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INTRODUCTION

The Oswego Lake quadrangle is in the Barnegat Bay region of the New Jersey Coastal Plain, in the southeastern part of the state. Outcropping and shallow subsurface geologic materials in the map area include surficial deposits of late Miocene to Holocene age that overlie the Cohansey and Kirkwood formations, which are marginal marine deposits of Miocene age. Shelf deposits of early Oligocene and late Eocene age (the Atlantic City and Absecon Inlet formations) underlie the Miocene deposits. The surficial deposits include estuarine, river, hillslope, wetland, and windblown sediments. The Kirkwood Formation was deposited in marine delta and shallow shelf settings in the early and middle Miocene. The Cohansey Formation was deposited in coastal settings in the middle and late Miocene, when sea level was at times more than 200 feet higher than at present in this region. As sea level lowered after deposition of the Cohansey, rivers flowing on the emerging Coastal Plain deposited fluvial gravel. Continued lowering of sea level caused streams to erode into the gravel and the underlying Cohansey Formation. During the latest Miocene, Pliocene, and Pleistocene, about 8 million years ago (8 Ma) to 11,000 years ago (11 ka), stream and hillslope sediments were deposited in several stages as valleys were progressively deepened by stream incision, and widened by seepage erosion, in step with lowering sea level. During at least two interglacial periods in the middle and late Pleistocene, when sea level was higher than at present, estuarine sediments were laid down in terraces in the southern and western parts of the quadrangle. Most recently, alluvial and wetland deposits were laid down during the Holocene (11 ka to present).

A brief summary of the stratigraphy and depositional settings of the Kirkwood and Cohansey formations, and of the geomorphic history of the map area as recorded by surficial deposits and landforms, is provided below. The age of the deposits and episodes of valley erosion are shown on the correlation chart. Lithologic logs of three test borings drilled for this study are in table 1.

Cross section AA’ shows materials to a depth of 500 to 700 feet (elevation -600 feet), which includes the Cohansey Formation, the Kirkwood Formation, the Atlantic City Formation, and part of the Absecon Inlet Formation. The few water wells in the quadrangle tap sands in the Cohansey Formation at depths between 70 and 165 feet. A thick aquifer sand in the Kirkwood Formation (unit 5 on section AA’) is not tapped in the quadrangle but provides water to several public-supply wells just outside the quadrangle to the south and east. This sand is known as the “Atlantic City 800-foot sand” aquifer (Zapecza, 1989). Formations below an elevation of -600 feet are described in Owens and others (1998).

KIRKWOOD FORMATION

The Kirkwood Formation consists of back-bay, marine-delta, and shallow-shelf sediments. In the Barnegat Bay region, these sediments form six lithologic units which were identified and numbered in the Island Beach corehole, located 22 miles northeast of Lake Absegami (Miller and others, 1994). These units are traceable using gamma-ray well logs from Island Beach through southern Ocean County (Stanford, 2013; 2014; Stanford and Sugarman, 2017) and into the Oswego Lake quadrangle (section AA’). They are also present in the Bass River corehole, which is one mile south of Lake Absegami, although they were not used to subdivide the Kirkwood there (Miller and others, 1998). In the Bass River corehole, using the Island Beach unit numbers, basal prodelta clay (unit 6) is overlain by delta-front sand (unit 5), in turn overlain by thin prodelta clay (unit 4) and thin nearshore sand (unit 3). Unit 3 is overlain by thick inner-shelf to prodelta clay (unit 2), which is overlain by interbedded inner-shelf, nearshore, and back-bay sand and clay (unit 1). At Bass River, units 6 and 5 are in the Lower member of Owens and others (1998), also known as the Brigantine Member of Miller and others (1997), or the Kirkwood 1a sequence of Sugarman and others (1993). Shells at the base of unit 6 in the Bass River corehole yield strontium stable-isotope ages of 20.8, 20.9, 21.1, and 21.4 Ma (Miller and others, 1998), indicating an early Miocene age for this sequence. Unit 4 and most of unit 3 are in the Shiloh Marl member of Owens and others (1998), or the Kirkwood 1b sequence of Sugarman and others (1993). The upper part of unit 3, unit 2, and unit 1 are in the Wildwood Member of Owens and others (1998), or the Kirkwood 2 sequence of Sugarman and others (1993). Diatoms in this sequence indicate an early to middle Miocene age (Miller and others, 1998). A boundary between sequences 2a and 2b of Sugarman and others (1993) may be present in the lower part of unit 1.

Gamma-ray logs of wells 32-436 and 32-10890, and a lithologic log of test boring 32-23041 (section AA’) allow mapping of these units from the Bass River corehole into the map area (tielines on section AA’). Units 1 and 2 thin and pinch-out, or are eroded away, from south to north. Unit 4 pinches out between wells 32-10890 and 32-436, and unit 3 becomes lithically indistinguishable from unit 5 updip from this pinch-out. This pattern suggests that the Wildwood Member either transitions updip to coastal sediments in the lower part of the Cohansey Formation, or was eroded before deposition of the Cohansey.

COHANSEY FORMATION

The Cohansey Formation consists of stacked successions composed of beach and shoreface sand overlain by interbedded sand and clay deposited in tidal flats, bays, and coastal swamps (Carter, 1972, 1978). Pollen and dinoflagellates recovered from peat beds in the Cohansey at Legler, in northern Ocean County, are indicative of a coastal swamp-tidal marsh environment (Rachele, 1976). The Legler pollen (Greller and Rachele, 1983), pollen recovered from a corehole near Mays Landing, New Jersey (Owens and others, 1988), and dinocysts obtained from coreholes in Cape May County, New Jersey (deVerteuil, 1997; Miller and others, 2001), indicate a middle to early late Miocene age for the Cohansey. The Cohansey generally lacks datable marine fossils, particularly in updip areas where it has been weathered. As discussed above, lower parts of the Cohansey in updip settings like the map area may be age-equivalent to the upper Kirkwood downdip (for example, Kirkwood sequence 2, about 17-15 Ma, and sequence 3, 12-14 Ma, Sugarman and others, 1993) and may represent the coastal facies of the Kirkwood shallow-shelf deposits.

In the map area, clays in the Cohansey are in beds or laminas generally less than 6 inches thick, but as much as 5 feet thick, and are interbedded with sand. In outcrop they commonly are oxidized and multicolored but, in the subsurface, dark organic clays are reported in a few drillers’ logs (abbreviated as “Tchco” in well logs on map). Clay strata are generally less than 15 feet thick. In outcrop, two clay beds can be traced through most of the quadrangle. The upper bed (“1” on fig. 1) is at an elevation of around 90 feet. It extends around the base of the Warren Grove upland, although it is discontinuous on the west edge of the upland in the headwaters of Beaver Branch and Buck Run. It is also present discontinuously north of the Oswego River, and occurs on hills and uplands that reach 80 to 90 feet in altitude in the southern part of the quadrangle. This clay bed continues to the northeast of the quadrangle in the Oswego River valley and beneath the upland on the east side of the valley, for a northeast-southwest distance of about 15 miles (Stanford, 2011). The lower bed (“2” on fig. 1) crops out at 50 to 60 feet in altitude in the southern half of the quadrangle. It is less continuous than the upper clay, as indicated by the patchy outcrop pattern, although gamma-ray logs for wells 32-431 and 32-10890 (section AA’), and gamma-ray logs of test borings, and outcrop mapping, in the West Creek quadrangle just east of the map area (Stanford, 2014) show north-south continuity of about four miles for this bed. Gamma-ray and lithologic logs (section AA’) show an additional three clay beds in the subsurface, two of which extend southward to the Bass River corehole (Miller and others, 1998) and southeastward into the West Creek quadrangle (Stanford, 2014).

The laminated bedding, and thin but areally extensive geometry of the clayey beds, are indicative of bay or estuarine intertidal settings. Alluvial clays generally are thicker and more areally restricted because they are deposited in floodplains and abandoned river channels. The repetitive stacking of bay clays and beach sand (chiefly tidal-delta and shoreface deposits) indicates that the Cohansey was deposited during several rises and falls of sea level during a longer period of overall rising sea level.

SURFICIAL DEPOSITS AND GEOMORPHIC HISTORY

Sea level in the New Jersey region began a long-term decline following deposition of the Cohansey Formation. As sea level lowered, the inner continental shelf emerged as a coastal plain. River drainage was established on this plain. The Beacon Hill Gravel, which caps the highest elevations in the Coastal Plain, is the earliest record of this drainage. It occurs at elevations above 165 to 180 feet to the north of the map area in the Brookville and Woodmansie quadrangles. The highest parts of the Upland Gravel on the Warren Grove upland (fig. 1), above 150 feet, may be erosional remnants of the Beacon Hill. The Beacon Hill is quartz-chert gravel deposited by rivers draining southward from the Valley and Ridge province in northwestern New Jersey and southern New York (Stanford, 2009). In the Beacon Hill, and in upland gravels reworked from the Beacon Hill, rare chert pebbles containing coral, brachiopod, and pelecypod fossils of Devonian age indicate that some of these rivers drained from north of what is now Kittatinny and Shawangunk Mountains, where chert-bearing Devonian rocks crop out.

Continued decline of sea level through the late Miocene and early Pliocene (approximately 8 to 3 Ma) caused the regional river system to erode into the Beacon Hill plain. As it did, it shifted well to the west of the map area into what is now the Delaware River basin. The map area became an upland from which local streams drained westward to the regional river system and eastward to the Atlantic Ocean. These local streams eroded shallow valleys into the Beacon Hill Gravel. Groundwater seepage, slope erosion, and channel erosion reworked the gravel and deposited it in floodplains, channels, and pediments, between 40 and 60 feet below the level of the former Beacon Hill plain. These deposits are mapped as Upland Gravel, High Phase (unit Tg). Today, owing to topographic inversion, they cap ridgetops above an elevation of between 100 and 130 feet, chiefly in the northern half of the quadrangle. Purple arrows on figure 1 show drainage routes of streams during deposition of the gravel, as inferred from the location and elevation of the ridgetop deposits.

A renewed period of lowering sea level in the late Pliocene and early Pleistocene (approximately 3 Ma to 800 ka) led to another period of valley incision. Groundwater seepage and channel and slope erosion reworked the Upland Gravel, High Phase and deposited the Upland Gravel, Lower Phase (unit TQg) in shallow valleys 20 to 50 feet below the higher gravels. These deposits today cap interfluves and form more extensive mantles in head-of-valley areas and upper slopes. Stream drainage during deposition of these sediments, inferred from the interfluve deposits, is shown by red arrows on figure 1.

Continuing incision in the middle and late Pleistocene (about 800 to 11 ka) formed the modern valley network. Fluvial sediments laid down in modern valleys include Upper and Lower Terrace Deposits (units Qtu and Qtl), inactive floodplain deposits in dry valleys (unit Qald), and active floodplain and wetland (Qals) deposits in valley bottoms. Like the upland gravels, the terrace and floodplain deposits represent erosion, transport, and redeposition of sand and gravel reworked from older surficial deposits and the Cohansey Formation by streams, groundwater seepage, and slope processes. Wetland deposits are formed by accumulation of organic matter in swamps and bogs.

Stream incision and seepage were enhanced in the headwaters and upper reaches of the Ives Branch, Bass River, and Governors Branch basins (collectively, “Atlantic basins”) because these basins gain groundwater from the Oswego River basin (the topographic basin divide is shown on fig. 1). For the period 1979-2015, the average annual discharge per square mile for the Oswego basin upstream of the gage at Harrisville (USGS gage 01410000) is 1.2 cubic feet per second (cfs) per square mile while that of the East Branch of Bass River upstream of the gage just south of Lake Absegami (USGS gage 01410150) is 2.1 cfs per square mile (discharge data from U. S. Geological Survey National Water Information System). The greater discharge per square mile in the Bass River basin indicates loss of groundwater from the Oswego basin to the Bass River basin. This loss is due in part to the steeper topographic gradient of the upper reaches of the Atlantic basins, and to southeastward movement of groundwater atop clay beds within the Cohansey Formation beneath the topographic basin divide (section AA’). These beds include the outcropping clays at 90 and 50 feet in altitude, and a deeper, continuous clay bed at sea level. Active seepage at the top of the 90-foot clay bed is evident at the headwaters of the West Branch of Bass River and Governors Branch. Groundwater movement from the Oswego basin to the Atlantic basins is also documented by long-term basin-wide recharge measurements for the Atlantic basins northeast of the Oswego Lake quadrangle (Gordon, 2004).

Upper Terrace Deposits form terraces and pediments 5 to 25 feet above modern floodplains. They also occur as thin fills in some headwater valleys that do not contain active streams. They were laid down chiefly during periods of cold climate in the middle Pleistocene. During cold periods, permafrost impeded the infiltration of rainfall and snowmelt and this, in turn, accelerated groundwater seepage, runoff, and slope erosion, increasing the amount of sediment entering valleys, leading to terrace deposition. Some of the deposits may have been laid down during periods of temperate climate when sea level was high, because at their downstream limit the upper terraces grade to the Cape May 2 marine terrace (see below). This topographic equivalence indicates that some of the upper terrace deposits aggraded during the Cape May 2 highstand. The upper terraces are inset into the Cape May 1 estuarine deposits, indicating that they are younger than the Cape May 1 highstand (see below).

Lower Terrace Deposits (unit Qtl) form low, generally wet, terraces with surfaces less than 5 feet above modern valley bottoms. Like the upper terrace, they also form thin fills in some headwater valleys that lack active streams. They are inset into the upper terrace and the Cape May 2 terrace, and were laid down in shallow valleys and lowlands eroded after deposition of the Cape May 2. This erosion occurred during a period of lower-than-present sea level and colder-than-present climate known as the Wisconsinan stage, between about 80 ka and 11 ka. The approximate extent of Wisconsinan valley erosion is shown by black lines on figure 1.

Lower terraces are most prominent along the Oswego River and in the southwestern corner of the quadrangle. Along the Oswego, the lower terrace is scribed in places by a network of shallow braided channels (fig. 2, shown as lines on map). These channels are wetter than the adjacent unchanneled terrace and are marked by grass and shrub glades, distinct from pine forest on the slightly higher terrace. The braided channels formed when permafrost impeded infiltration and thus increased seepage and runoff. The increased runoff washed sand from uplands into valleys, choking streams with sediment and causing channels to aggrade and split to form a braided pattern. The braided channels on the lower terrace contrast with the single, meandering channel of the modern Oswego, which does not receive sediment from upland runoff (fig. 2).

The lower terrace deposits were laid down chiefly during or slightly after the last period of cold climate between 25 and 15 ka. Near Manahawkin, northeast of the quadrangle, sand and gravel of the lower terrace overlie an organic silt dated to 34,890±960 radiocarbon years (GX-16789-AMS, Newell and others, 1995) (38,410-40,550 calibrated years with one sigma error, calibrated using Reimer and others, 2013). In the Chatsworth quadrangle, north of the Oswego Lake quadrangle, organic sediment within lower terrace sand dated to 20,350±80 radiocarbon years (Beta 309764, Stanford, 2012) (24,450-24,150 calibrated years with one sigma error). These dates indicate deposition of the terrace deposits in the late Wisconsinan. Dry-valley alluvium (unit Qald), which grades downvalley to lower terraces in places, was likely also laid down during this time, when permafrost fostered runoff in headwater valleys that are dry today.

Another feature related to permafrost are thermokarst basins. These are shallow closed basins, circular to oval in plan, generally less than an acre in area, and less than 5 feet in depth (symboled on map). They are most common on upper terraces but also occur on the surface of the Cape May 1 and Upland Gravel, Lower Phase deposits. Most formed when ice-rich lenses at shallow depth in the frozen sediments melted, leaving small depressions (Wolfe, 1953; French and others, 2005). Some basins are bordered by dunes. These basins were likely formed, or enlarged from an initial thermokarst basin, by wind erosion (French and Demitroff, 2001).

Modern floodplain and wetland deposits (unit Qals) were laid down within the past 10 ka, based on radiocarbon dates on basal peat in other alluvial wetlands in the region (Buell, 1970; Florer, 1972; Stanford, 2000). Pollen in organic silt at a depth of 4 feet in unit Qals in the pond on Governors Branch contains 50% spruce, 38% birch, 3% pine, 1% oak, and 6% herb (Watts, 1979). This pollen assemblage indicates an age no younger than about 10 radiocarbon ka (about 12,000 calibrated years) for the onset of deposition of the alluvial deposit here, based on the youngest occurrence of spruce in the region (Sirkin and others, 1970).

Eolian deposits (Qe) are common in the quadrangle. They include elongate dune ridges, generally oriented east-west or northwest-southeast, as much as a mile long and 15 feet tall. A few dunes are sinuous or rippled, with ridgecrests oriented northeast-southwest and bowed to the southeast (fig. 3). These orientations suggest that the dunes were formed by winds blowing from the west and northwest. Other areas of eolian sand lack distinct dune ridges and instead show subdued swell-and-swale topography. The windblown deposits occur chiefly on upper terraces, the Cape May 2 terrace in the southwestern corner of the quadrangle, and older surfaces, but are generally absent from lower terraces and modern floodplains. In many places, windblown deposits were laid down at the upland edge of lower terraces, most notably along the south edge of the lower terrace along the Oswego River, but also at the east edge of the lower terraces and floodplains along Bartletts Branch, the West Branch of Bass River, Dans Bridge Branch, and the East Branch of Bass River. This association suggests the windblown sand in these settings was blown from the lower terrace as the terrace deposits were laid down. In a few places, for example, in the Beaver Branch, Arnold Branch, and Tub Mill Branch valleys, dunes occur on the lower terrace itself. This distribution shows that the eolian deposits largely postdate the Cape May 2 and the Upper Terrace Deposits and, in places are the same age, or slightly younger than, the Lower Terrace Deposits. These relations indicate that deposition was mostly during the Wisconsinan stage (80-11 ka). Deposits on older surfaces, such as the Cape May 1 terrace or upland gravels, may be older.

During at least two periods of higher-than-present sea level in the middle and late Pleistocene, beach and estuarine deposits were laid down in terraces in the southern and western parts of the quadrangle (fig. 1). These marine deposits are grouped into the Cape May Formation. The Cape May includes an older, eroded terrace (Cape May Formation, unit 1, Qcm1) with a maximum surface elevation of 65 feet, and a younger, less eroded terrace with a maximum surface elevation of 35 feet (Cape May Formation, unit 2, Qcm2). The Cape May 1 deposits lie within wide valleys which are inset into the Upland Gravel, Lower Phase. The valleys were shallower and broader at the time of deposition of the Cape May 1 than they are today, because the base of the Cape May 1 is higher than that of the upper and lower terrace deposits, and of modern floodplain sediments. The upper terraces are inset 10 to 30 feet into the Cape May 1 terrace and grade to, or are onlapped by, the Cape May 2 deposits.

Amino-acid racemization ratios (AAR), optically stimulated luminescence ages, and radiocarbon dates from the Delaware Bay area (Newell and others, 1995; Lacovara, 1997; O’Neal and others, 2000; O’Neal and Dunn, 2003; Sugarman and others, 2007; Stanford and others, 2016) suggest that the Cape May 1 is of middle Pleistocene age (possibly oxygen-isotope stage 11, around 420 ka, or stage 9, around 330 ka, or older) and that the Cape May 2 is of Sangamonian age (stage 5, 125-80 ka). AAR data from vibracores on the inner continental shelf off Long Beach Island east of the quadrangle indicate that sediments there, which correlate to the Cape May, are of Sangamon age (Uptegrove and others, 2012).

DESCRIPTION OF MAP UNITS

ARTIFICIAL FILL—Sand, pebble gravel, minor clay and organic matter; gray, brown, very pale brown, white. In places includes man-made materials such as concrete, asphalt, brick, cinders, and glass. Unstratified to poorly stratified. As much as 15 feet thick. In road embankments, dams, dikes around cranberry bogs, and infilled pits.

Qals WETLAND AND ALLUVIAL DEPOSITS—Fine-to-medium sand and pebble gravel, minor coarse sand; light gray, yellowish-brown, brown, dark brown; overlain by brown to black peat and gyttja. Peat is as much as 10 feet thick. Sand and gravel are chiefly quartz and are generally less than 3 feet thick. Sand and gravel are stream-channel deposits; peat and gyttja form from the vertical accumulation and decomposition of plant debris in swamps and marshes. In alluvial wetlands on modern valley bottoms.

Qald DRY-VALLEY ALLUVIUM—Fine-to-medium sand and pebble gravel, minor coarse sand; very pale brown, white, brown, dark brown, light gray. As much as 5 feet thick. Sand and gravel are quartz. In dry valley bottoms forming headwater reaches of streams.

Qe EOLIAN DEPOSITS—Fine-to-medium quartz sand; very pale brown, white. As much as 20 feet thick. Form linear to crescentic dune ridges as much as 15 feet tall and a mile long, and areas of gentle swell-and-swale topography with less than 5 feet of relief.

Qtl LOWER TERRACE DEPOSITS—Fine-to-medium sand, pebble gravel, minor coarse sand; light gray, very pale brown, brown, dark brown. As much as 15 feet thick. Sand and gravel are quartz with a trace (<1%) of chert in places. Form terraces and pediments in valley bottoms with surfaces 2 to 5 feet above the modern floodplain, and narrow valley-bottom plains in a few dry headwater valleys. Include both stratified stream deposits and unstratified pebble concentrates formed by seepage erosion of older surficial deposits. Sand includes gyttja in places, and peat less than 2 feet thick overlies the sand and gravel in places. The gyttja and peat are younger than the sand and gravel and accumulate due to poor drainage. Gravel generally is more abundant in lower terrace deposits than in upper terrace deposits and the Cape May Formation due to removal of sand by seepage erosion.

Qtu UPPER TERRACE DEPOSITS—Fine-to-medium sand, pebble gravel, minor coarse sand; very pale brown, brownish-yellow, yellow. As much as 15 feet thick. Sand and gravel are quartz with a trace of chert in places. Form terraces and pediments with surfaces 5 to 25 feet above the modern floodplain, and valley-bottom plains in a few dry headwater valleys. Include stratified stream-channel deposits and poorly stratified to unstratified deposits laid down by groundwater seepage on pediments (fig. 4).

CAPE MAY FORMATION—Estuarine and beach deposits of middle and late Pleistocene age forming an upper (Qcm1) and lower (Qcm2) marine terrace.

Qcm2 CAPE MAY FORMATION, UNIT 2—Fine-to-medium sand, pebble gravel, minor clayey sand and coarse sand; yellow, very pale brown, yellowish-brown. Sand and gravel are quartz with a trace of chert. As much as 30 feet thick. Forms an eroded terrace with a maximum surface elevation of 35 feet.

Qcm1 CAPE MAY FORMATION, UNIT 1—Fine-to-medium sand, pebble gravel, minor clayey sand to sandy clay, and coarse sand; yellowish-brown, yellow, reddish-yellow, very pale brown, light gray. Weakly horizontally stratified to unstratified. Sand and gravel are quartz with a trace to few (<5%) white and yellow weathered chert. As much as 20 feet thick. Forms eroded terraces, and caps low hilltops and uplands in the southwestern part of the quadrangle, with a maximum surface elevation of 65 feet.

TQg UPLAND GRAVEL, LOWER PHASE—Fine-to-medium sand, clayey in places, and pebble gravel; minor coarse sand; yellow, very pale brown, reddish-yellow. Sand and gravel are quartz with a few (<5%) white, yellow, and brown weathered and decomposed cherts in the coarse sand-to-pebble gravel fraction. Clay is chiefly from weathering of chert. Weakly horizontally stratified to unstratified; sand beds have low-angle cross beds in places. As much as 20 feet thick, generally less than 10 feet thick. Occurs as erosional remnants on interfluves, and as more continuous deposits in headwater valleys. Maximum elevation of the top of the deposit declines from 130 feet on the Warren Grove upland, to 80 feet in the southeastern corner of the quadrangle, and to 70 to 80 feet on uplands in the Oswego River valley. Elevation of the base of the deposit declines from 120 feet to between 60 and 70 feet over the same distances. Includes stream deposits, deposits laid down by groundwater seepage on pediments, and pebble concentrates formed by winnowing of sand from older surficial deposits and the Cohansey Formation by groundwater sapping or surface runoff.

Tg UPLAND GRAVEL, HIGH PHASE—Fine-to-medium sand, some coarse sand, clayey in places, and pebble gravel; yellow, brownish-yellow, reddish-yellow, very pale brown, rarely red. Sand and gravel are quartz, with as much as 5% chert, and traces of weathered feldspar, in the coarse sand-to-fine pebble gravel fraction. Most chert is weathered to white and yellow clay, some chert pebbles are gray to dark gray and unweathered to partially weathered. Clay-size material chiefly is from weathering of chert and feldspar. Weakly horizontally stratified to unstratified; rarely weakly cross bedded (figs. 5, 6). As much as 25 feet thick. Occurs as erosional remnants on ridgetops and hilltops. Elevation of base of the deposit declines from 130 feet in the northeast sector of the Warren Grove upland to between 90 and 100 feet on ridgetops in the Oswego River valley and in the southeastern corner of the quadrangle. Includes stream deposits and pebble concentrates formed by washing of sand and clay by groundwater sapping or surface runoff.

COHANSEY FORMATION—Fine-to-medium quartz sand, with some strata of medium-to-very coarse sand, very fine sand, and interbedded clay and sand, deposited in estuarine, bay, beach, and inner shelf settings. The Cohansey is here divided into two map units: a sand facies and a clay-sand facies, based on gamma-ray well logs and surface mapping using 5-foot hand-auger holes, exposures, and excavations. Total thickness of the Cohansey in the map area is as much as 210 feet.

Tchs Sand Facies—Fine-to-medium sand, some medium-to-coarse sand, minor very fine sand, minor very coarse sand to very fine pebbles, trace fine-to-medium pebbles; very pale brown, brownish-yellow, white, reddish-yellow, rarely reddish-brown, red, and light red. Well-stratified to unstratified; stratification ranges from thin, planar, subhorizontal beds to large-scale trough and planar cross-bedding in sets as much as 3 feet thick (figs. 5, 6). Sand is quartz; coarse-to-very coarse sand may include as much as 5% weathered chert and a trace of weathered feldspar. Coarse-to-very coarse sands commonly are slightly clayey; the clays occur as grain coatings or as interstitial infill. This clay-size material is from weathering of chert and feldspar rather than from primary deposition. Pebbles are chiefly quartz with minor gray chert and rare gray quartzite. Pebbles commonly are subangular. Some chert pebbles are light gray, partially weathered, pitted, and partially decomposed; some are fully weathered to white clay. In a few places, typically above clayey strata, sand may be hardened or cemented by iron oxide, forming reddish-brown hard sands or ironstone masses. Locally, sand facies includes isolated lenses of interbedded clay and sand like those within the clay-sand facies described below. The sand facies is as much as 90 feet thick.

Tchc Clay-Sand Facies—Clay interbedded with clayey fine sand, very fine-to-fine sand, fine-to-medium sand, less commonly with medium-to-coarse sand and pebble lags. Clay beds are commonly 0.5 to 3 inches thick, rarely as much as 2 feet thick, sand beds are commonly 1 to 6 inches thick but are as much as 2 feet thick. Clays are white, yellow, very pale brown, reddish-yellow, light gray; sands are yellow, brownish-yellow, very pale brown, reddish-yellow (fig. 4). Rarely, clays are black, dark gray, and dark brown and contain organic matter (symboled “Tchco” where described in well logs). As much as 20 feet thick.

Tkw KIRKWOOD FORMATION—Fine sand, fine-to-medium sand, sandy clay, and clay, minor medium-to-coarse sand; gray, dark gray, brown. Sand is quartz with some mica and lignite. In subsurface only. Approximately 400 feet thick in the southern part of the quadrangle, thins to about 200 feet in the northern part of the quadrangle. In the southern part of the quadrangle the Kirkwood consists of six clay-sand units traceable on gamma-ray logs and sampled in the Bass River and Island Beach coreholes (Miller and others, 1994, 1998, see discussion under “Kirkwood Formation” above). These units are shown by tielines on section AA’. The upper four units either merge or pinch-out up-dip to the north, or were eroded prior to deposition of the Cohansey Formation. The Kirkwood in the quadrangle is of early to middle Miocene age, based on strontium stable-isotope ratios and diatoms (Miller and others, 1998).

Tac ATLANTIC CITY FORMATION—Silty, clayey, glauconitic (as much as 10%) fine-to-medium quartz sand, minor coarse sand; olive, olive-brown, brown, dark gray; with mica, shells, and shell fragments. In subsurface only. As much as 80 feet thick on the southern edge of the quadrangle, thins to 50 feet up-dip. Assigned to Atlantic City Formation of Pekar and others (1997) based on the presence of this formation in the Bass River corehole (Miller and others, 1998). Of early Oligocene age, based on strontium stable-isotope ratios and calcareous nannofossils (Miller and others, 1994, 1998; Pekar and others, 1997).

Tai ABSECON INLET FORMATION—Clayey, glauconitic to very glauconitic (as much as 25%) fine-to-medium quartz sand; olive, olive-brown, olive-gray; with mica, shells, and shell fragments. In subsurface only. More than 80 feet thick. Full thickness not penetrated in quadrangle; formation is 160 feet thick in the Bass River corehole one mile south of Lake Absegami. Calcareous nannofossils of Zones NP19-20 are present from a depth of 535 to 625 feet in the Oswego Lake observation well (well 32-436) (J. P. Owens, unpublished notes on file at N. J. Geological and Water Survey). These fossils indicate a late Eocene age and correlate the sediments to the Absecon Inlet Formation, which contains the same nannofossil zone in the Bass River corehole (Miller and others, 1998).

MAP SYMBOLS

Contact of surficial deposits—Solid where well-defined by landforms as visible on 1:12,000 stereo airphotos and LiDAR imagery, long-dashed where approximately located, short-dashed where gradational or featheredged, dotted within excavations.

Contact of Cohansey facies—Approximately located. Dotted within excavations.

Tchc Concealed Cohansey facies—Covered by surficial deposits.

4 ● / ● / Qe4/Qtu ● Material penetrated by hand-auger hole, or observed in exposure or excavation. Number indicates thickness of surficial material, in feet, where penetrated. Symbols within surficial deposits without a thickness value indicate that surficial material is more than 5 feet thick. Where more than one unit was penetrated, the thickness (in feet) of the upper unit is indicated next to its symbol and the lower unit is indicated following the slash.

figure 4 ● Photograph location

Oswego Lake 2 ● Test boring—Log in table 1.

32-20214 ● 30 Tchs+Tchc 60 Tchc 90 Tchs — Well or test boring showing formations penetrated—Location accurate to within 200 feet. Identifiers are N. J. Department of Environmental Protection well-permit numbers. Number followed by map-unit symbol is depth, in feet below land surface, of base of unit. Final number is total depth of well rather than base of unit. “Tchco” indicates organic clay in the Cohansey Formation. Units penetrated are inferred from drillers’ lithologic logs and, for wells 32-436 and 32-10890, gamma-ray logs. For many wells, surficial deposits cannot be identified from drillers’ logs. Where present, they are included in the uppermost Cohansey Formation, Sand Facies.

32-15446 ⊙ 10 Qtu 50 Tchs+Tchc 100 Tchs — Well or test boring showing formations penetrated—Location accurate to within 500 feet. Identifiers and symbols as above.

Gamma-ray log—On sections. Radiation intensity increases to right.

Head of seepage valley—Line at top of scarp, ticks on slope. At head of small valleys and hillslope embayments formed by seepage erosion.

Active seepage—Line at position of groundwater emergence. Seepage drains downslope from this position.

Abandoned channels—Line in channel axis. Shows relict braided channels on lower terrace.

Dry valley—Line in bottom of narrow, incised stream channel with no evidence of active drainage.

Dune ridge—Line on crest.

Shallow topographic basin—Line at rim, pattern in basin. Includes thermokarst basins formed from melting of permafrost and a few deflation basins, bordered by eolian deposits, formed from wind erosion.

Excavation perimeter—Line encloses excavated area.

Sand pit—Inactive in 2017.

Sand pit—Active in 2017.

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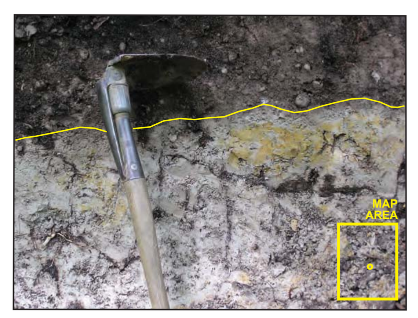


Figure 4.--Upper Terrace Deposits (unit Qtu, above line) overlying Cohansey Formation, Clay-Sand Facies (unit Tchc). Terrace deposits here include black organic sand and pebble gravel deposited in a seepage wetland formed on the clay bed. Location shown on map and inset.

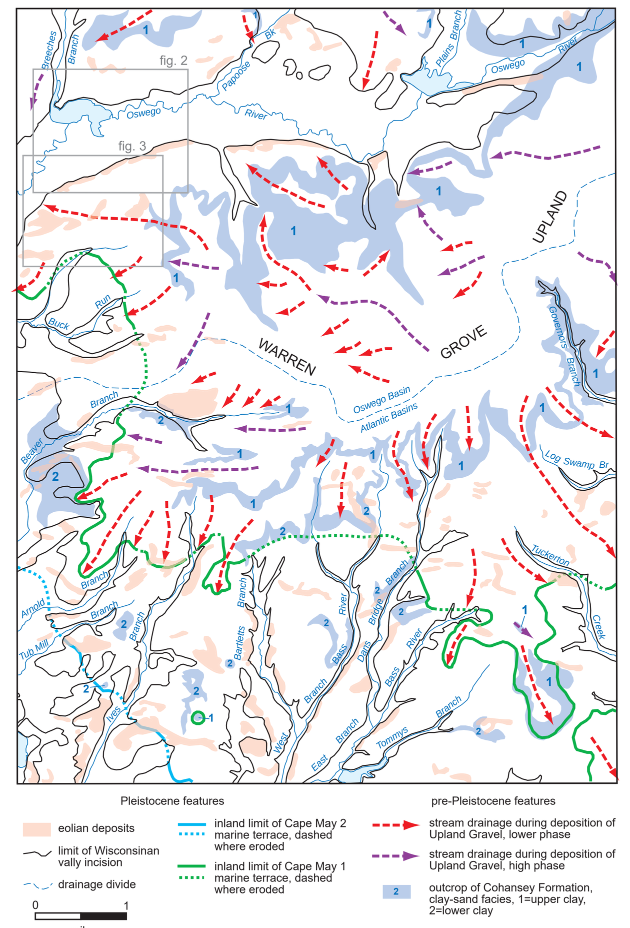


Figure 1.--Geomorphic features, modern drainage, and outcrop of Cohansey clay-sand facies in the Oswego Lake quadrangle. Locations of figures 2 and 3 shown by gray boxes.

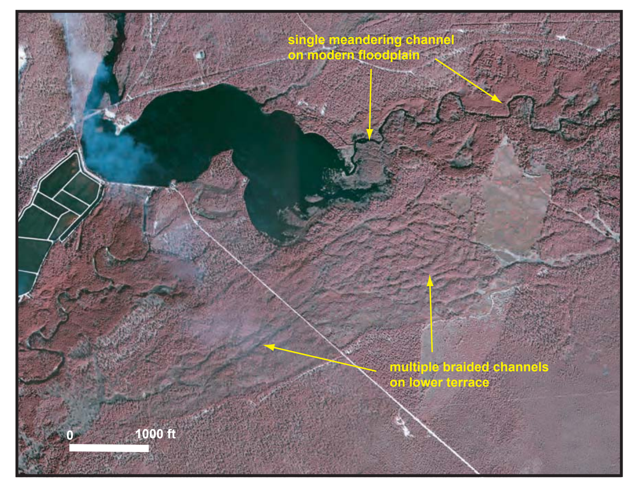


Figure 2.--Color infrared aerial photograph showing braided channels on lower terrace south of Oswego Lake. Note contrast with single meandering channel of the modern Oswego River. Imagery from N. J. Department of Environmental Protection, 2002 (at http://njwebmap.state.nj.us/geowebsplash.htm). Location shown by gray box on figure 1.

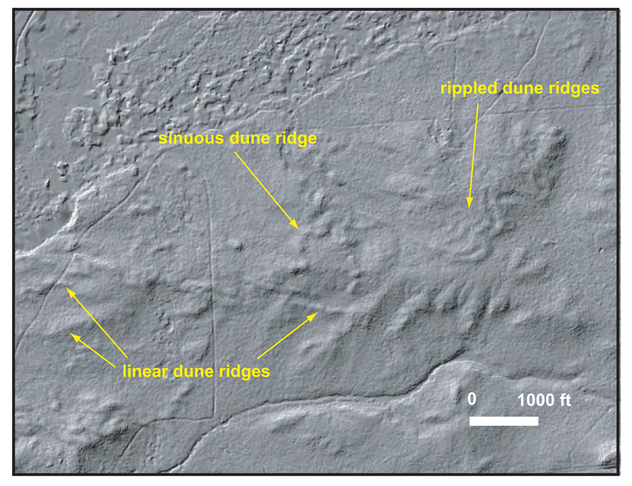
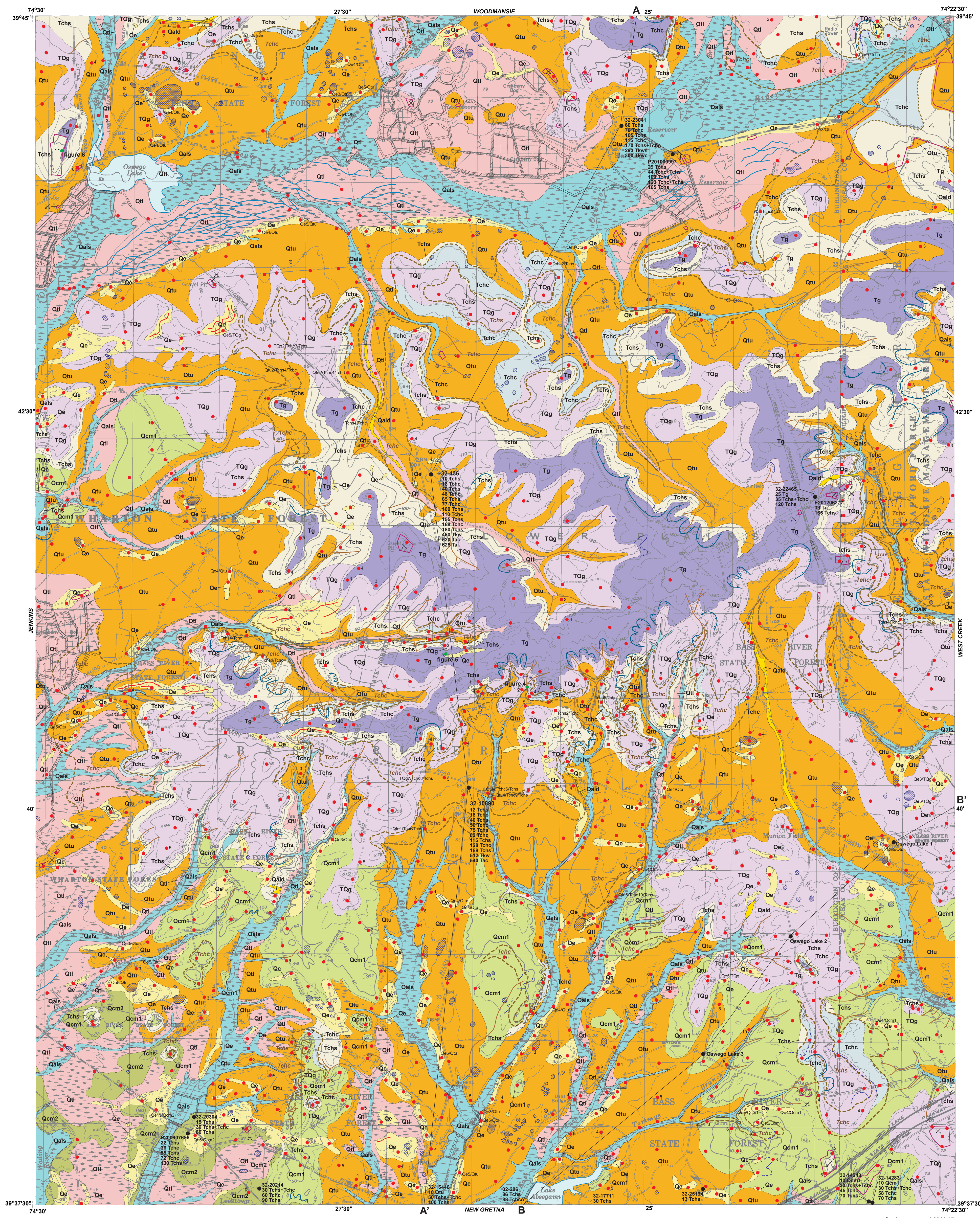


Figure 3.--Shaded-relief LiDAR image showing linear, sinuous, and rippled dune ridges. Ripppled pattern indicates wind blowing from the west and northwest. Location shown by gray box on figure 1. LiDAR image is from N. J. Department of Environmental Protection 10-foot digital elevation hillshade dataset.



Base from U. S. Geological Survey, 1997
North American Datum of 1927
North American Datum of 1983 shown by dashed corner ticks

Geology mapped 2016-17
Drilling by B. Buttari
Geophysical logging by M. Kuhn and B. Buttari
Drilling assistance by M. Castelli, N. Thistle, B. Lubenow, J. Caporossi
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.

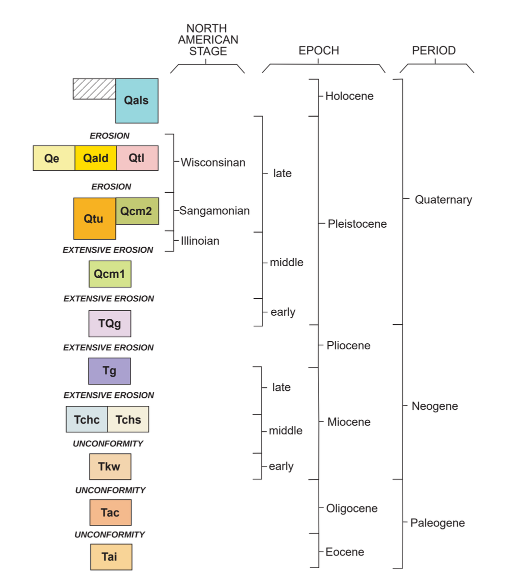
APPROXIMATE MEAN DECLINATION, 1998

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

LOCATION IN NEW JERSEY

CORRELATION OF MAP UNITS



GEOLOGY OF THE OSWEGO LAKE QUADRANGLE
BURLINGTON AND OCEAN COUNTIES, NEW JERSEY

by
Scott D. Stanford
2017

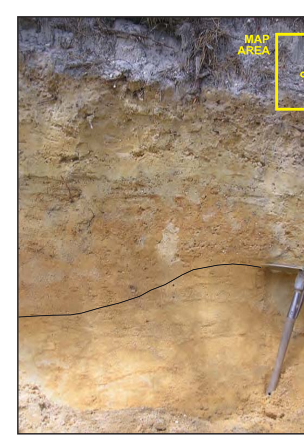
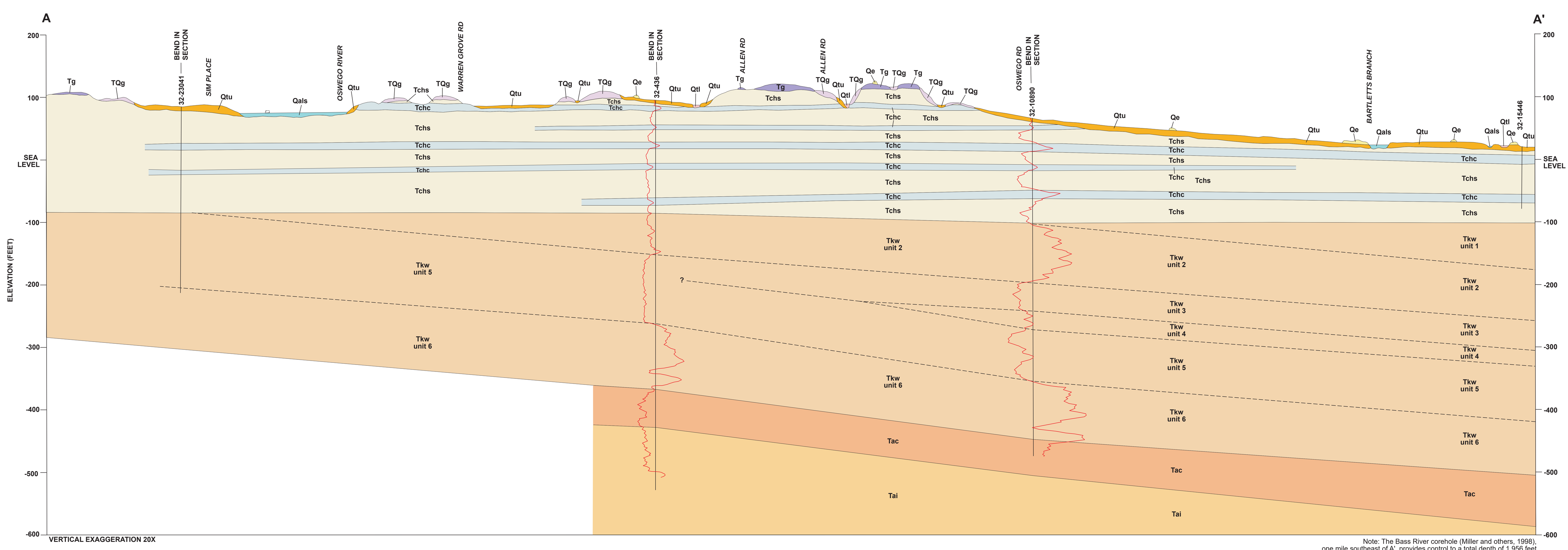


Figure 5.--Upland Gravel, High Phase (unit Tg, above line) over Cohansey Formation, Sand Facies (Tchs). Note faint cross bedding in the Cohansey sand. Location shown on map and inset.

Figure 6.--Upland Gravel, High Phase (unit Tg, above line) over Cohansey Formation, Sand Facies (Tchs). Note stacked sets of planar, tabular cross-bedded sand and thin, planar, horizontally bedded sand in the Cohansey. These bedforms are typical of tidal deltas, tidal flats, and beaches. Height of exposure approximately 20 feet. Location shown on map and inset.

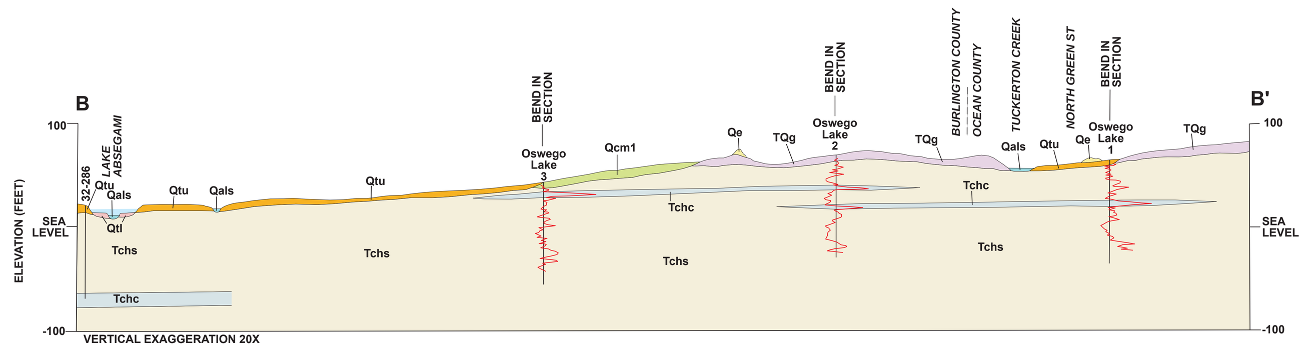
Table 1.—Lithologic logs of test borings. Gamma-ray logs on section BB’.

N. J. permit number and identifier	Lithologic log: Depth (feet below land surface)	Lithologic log: Description (map unit assignment in parentheses) Color names from Munsell Soil Color Charts, 1975
E201704086 Oswego Lake 1	0-13	very pale brown to brownish-yellow medium-to-coarse quartz sand with some quartz pebbles (Qtu)
	13-39	yellow fine quartz sand, minor medium sand (Tchs)
	39-42	pale brown, grayish-brown, dark brown clay (Tchc)
	42-99	very pale brown to light yellowish-brown fine quartz sand, minor medium sand (Tchs)
E201704089 Oswego Lake 2	0-10	pale brown to brown fine-to-medium quartz sand, trace coarse sand (TQg)
	10-25	light gray to very pale brown fine quartz sand (Tchs)
	25-32	yellow fine quartz sand (Tchs)
	32-35	white to very pale brown clay with thin beds of yellow fine sand (Tchc)
	35-51	very pale brown to light yellowish-brown fine-to-medium quartz sand (Tchs)
	51-53	white to very pale brown clay with thin beds of yellow fine sand (Tchc)
	53-99	yellow fine-to-medium quartz sand, trace coarse sand (Tchs)
E201704093 Oswego Lake 3	0-10	brownish-yellow fine-to-coarse quartz sand with few to some quartz pebbles (Qcm1)
	10-12	yellow to brownish-yellow fine-to-medium sand (Tchs)
	12-15	yellow to very pale brown clay (Tchc)
	15-99	yellow fine quartz sand, minor medium sand (Tchs)



VERTICAL EXAGGERATION 20X

Note: The Bass River corehole (Miller and others, 1998), one mile southeast of A', provides control to a total depth of 1,956 feet. Clay beds (unit Tchc) extending to A' are mapped from the corehole.



VERTICAL EXAGGERATION 20X