), but the deep weathering of this deposit may form clay and soft, decomposed gravel clasts that hinder usability. Also, the outcrop of the Pensauken in the map area is fully urbanized. Large diabase boulders within units Qwd, Qcd, and Qalb, primarily in the central and southern belts of the diabase outcrop belt on Sourland Mountain, were quarried for building stone, as evidenced by drill holes and extracted blocks still visible today. Silty fine sand eolian deposits (Qes) in the Delaware Valley between Scudders Falls and Wilburtha, exposed during quarrying of the underlying sandstone, were dug in the early 20th century for molding sand (Kummel, 1905). Eolian silt (Qel) on the Pensauken Formation in the West Trenton-Fernwood area, and elsewhere northward to Pennington, was dug for brick clay (Ries and Kummel, 1904).

GEOMORPHIC HISTORY

The oldest landscape feature in the map area is the flat to gently sloping summits of Sourland Mountain, and, to a lesser extent, Baldpate Mountain and the sandstone ridge to its northeast (erosion surface 1 on fig. 1). This upland surface, which in the map area cuts across diabase, hornfels, mudstone, and sandstone bedrock dipping between 10° and 25° to the northwest, is part of a regional low-relief erosion surface, termed the "Schooley peneplain" by Davis and Wood (1889), and "Kittatinny base level" by Salisbury (1898). This surface was thought to be the product of fluvial erosion during an extended period of stable base level, and then preserved as upland remnants on resistant rock during later fluvial incision as base level lowered. This view fell into disfavor in the latter half of the twentieth century, in part because it had been widely and, in some cases, uncritically, applied to broad regions and different geologic settings. More recently, improved records of past global sea level (for example, Hansen and others, 2013) and regional tectonic deformations (for example, Liu, 2014) indicate that stepwise drops in sea level and tectonic uplift within the past 30 million years provide the conditions to produce and incise planation surfaces in the Mid-Atlantic coastal region. These observations, and the age of fluvial and marine deposits in the Coastal Plain related to the upland surface, suggest that the surface reached its final form in the middle to late Miocene (15-10 Ma (Ma = million years ago)) and was dissected into the remnants seen today by incision in the late Miocene (10-5 Ma) (Stanford and others, 2001). This incision occurred in response to a combination of global lowering of sea level and regional tectonic uplift. By the early Pliocene, the Delaware River and its tributaries were established in their present valleys and the southern part of the map area had been eroded to a lowland (erosion surface 2 on fig. 1). These valleys and lowlands are about 300 feet below erosion surface 1. While erosion on moderate to gentle slopes has continuously modified the upland surface, it has done so at a rate much slower than in the valleys, preserving the general form, if not the details, of the surface.

The oldest remaining surficial deposit in the map area is the Pensauken Formation (Tp). It is a fluvial sand and gravel of Pliocene to early Pleistocene age that forms a dissected plain in the southeastern part of the map area. Rare pebbles and cobbles of rounded gray and white quartz and quartzite on erosion surface 2 north of the Pensauken plain are remnants from an even older fluvial deposit of late Miocene age. These are covered by eolian silt in places. Some of the cobbles have a brown weathering varnish from long surface exposure. This late Miocene deposit, which may correlate to the Bridgeton Formation in southern New Jersey (Salisbury and Knapp, 1917; Stanford, 2010), formerly mantled the lowland. Its base is above 220 feet in elevation. A similar gravel younger than that on erosion surface 2 but older than the Pensauken is present above an elevation of 160 to 180 feet southeast of the map area near Yardley, Pennsylvania ("pre-Illinoian gravel" of Peltier, 1959; "Upland Gravel" of Owens and Minard, 1975).

The southeast corner of the map area includes the northwest edge of the Pensauken fluvial plain, which is about 12 miles wide in central New Jersey. The Pensauken Formation was deposited by a large river that flowed southwestward along the inner edge of the Coastal Plain from the New York City area to the Delmarva Peninsula. The Pensauken River included precursors of the Hudson and Raritan rivers, and rivers from southern New England (Owens and Minard, 1979; Stanford, 2010). The Delaware River was a tributary to the Pensauken River, joining the plain south of West Trenton. The base of the Pensauken Formation in the map area ranges from an elevation of about 90 feet in the southeastern corner to 120 feet at its northwest limit, where it terminates at a gradual 20- to 60-foot tall scarp cut into bedrock (fig. 1). The original aggradation level of the Pensauken in the map area was about 130 to 140 feet. Now, due to erosion, the top of the Pensauken is generally between 110 and 130 feet.

In the Delaware trunk valley, the Pensauken plain traces to a series of rock-cut benches (shown by pattern on the geologic map) on the New Jersey side of the valley) between 120 and 140 feet in elevation. The most prominent of these is at Titusville, between Baldpate Mountain and Church Road, where rounded pebbles, cobbles, and a few boulders, of quartz, quartzite, quartzite-conglomerate, chert, and weathered sandstone are on the surface and mixed into the upper several feet of weathered shale. These clasts also occur on rock benches at similar elevation at several places on the Pennsylvania side of the valley (Peltier, 1959). In the Scudders Falls-West Trenton area, these benches widen and merge into the rock surface which passes beneath the Pensauken at an elevation of about 100 feet. This indicates that the benches and gravel lags are contemporaneous with cutting and aggradation of the Pensauken valley.

The Pensauken Formation is of Pliocene to early Pleistocene age because it is deeply inset into middle-to-late Miocene deposits in the Coastal Plain, is overlain by early Pleistocene till near Somerville in central New Jersey, and contains pollen with some pre-Pleistocene taxa (Stanford and others, 2001). The Pensauken plain probably aggraded during a global highstand of sea level in the middle Pliocene around 3.5 Ma. During an early Pleistocene glaciation, sometime between 2.5 Ma and 800 ka (ka = thousand years ago), the Pensauken River was diverted southeastward to the Atlantic Ocean in the New York City area. At the time of diversion, the plain was abandoned by the Pensauken River and a new local drainage network began forming on the plain.

Before the diversion the Pensauken plain was stable for 1 to 2 million years. During this time, the Delaware River and other local streams could not deepen their valleys below the level of the plain. Instead, valleys were widened by stream and hillslope erosion. On shale, this widening removed almost all of the late Miocene gravel on erosion surface 2, and wore most of that surface to a lower elevation. In the Delaware trunk valley, the widened valleys are marked today by the rock benches described above, and by gently sloping pediments, 50 to 100 feet above the modern valley bottom, on the sides of some tributary valleys. Some of these pediments are mantled with colluvium. These include the pediments capped by diabase colluvium around the foot of Baldpate Mountain and small pediments capped by mudstone colluvium on the north side of the Moores Creek valley.

Glacial diversion of the Pensauken River was followed by an extended period of lowered sea level through the Quaternary (2.5 Ma to present). The lowered sea level allowed rivers to downcut into the Pensauken plain, the rock benches and pediments, and erosion surface 2, forming the modern valley network. Incision down to the present valley bottoms was completed by the time of Illinoian glaciation at about 150 ka based on glaciofluvial deposits of Illinoian age being close to the modern valley bottom in the Delaware trunk valley both upstream of the map area and downstream in the Trenton area (Stanford and others, 2016). These have not been observed in the map area.

During the late Wisconsinan glaciation, ice advanced into the Delaware River basin at about 28 ka and reached its terminal position in the Belvidere area (40 miles upstream of Lambertville) by 25 ka. This is consistent with a radiocarbon date of 23,680±120 yrs BP (Beta 354600) (27.7-27.9 calibrated ka, using the calibration of Reimer and others [2013] with one sigma error) on fine organic matter in silt at a depth of 15 feet beneath pebbly sand in the glaciofluvial deposit near Belle Mountain (fig. 1). The dated sample was from fine sediment along the side of the valley. The silt was laid down before deposition of overlying pebbly glaciofluvial sand and thus dates the early stage of aggradation of the glaciofluvial deposit. The glacier began to retreat from its terminal position at about 25 ka, and had retreated from the Delaware basin by 18 ka (Stanford and others, 2016). The glaciofluvial deposit (Qwf) was laid down between 28 and 18 ka, while the glacier was in the basin.

After the glacier retreated from the basin the Delaware River cut down as much as 60 feet into the glaciofluvial plain. This incision formed the present floodplain. Radiocarbon dates from postglacial alluvial deposits along the river, mostly at archeologic sites north of the map area, indicate that downcutting was largely completed by 12 ka (Stanford and others, 2016). Since then the river has laid down sand and silt on the overbank area of the floodplain to form the postglacial stream-terrace deposit (Qst). These sediments accrete vertically during floods. Most of the terrace is within the 100-year floodplain, so sediment still accretes during floods.

In the Moores Creek, Jacobs Creek, Shabakunk Creek, and Stony Brook basins, floodplains aggraded during the late Wisconsinan to form what are today lower terraces (Qtl). This aggradation occurred because more sediment washed into valleys during the period of cold climate in the late Wisconsinan. Tundra replaced forest, reducing the stabilizing effect of tree roots, and permafrost impeded infiltration of water, increasing runoff and seepage. Aggradation also occurred where valleys drained into the Delaware trunk valley and build-up of the glaciofluvial deposit and, later, the postglacial stream-terrace deposit, raised the base level at the mouth of tributary valleys. In places, particularly in the Stony Brook and Shabakunk Creek basins, the lower terraces are only slightly higher than the active floodplain and are partly inundated during floods. In these settings, fine sediment still accumulates on the terrace. For example, charcoal at a depth of 6 feet in the lower terrace near Pennington (fig. 1) dates to 590±30 yrs BP (Beta 470438) (580-650 calibrated years, using the calibration of Reimer and others [2013] with one sigma error). This indicates that the overlying fine sand and silt there were laid down within the past 600 years. Here, the lower terrace surface is only a couple of feet higher than the highest overbank surfaces of the active floodplain.

Weathered rock material on hillslopes became mobile during periods of cold climate, again because of the loss of tree-root stability and increased water retention in the sediment. Some of this material moved downslope and collected in aprons on footslopes, forming colluvium (Qcd, Qcs). This occurred during the late Wisconsinan and earlier periods of cold climate. In a few places, older, weathered colluvium of pre-Wisconsinan age underlies less-weathered surface colluvium of Wisconsinan age. In the Delaware trunk valley, colluvium is interbedded with late Wisconsinan glaciofluvial gravel along the valley wall, indicating that the colluvium is partly of late Wisconsinan age. On some gently sloping footslopes, particularly on diabase bedrock on Sourland Mountain, the colluvium consists largely of silt, clay, and sand mobilized by seepage rather than mass movement. This sediment is interspersed with boulder and cobble lags.

In places, hillslopes continue to erode up to the present due to human land clearing, forest fires, or streambank erosion into footslopes. Radiocarbon dates of 3,882±47 yrs BP (GX 17277 AMS) (4.25-4.41 calibrated ka using the calibration of Reimer and others [2013] with one sigma error) and 6,040±30 yrs BP (Beta 470439) (6.81-6.94 calibrated ka) on charcoal from an organic clayey silt bed beneath 6 feet of colluvium along Moores Creek (fig. 1) indicate deposition of the colluvium there within the past 4 ka, perhaps in response to bank erosion by Moores Creek. The organic clay contains pollen and spores of aquatic taxa like reeds, rushes, algae, and alder, and tree pollen including pine, hemlock, birch, hickory, oak, ash, and blackgum (L. A. Sirkin, written communication, 1990). The clay and overlying colluvium may record ponding of the valley, either from beaver damming or in response to aggradation of the postglacial terrace deposit in the main Delaware Valley just downstream, between 7 and 4 ka, followed by downcutting and bank erosion after 4 ka.

In the Delaware trunk valley at Titusville and south, winds from the west blew sand and silt from the glaciofluvial plain, and perhaps, later, from the postglacial terrace, onto the adjoining valley-side slope, where they form a thin blanket on the shale bedrock (Qes). This deposition most likely occurred during the late Wisconsinan glaciation, while the plain was aggrading and unvegetated. The widespread eolian silt farther east (Qel) may also be partly from the Delaware trunk valley (Tedrow and MacClintock, 1953), but its distribution, most continuous adjacent to the Pensauken Formation and above 200 feet in elevation, suggests that much of it was blown from the Pensauken plain in the Pliocene and early Pleistocene (Stanford, 1993).

Warming climate caused permafrost to melt and forests to regrow by 14 ka. Hillslopes stabilized and less sediment washed into valleys. Streams have since incised between 5 and 20 feet into the valley-bottom sediment, forming present-day floodplains and leaving the older sediments as terraces. The older alluvial sediments were completely eroded in most tributary valleys, especially where the valleys are narrow. Alluvium (Qal), consisting of thin channel gravel overlain by overbank silt, clay, and fine sand, was deposited on the floodplains. Where steep streams emptied into valleys, they laid down small alluvial fans of gravel (Qaf). In headwater valleys, seepage eroded colluvium, forming gullies, depositing silt, clay, sand, and gravel in places (Qcal), and leaving boulder lags on diabase bedrock (Qalb). These processes continue today.

DESCRIPTION OF MAP UNITS

ARTIFICIAL FILL—Artificially emplaced sand, gravel, silt, clay, and rock fragments, and human-made materials including cinders, ash, brick, concrete, wood, slag, asphalt, metal, glass, and trash. Color variable but generally brown, gray, or black. In highway, canal, runway, and railroad fills, dams, and waste-rock or waste-soil disposal piles. As much as 20 feet thick. Many small areas of fill, particularly along streams in urban areas, are not mapped.

Qal ALLUVIUM—Silt, clay, fine sand, pebble-to-cobble gravel, minor boulder gravel. Color of fine sediment is brown, gray, reddish-brown, yellowish-brown. Moderately to well-sorted and stratified. As much as 15 feet thick. Sand is quartz and rock fragments, mostly red and gray shale. Gravel consists chiefly of subangular to subrounded chips and flagstones of red and gray shale and mudstone, with lesser amounts of subangular to subrounded pebbles and cobbles of red, brown, and gray sandstone and mudstone, and dark gray hornfels, and subrounded to rounded pebbles, cobbles, and boulders of gray diabase, and rare subrounded pebbles and cobbles of white, gray, and red quartz and quartzite. In basins containing the Pensauken Formation gravel includes subrounded to rounded pebbles of white quartz, gray and brown quartzite and quartzite-conglomerate, and black to brown chert. Along the Delaware River, gravel includes white to gray gneiss, white quartz, black chert, and white to gray quartzite and quartzite-conglomerate. Silt, clay, and fine sand are overbank deposits laid down on floodplains, primarily along gently sloping stream reaches, and are nonstratified to weakly horizontally stratified. The overbank deposits typically overlie, or interbed at depth with, channel gravel. Gravel is deposited in stream channels and is nonstratified to weakly stratified. Flagstone gravel is strongly imbricated. Gravel is the dominant deposit along steep stream reaches.

Qcal ALLUVIUM AND COLLUVIUM, UNDIVIDED—Interbedded colluvium as in units Qcd and Qcs, and alluvium consisting of dark brown, yellowish-brown, reddish-yellow, reddish-brown silty sand, sandy silt, to clayey silt, with some organic matter and beds and lag veneers of subangular to subrounded cobbles and boulders of diabase (adjacent to units Qcd and Qwd), and shale and mudstone chips and flagstones (adjacent to units Qcs and Qws). As much as 10 feet thick. Lag deposits are dominant in steeper reaches of valleys. Fine sediment, with variable organic matter, discontinuously overlies and infills lag deposits in gently sloping reaches. In some steep, narrow valleys, lags have moved downvalley to accumulate as bouldery lobes. This movement may have occurred under cold climate.

Qaf ALLUVIAL FAN DEPOSITS—Subangular shale and mudstone chip and flagstone gravel; sand, silt, minor clay; reddish-brown, gray; moderately sorted, weakly stratified. As much as 10 feet thick. Two fans are mapped in Lambertville where streams empty onto the glaciofluvial plain. Elsewhere, small fans at the mouths of steep drainages are included in units Qcal and Qal.

Qalb ALLUVIUM AND BOULDER LAG—Silt, sand, minor clay and organic matter, dark brown, brown, gray, yellowish-brown, moderately sorted, weakly stratified, overlying and alternating with surface concentrations (lags) of rounded to subrounded diabase cobbles and boulders. Formed by washing of weathered diabase and diabase colluvium by groundwater seepage and runoff. As much as 10 feet thick.

Qst POSTGLACIAL STREAM-TERRACE DEPOSIT—Fine-to-medium sand, silt, minor pebbly sand and pebble-to-cobble gravel at base; yellowish-brown, very pale brown, brown, gray. Moderately to well-sorted, weakly horizontally stratified (figs 2, 3). Gravel composition as in unit Qwf. As much as 20 feet thick. Forms a terrace in the Delaware Valley with a top surface 15 to 20 feet above the modern floodplain.

Qes EOLIAN SAND—Very fine-to-fine sand and silt, yellow, reddish-yellow, very pale brown, well-sorted, nonstratified to weakly horizontally stratified. As much as 8 feet thick, generally less than 3 feet thick. Forms a sheet on gentle slopes in the Delaware Valley. Mapped only where continuous and generally greater than 1 foot thick.

Qtl LOWER STREAM TERRACE DEPOSITS—Silt, fine-sandy silt, clayey silt; yellowish-brown, reddish-brown, light reddish-brown, gray; and pebble gravel, minor cobble gravel. Moderately to well-sorted, nonstratified to weakly horizontally stratified (fig. 4). Gravel consists of subangular chips and flagstones of red and gray shale and mudstone and a few subrounded gray diabase and gray to brown sandstone pebbles and cobbles. Some rounded white quartz and black to brown chert pebbles occur in the deposit along Shabakunk Creek, and rare white quartz pebbles occur in deposits along Stony Brook. In deposits along the lower reach of Moores Creek, there are a few pebbles and cobbles of white and gray quartzite and quartzite-conglomerate, black chert, and white to gray gneiss, derived from unit Qwf. Fine sand and silt is as much as 6 feet thick and generally overlies gravel, which is commonly less than 3 feet thick. Form stream terraces with top surfaces generally 5 to 10 feet above the modern floodplain, but as much as 20 feet above the modern floodplain near the mouth of Moores Creek.

Qwf LATE WISCONSINAN GLACIOFLUVIAL DEPOSIT—Pebble-to-cobble gravel, pebbly sand, minor boulder gravel, minor silt and fine sand (fig. 3). Sand and silt are yellowish-brown, brown, light reddish-brown, very pale brown, gray. Gravel includes, in approximate order of abundance, gray mudstone and sandstone, red mudstone and sandstone, white to gray quartzite and quartzite-conglomerate, white to gray gneiss, white quartz, black chert, gray diabase, and gray to yellow-weathering carbonate rock. Moderately to well-sorted and stratified; sand, pebbly sand, and silt are horizontally bedded to low-angle cross-bedded; gravel is massive to weakly horizontally stratified. As much as 50 feet thick. Forms an eroded plain in the Delaware Valley with a top surface about 40 feet above the modern floodplain.

Qel EOLIAN SILT—Silt, minor very fine sand, yellow, reddish-yellow, very pale brown, well-sorted, nonstratified (fig. 5). As much as 6 feet thick, generally less than 3 feet thick. Forms a sheet on flat to very gently sloping terrain on interfluves in the shale lowland south of Baldpate and Pennington Mountains. Mapped where continuous and generally greater than 1 foot thick.

Qcs SHALE, SANDSTONE, AND MUDSTONE COLLUVIUM—Silt, clayey silt, minor sandy silt; reddish-brown, gray, yellowish-brown; with some (5-10% by volume) to many (10-30%) subangular flagstones, chips, and pebbles of red and gray shale, mudstone, and minor sandstone. Poorly sorted, nonstratified to weakly stratified. Flagstones and chips have strong slope-parallel alignment of a-b planes (fig. 6). As much as 20 feet thick. Forms aprons along base of hillslopes. Deposits on gently sloping aprons are predominantly silt and are laid down by seepage and unchanneled runoff. Deposits on steeper aprons are more clast-rich and are laid down by mass movement.

Qcd DIABASE COLLUVIUM—Clayey silt to clayey sandy silt; yellowish-brown, brown, gray, reddish-yellow; with some to many subrounded cobbles and boulders of diabase, and few (<5%) to some subangular gray and red shale and mudstone chips and flagstones and dark gray hornfels pebbles and cobbles in places. Poorly sorted, nonstratified to weakly stratified (fig. 7). As much as 20 feet thick. In places, colluvium containing unweathered or lightly weathered diabase clasts overlies colluvium containing weathered diabase clasts (fig. 8), indicating at least two periods of deposition separated by a period of weathering. Forms aprons along base of hillslopes. Deposits on gentle aprons may include cobble and boulder lags formed by washing of weathered diabase by seepage and unchanneled runoff, interspersed with sandy silt laid down by the runoff. Deposits on steeper aprons are laid down by mass movement. In places, scattered diabase pebbles and cobbles occur on and within units Qws and Qel beyond the distal edge of mapped colluvium. These clasts may have been emplaced by downslope movement but some may have been moved by humans or animals.

Tp PENSAUKEN FORMATION—Fine-to-coarse sand to silty clayey sand; reddish-yellow, yellow, yellowish-brown, light gray; pebble gravel, minor pebble-to-cobble gravel. Moderately sorted, nonstratified to well-stratified, with tabular, planar cross-beds in sand. Pebble gravel occurs as thin layers (generally less than 3 inches thick) within sand and as thicker beds at the base of the formation, where it may include cobble gravel and minor boulder gravel. Sand consists mostly of quartz with some feldspar, mica, and rock fragments (chiefly shale). The feldspar and some rock fragments are partially or fully weathered to clay. Gravel consists of white quartz (typically with a yellow to reddish-yellow surface stain), white to gray quartzite, brown to gray chert, red and gray mudstone and sandstone, and minor white to gray gneiss. The sandstone, mudstone, and gneiss, and some chert, are partly weathered or fully decomposed. As much as 40 feet thick.

Qws **Qwst** WEATHERED SHALE, SANDSTONE, AND MUDSTONE—Clayey silt, silty clay, reddish-brown, gray, yellowish-brown, with some to many angular to subangular chips, flagstones, pebbles, and cobbles of red and gray shale and mudstone, and dark gray hornfels. Poorly sorted, nonstratified. On sandstone bedrock (fig. 1), locally includes white to very pale brown clayey medium-to-coarse sand and angular fine pebbles of weathered to decomposed arkose, and rounded pebbles of white quartz in places from weathering of conglomerate beds. Generally less than 10 feet thick on shale, mudstone, and hornfels. Outcrops of these rock types are common in streambeds, banks, and shallow excavations. As much as 40 feet thick on sandstone, where weathering occurs preferentially in coarse-grained arkose, and zones of unweathered rock may overlie or interbed with zones of weathered rock. **Qwst** indicates areas of steep slope where weathered material is generally less than 3 feet thick and consists chiefly of rubble.

Qwd **Qwdt** WEATHERED DIABASE—Clayey silt, sandy clayey silt, clayey silty coarse sand; brown, yellowish-brown, reddish-yellow; with few to many subangular to subrounded pebbles, cobbles, and boulders of gray diabase. Poorly sorted, nonstratified. The weathered material is sandier and has fewer cobbles and boulders where the diabase is densely jointed and coarse-grained, for example, in the upper third (more northerly part of the outcrop belt) of the Sourland Mountain sill. The weathered material is clayey and bouldery where the diabase is sparsely jointed and fine-grained, for example, in the lower two-thirds (central and southern parts of the outcrop belt) of the Sourland Mountain sill. As much as 40 feet thick. **Qwdt** indicates areas of steep slope where weathered material is generally less than 10 feet thick and consists chiefly of rubble.

MAP SYMBOLS

Contact—Solid where well-defined by landforms. Long-dashed where approximately located, short-dashed where gradational or feather-edged, dotted where removed by excavation. Some contacts of unit Qel are based on soil mapping by Jablonski (1972).

4 e3 **Material observed in hand-auger hole, exposure, or excavation—**Number, if present, indicates thickness of eolian sediment in feet. Letter "e" followed by a number indicates thickness of eolian sediment outside of mapped extent of units Qes and Qel.

figure 5 **Photograph location**

Excavation perimeter—Outlines pits and quarries.

Bedrock ridge or scarp—Line on crest of ridges or scarps parallel to strike of bedrock. Drawn from stereo aerial photography and LiDAR imagery.

Rock bench—Line on perimeter, ruling on bench. Formed by fluvial erosion in the Delaware Valley. Of Pliocene to early Pleistocene age.

Gravel lag—Pebbles and cobbles from early Pleistocene and Pliocene fluvial gravel, on and in the upper several feet of weathered shale on rock benches in the Delaware Valley at Titusville. Traces of gravel may also occur on other rock benches.

Fluvial scarp—Line at top, ticks on slope.

Sand and gravel pit—Inactive in 2017.

Quarry—Inactive in 2017.

Quarry—Active in 2017.

147 **Well with log of surficial material—**Data in table 1. Location accurate within 100 feet.

47 **Well with log of surficial material—**Data in table 1. Location accurate within 500 feet.

47 **Well on sections—**Projected to line of section.

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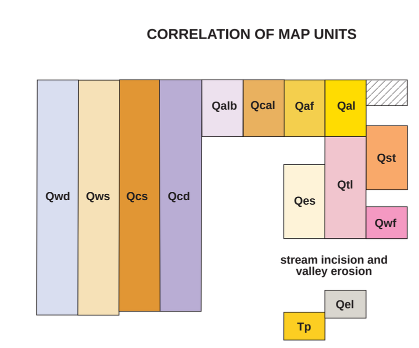


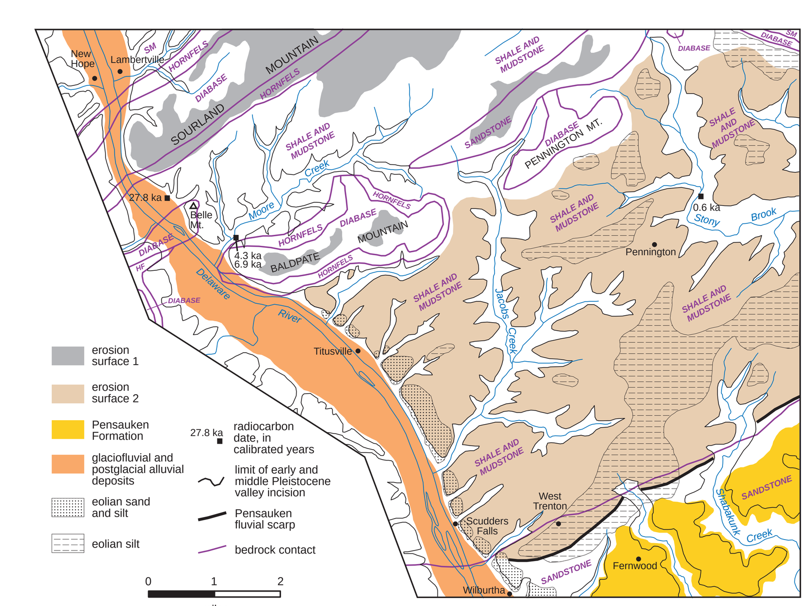
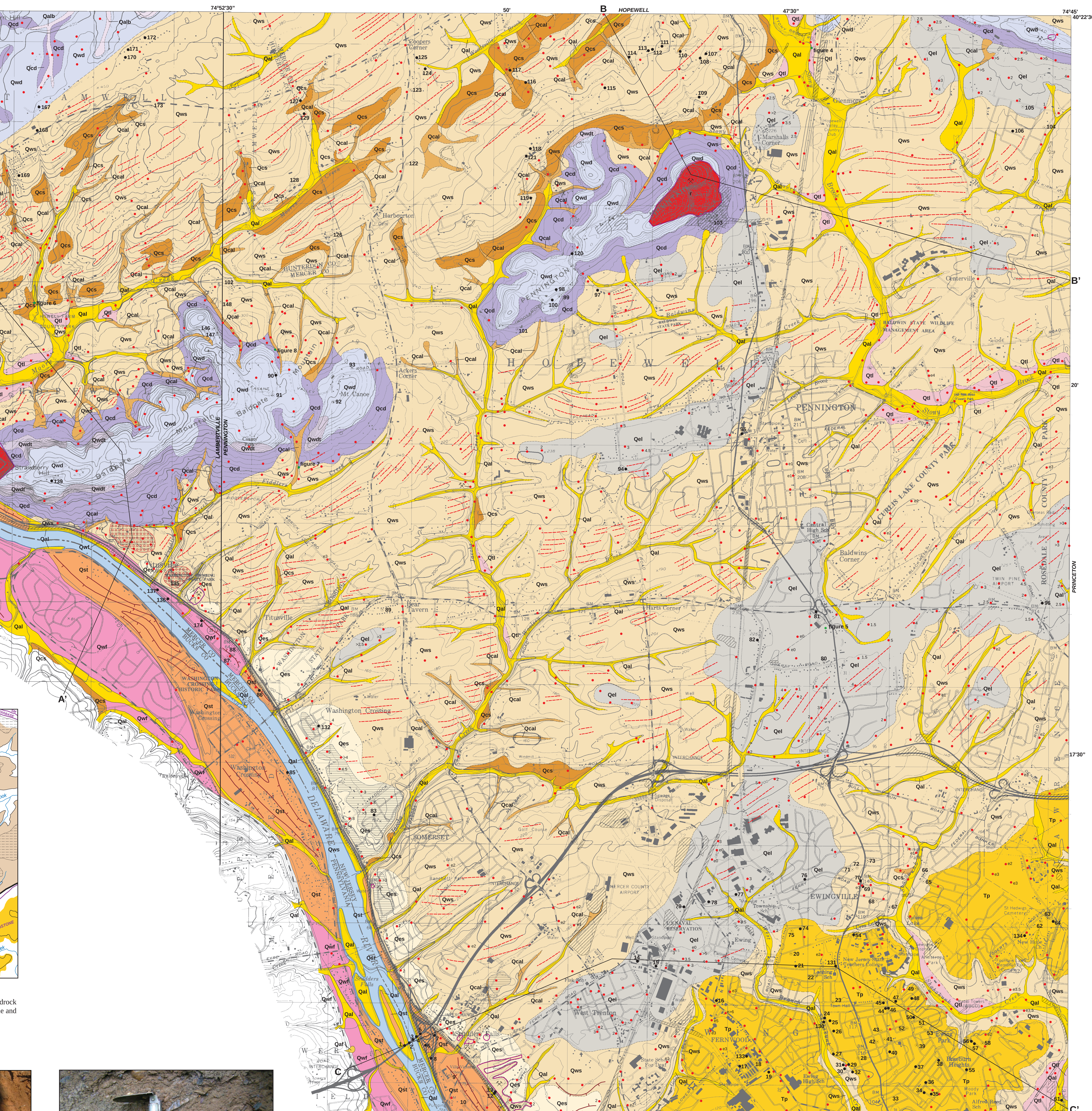


Figure 1.--Geomorphic features, fluvial and eolian deposits, and bedrock lithologies in the map area. Bedrock lithologies are simplified from Owens and others (1998). Abbreviations for bedrock lithologies are: SM=shale and mudstone, HF=hornfels.



Base map from U. S. Geological Survey Lambertville and Pennington quadrangles, 1995. Topography compiled 1942. Planimetry derived from imagery taken 1995. Survey control current as of 1953 (Lambertville) and 1954 (Pennington). North American Datum of 1983.

Geology mapped 1989, 2017
Cartography by S. Stanford

Research supported by the U. S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number G16AC00284. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U. S. Government.

Figure 2.--Horizontally bedded fine-to-medium sand (gray to dark gray beds) and silty fine sand (light gray to light brown) of the postglacial stream-terrace deposit (Qst). Sediments were accreted vertically from overbank flood deposition. Location shown on map and inset.

Figure 3.--Fine sand and silt of the postglacial stream terrace deposit (Qst, above line) overlying horizontally bedded sand and pebble-to-cobble gravel of the late Wisconsinan glaciofluvial deposit (Qwf). Location shown on map and inset.

Figure 4.--Shale and siltstone channel gravel (below shovel head) and clay-silt overbank deposits (above shovel head) of the lower terrace deposit (Qtl). Location shown on map and inset.

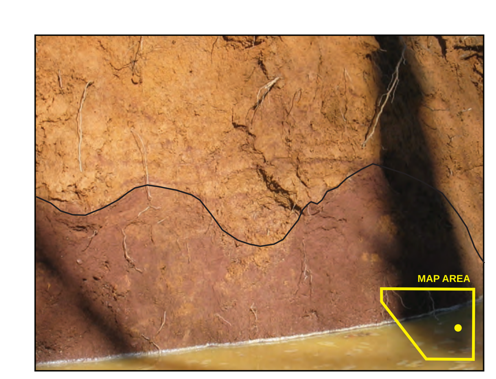


Figure 5.--Eolian silt (Qel, above line) overlying weathered shale (Qws). Location shown on map and inset. Contact deformed by cryoturbation. Height of exposure about 4 feet. Photo by D. P. Harper.

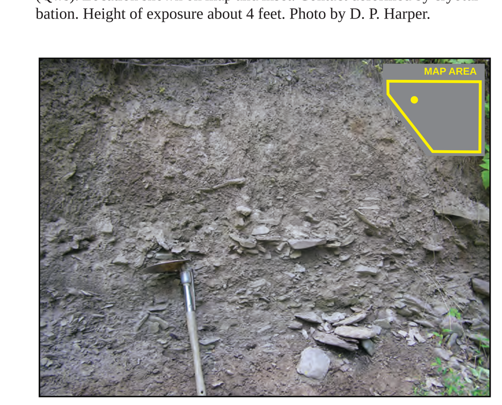


Figure 6.--Mudstone colluvium (Qcs). Note horizontal alignment of planar clasts. Location shown on map and inset.

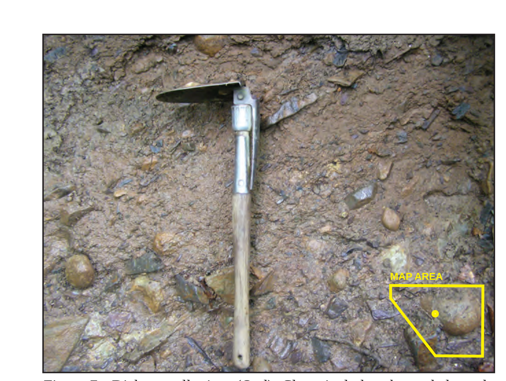


Figure 7.--Diabase colluvium (Qcd). Clasts include subrounded, partly weathered diabase (yellowish brown) and more angular hornfels and mudstone (dark gray and reddish brown), which crop out below the diabase on the feeder slope. Location shown on map and inset.

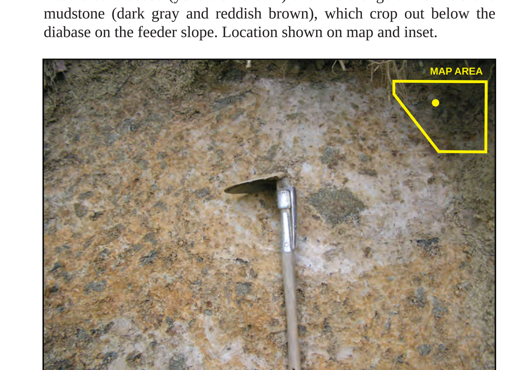


Figure 8.--Weathered diabase colluvium (Qcd). Diabase clasts (dark gray) were saprolitized after deposition. Location shown on map and inset.

SURFICIAL GEOLOGY OF THE LAMBERTVILLE AND PENNINGTON QUADRANGLES HUNTERDON AND MERCER COUNTIES, NEW JERSEY

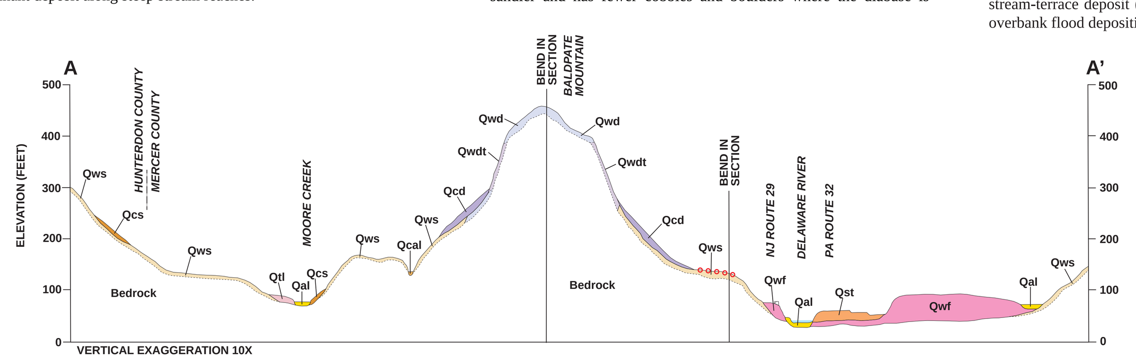
by
Scott D. Stanford
2018

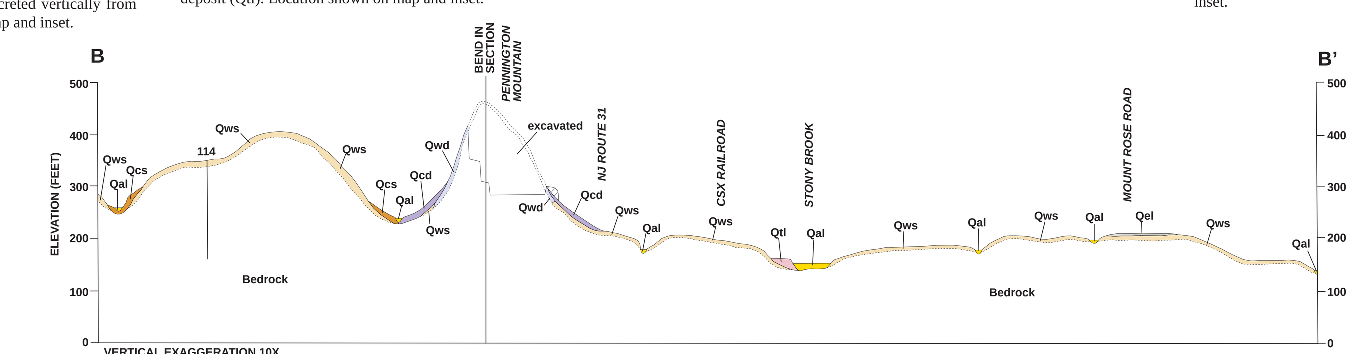
APPROXIMATE MEAN DECLINATION, 2018

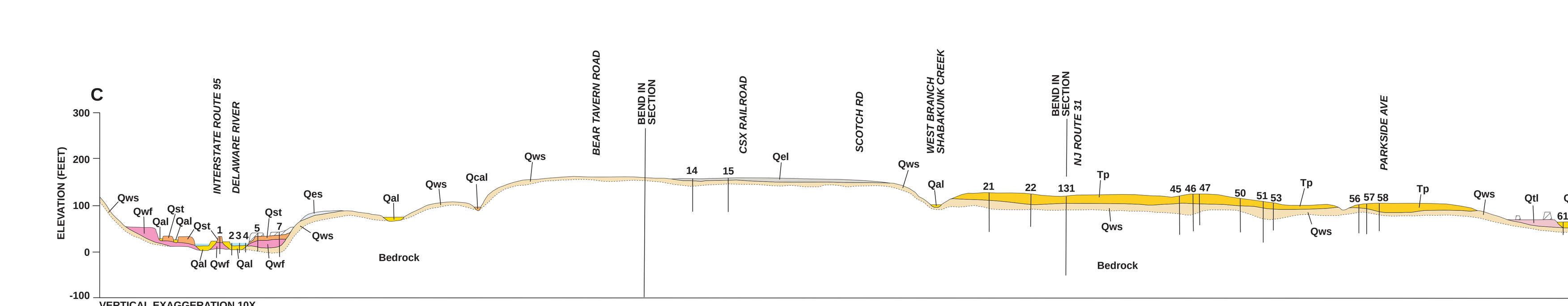
LOCATION IN NEW JERSEY

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929







Surficial Geology of the Lambertville and Pennington Quadrangles
Hunterdon and Mercer Counties, New Jersey

New Jersey Geological and Water Survey
Open-File Map OFM 119
2018

Pamphlet with Table 1 to accompany map

Table 1. Selected well and boring records. Footnotes at end of table (p. 4).

Well Number	Identifier[1]	Thickness and Stratigraphy of Surficial Material[2]	Total Depth[3]
1	B24	11 Qst 26 Qwf	36
2	B29	17 Qal+Qwf	27
3	B32	9 Qal 13 Qws	23
4	B36	6 Qal	19
5	B42	8 Qst 27 Qwf	38
6	DOT 242W-138	12 Qst 28 Qwf 56 Qws	56
7	DOT 242W-139	14 Qst 34 Qwf 49 Qws	54
8	DOT 242W-141	15 Qst 35 Qwf	45
9	27-6379	6 Qst 20 Qwf	100
10	27-4601	43 Qst+Qwf	80
11	27-631	34 Qst+Qwf	61
12	H16	6 Qst 15 Qws	31
13	H17	13 Qst 22 Qwf 32 Qws	48
14	27-11939	6 Qel 18 Qws	72
15	27-11940	6 Qel 8 Qws	77
16	27-11778	6 Qel+Tp	35
17	DOT 138W-13	15 Tp 21 Qws	21
18	27-1209	38 Qel+Tp	500
19	DOT 138W-45	16 Tp 19 Qws	19
20	27-723	40 Tp+Qws	75
21	27-1666	15 Tp 33 Qws	85
22	27-6272	24 Tp 28 Qws	70
23	27-4155	10 Tp 27 Qws	78
24	27-6039	18 Tp 35 Qws	80
25	27-6053	17 Tp 42 Qws	70
26	28-7333	9 Tp	75
27	27-6974	11 Tp 20 Qws	70
28	27-2964	19 Tp 27 Qws	65
29	27-8541	7 Tp 19 Qws	80
30	27-9111	14 Tp 38 Qws	45
31	27-8701	12 Tp 32 Qws	70
32	27-6007	26 Tp 44 Qws	80
33	27-2659	20 Tp 37 Qws	75
34	27-257	47 Tp+Qws	100
35	27-6687	30 Tp 44 Qws	75
36	28-6171	40 Tp 48 Qws	105

Well Number	Identifier[1]	Thickness and Stratigraphy of Surficial Material[2]	Total Depth[3]
37	27-717	40 Tp+Qws	97
38	27-9704	35 Tp+Qws	100
39	28-5059	16 Tp 37 Qws	80
40	27-10942	6 Tp 18 Qws	85
41	27-2770	35 Tp 39 Qws	70
42	27-3171	18 Tp 34 Qws	70
43	27-4130	38 Tp+Qws	80
44	27-6093	18 Tp 42 Qws	80
45	27-2603	33 Tp+Qws	85
46	27-5560	23 Tp 50 Qws	82
47	27-6296	24 Tp 34 Qws	70
48	27-6338	18 Tp 24 Qws	65
49	27-9415	9 Tp 44 Qws	90
50	27-5483	12 Tp 25 Qws	75
51	27-2741	37 Tp+Qws	90
52	27-4483	38 Tp+Qws	75
53	27-240	12 Tp 36 Qws	65
54	DOT 380W-3	16 Tp	21
55	27-2247	32 Tp 91 Qws	150
56	28-17398	7 Tp 14 Qws	65
57	28-17397	7 Tp 14 Qws	65
58	27-1029	17 Tp 22 Qws	60
59	28-2166	22 Tp 40 Qws	75
60	27-2456	15 Qtl 33 Qws	71
61	28-30936	16 Qal 20 Qws	20
62	27-2601	8 Tp 23 Qws	87
63	27-5077	45 Tp+Qws	75
64	28-19813	9 Tp 33 Qws	75
65	27-1194	19 Qws	80
66	27-596	49 Qws	78
67	27-419	35 Qws	91
68	27-1493	13 Qws	62
69	27-2368	22 Qws	100
70	27-10470	15 Qws	25
71	27-1023	7 Qws	90
72	27-882	17 Qws	94
73	27-1068	19 Qws	96
74	27-6534	12 Tp 24 Qws	70
75	27-4596	18 Tp+Qws	80
76	DOT 439W-34	8 Qel 16 Qws	16
77	DOT 439W-27	3 Qel 6 Qws	17
78	DOT439W-25	13 Qel 16 Qws	16
79	27-10106	23 Qel+Qws	257
80	27-123	7 Qel	111
81	27-11353	6 Qel 11 Qws	11
82	27-8851	21 Qel+Qws	305
83	27-5080	43 Qes+Qws	360
84	27-5404	28 Qws	75
85	N 27-14-739	42 Qst+Qwf	45
86	DOT 403W-30	7 Qst 22 Qwf	27
87	27-669	40 Qwf	92
88	27-1202	29 Qwf	103
89	27-7374	7 Qws	302

Well Number	Identifier[1]	Thickness and Stratigraphy of Surficial Material[2]	Total Depth[3]
90	27-8939	25 Qwd	450
91	27-10008	20 Qwd	325
92	27-1320	10 Qwd	404
93	27-5934	16 Qwd	230
94	27-8641	8 Qel+Qws	300
95	27-8849	15 Qws	25
96	28-28027	12 Qel+Qws	170
97	27-8422	12 Qws	180
98	27-11567	20 Qwd	225
99	27-961	28 Qwd	70
100	28-20818	20 Qwd	225
101	27-5352	80 Qcd+Qws	203
102	27-9198	12 Qws	320
103	27-486	37 Qcd+Qwd	171
104	28-3729	16 Qws	125
105	28-3730	15 Qws	100
106	28-6909	13 Qws	158
107	27-8428	15 Qws	175
108	27-2425	20 Qws	170
109	27-8463	30 Qws	175
110	27-8719	25 Qws	175
111	27-8923	12 Qws	225
112	27-9579	12 Qws	360
113	27-9197	10 Qws	520
114	27-9172	12 Qws	200
115	27-9152	14 Qws	575
116	27-6310	15 Qcs+Qws	350
117	27-9752	10 Qcs+Qws	200
118	27-11905	20 Qws	200
119	27-9816	30 Qws	300
120	27-9257	25 Qwd	250
121	27-11233	12 Qws	113
122	27-10293	18 Qws	250
123	27-4540	25 Qws	198
124	27-5020	20 Qws	298
125	27-6825	20 Qws	175
126	27-10150	12 Qws	225
127	27-9379	14 Qws	200
128	27-949	10 Qws	370
129	27-9378	15 Qws	195
130	27-6792	20 Tp 38 Qws	63
131	27-2459	20 Tp+Qws	170
132	27-5290	15 Qes+Qws	145
133	DOT 138W-54	21 Tp 26 Qws	26
134	27-6295	12 Tp 39 Qws	70
135	27-5011	7 Qes	143
136	27-5820	24 Qwf	150
137	27-6924	19 Qwf	150
138	27-6856	50 Qst+Qwf	250
139	27-7973	15 Qwd	700
140	27-7667	40 Qst+Qwf	340
141	27-9828	35 Qst+Qwf	350
142	27-10824	22 Qst+Qwf	32

Well Number	Identifier[1]	Thickness and Stratigraphy of Surficial Material[2]	Total Depth[3]
143	27-10823	22 Qst+Qwf	37
144	27-11971	31 Qst 42 Qwf	42
145	27-4773	20 Qtl+Qws	545
146	27-5075	20 Qwd	98
147	27-4637	15 Qwd	328
148	27-9465	20 Qws	595
149	27-11411	6 Qwf 40 Qwf+Qcs	40
150	27-18	49 Qwf 50 Qws?	50
151	27-9841	20 Qws	220
152	27-9036	40 Qws	600
153	27-8499	25 Qwd	325
154	27-9878	12 Qwd	500
155	27-8799	40 Qwd	420
156	27-8691	40 Qwd	500
157	27-3508	11 Qwd	84
158	27-10580	9 Qwf	11
159	27-9492	10 Qwf	12
160	27-1407	12 Qws	285
161	27-5170	30 Qwf	123
162	27-11006	20 Qwf	20
163	27-5528	40 Qwf	200
164	27-10410	27 Qwf	28
165	27-10306	15 Qst 17 Qwf	17
166	27-6626	25 Qws+Qwd	200
167	27-6483	30 Qwd	100
168	27-10852	20 Qws	750
169	27-5078	41 Qws	248
170	27-6565	15 Qws	360
171	27-9873	20 Qws	520
172	27-9595	25 Qws	400
173	27-9356	17 Qws	300
174	27-7521	19 Qwf	100
175	27-10164	32 Qwd	300

[1]Identifiers of the form 27-xxxx or 28-xxxx are well permit numbers issued by the N. J. Department of Environmental Protection. Identifiers of the form N 27-xx-xxx are N. J. Atlas Sheet coordinates of well logs in the N. J. Geological and Water Survey permanent note collection. Identifiers of the form DOT-xxxx-xxx are test borings from the N. J. Department of Transportation accessed at http://www.state.nj.us/transportation/refdata/geologic/ in May 2017. Identifiers of the form Bxx and Hxx are bridge borings on file at the N. J. Geological and Water Survey.

[2]Number preceding map unit is depth, in feet below land surface, of base of unit. Where the depth of the unit equals the total depth, the base of the unit was not reached. Map units are inferred from drillers' descriptive lithologic logs. A "+" sign indicates that the units cannot be separately identified from the logs. The following terms are commonly used, in various combinations and with red, yellow, brown, and gray as color modifiers, for the map units indicated: Qst=sand, silt, soil; Qwf=sand, gravel, boulders, cobbles; Qel=silt, clay, earth, loam; Qes=silt, fine sand, sandy loam; Qal and Qtl=sand, clay, gravel; Tp=sand, loam, gravel, clay; Qws=clay, soft shale, soft sandstone, soft argillite, loam with boulders, sand and boulders, soil and decomposed rock, clay and loose rock, overlay, overburden. Qwd=overburden, overlay, earth, clay, broken rock, weathered trap, dirt and gravel, sand and boulders.

[3]Total depth to which well or boring was drilled, in feet below land surface. Depth below base of surficial material is in unweathered bedrock.