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U. S. GEOLOGICAL SURVEY
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INTRODUCTION

The Keswick Grove quadrangle is in the Pine Barrens region of the New Jersey Coastal Plain, in the southeastern part of the state. Outcropping geologic materials in the quadrangle include surficial deposits of late Miocene to Holocene age that overlie the Cohansey Formation, a marginal marine deposit of middle Miocene age. The surficial deposits include river, wetland, estuarine, hillslope, and windblown sediments. The Cohansey Formation includes beach, nearshore, bay, and marsh sediments deposited when sea level was, at times, more than 200 feet higher than at present in this region. As sea level lowered after the Cohansey was laid down, rivers flowing on the emerging Coastal Plain deposited the Beacon Hill Gravel, forming a broad regional river plain. With continued lowering of sea level, the regional river system shifted to the west of the quadrangle, and local streams began to erode into the Beacon Hill plain. During the latest Miocene, Pliocene, and Quaternary, stream and hillslope sediments were deposited in several stages as valleys were progressively deepened by stream incision, and widened by seepage erosion.

A brief summary of depositional settings of the Cohansey Formation, and of the geomorphic history of the quadrangle 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. Table 1 (in pamphlet) lists the formations penetrated in selected wells and test borings, as interpreted from drillers' descriptions and geophysical logs. Lithologic logs of four test borings drilled for this study are provided in table 2 (in pamphlet).

The cross sections show materials to a depth of 350 feet, which includes the Cohansey Formation (Tchs, Tchc), the Kirkwood Formation (Tkw), and the uppermost part of the Shark River Formation (Tsr), which was penetrated in three water wells in the northern part of the quadrangle (wells 10, 38, and 104 in table 1). Most domestic wells in the quadrangle, many of which are for lawn irrigation, and eight public-supply wells (wells 9, 57, 67, 88, 90, 92, 96, 99 in table 1), draw water from sand of the Cohansey Formation (Tchs) from depths of 50 to 175 feet. A few wells draw water from sand in the Kirkwood Formation, from depths of 150 to 200 feet. Four test holes in the quadrangle (wells 1, 2, 3, and 68 in table 1) penetrated below the Shark River, to total depths of 1621, 1700, 1653, and 1245 feet, respectively. Formations below the uppermost Shark River are shown on sections and described in Owens and others (1998) and Sugarman and others (2013). They are not shown or discussed on this map.

COHANSEY FORMATION

The Cohansey Formation consists of stacked successions composed of beach and nearshore sand (sand facies, Tchs) overlain by interbedded sand and clay (clay-sand facies, Tchc) deposited in tidal flats, bays, and coastal wetlands (Carter, 1972, 1978). Pollen and dinoflagellates recovered from peat beds in the Cohansey at Legler, about eight miles north of Keswick Grove, indicate a coastal swamp-tidal marsh environment (Rachele, 1976). The Legler pollen (Greller and Rachele, 1983), pollen from a corehole near Mays Landing, New Jersey (Owens and others, 1988), and dinocysts 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. Lower parts of the formation in updip locations like the map area may be age-equivalent to the upper Kirkwood downdip (for example, Kirkwood sequence 2, about 17-15 million years old (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 Keswick Grove quadrangle, sands in the Cohansey range from thin beds (generally less than 6 inches thick) having horizontal-planar and low-angle cross-bedded structure, to thick beds (as much as 3 feet thick) having tabular-planar to trough cross-bedded structure. In places, the sands are burrowed, with burrows defined by thin linings of white and yellow clay, and contain ghosts of shells weathered to white and yellow clay. The bedding structures, burrows, and shells indicate tidal-channel, tidal-flat, and beach depositional settings (Carter, 1972, 1978).

In the headwaters of the Sunken Brook, Green Brook, and Wrangel Brook valleys, some beds in the sand facies contain as much as 20% heavy minerals. The heavy minerals are 85-90% ilmenite and leucoxene, 1-4% zircon, kyanite, and sillimanite, and less than 1% staurolite, rutile, anatase, tourmaline, garnet, monazite, epidote, andalusite, and hypersthene (Markiewicz, 1969). These sands were mined in the 1970s for titanium from ilmenite and leucoxene. Large volumes of sand were mined by dredge from artificial lakes to depths of as much as 80 feet. Two of these lakes remain. Heavy minerals were separated by spiral gravity concentrators and titanium-bearing minerals were then separated from the other heavy minerals by electric and magnetic methods (American Smelting and Refining Company, undated). The non-ore sand was used to backfill some of the dredge ponds, and was also deposited in large onsite fills (afm on map).

In the Keswick Grove quadrangle, clays in the Cohansey are in thin beds or laminas generally less than 6 inches thick, and are consistently interbedded with sand. Most are oxidized to white, yellow, and reddish colors. Brown and black organic clay and peat was exposed or penetrated in hand-auger holes at several locations (noted by symbol "Tchco" on map): in the former clay pit two miles southwest of Keswick Grove, in the Wrangel Brook headwaters, in the bank of the dredge pond in the Green Brook valley, and in a former sand pit in the Factory Branch valley. Organic clay was also penetrated at depths of 33-37 and 60-86 feet in the Keswick Grove 3 test boring (table 2). Drillers' logs also report organic clay in a number of wells (intervals noted as "Tchco" in wells 17, 48, 52, 55, 56, 66, 70, 71, 76, 85, 89, 90, 92, 94, 96, 101, 106, 107, 122, 123 in table 1). Clayey strata are generally less than 25 feet thick, and extend less than one mile horizontally in outcrop. Some strata are continuous for more than 8 to 10 miles both downdip (northwest to southeast) and along strike (northeast to southwest). For example, the clay bed that crops out at an elevation of 150 feet in the southwest corner of the map can be traced along strike to the southwest for about 10 miles, and downdip to the southeast a similar distance, in the adjacent Brookville and Woodmansie quadrangles (Stanford 2010, 2011). The laminated bedding and thin but areally extensive geometry of the clay beds indicate bay or estuarine intertidal settings. Alluvial clays generally are thicker and more restricted areally because they are deposited in floodplains and abandoned river channels. The repetitive stacking of bay clays and beach sand (chiefly tidal delta and nearshore deposits) indicates that the Cohansey was deposited during several rises and falls of sea level during a 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 (Tbh), which caps the highest hills in the quadrangle, above an elevation of about 190 feet in three places on the west edge of the map area (fig. 1), is the earliest record of this drainage. The Beacon Hill consists of weathered quartz-chert gravel. Regionally, cross-beds, slope of the deposit, and gravel provenance indicate that the Beacon Hill was deposited by rivers draining southward from the Valley and Ridge province in northwestern New Jersey and southern New York (Owens and Minard, 1979; Stanford, 2009). Cross-beds exposed in one outcrop in the quadrangle (fig. 2) indicate southwestward paleoflow. 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 during 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 to the west of the Keswick Grove quadrangle. The area of the quadrangle became an upland from which local streams drained eastward to the Atlantic. 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, 20 to 50 feet below the level of the former Beacon Hill plain. These deposits are mapped as Upland Gravel, High Phase (Tg). Today, owing to topographic inversion, they cap interfluves and hilltops at elevations of 140 to 180 feet in the western part of the quadrangle. Purple arrows on figure 1 show drainage routes of streams at this time, as inferred from the location and elevation of the interfluve deposits.

A renewed period of lowering sea level in the Pliocene and early Pleistocene (approximately 3 Ma to 800,000 years ago (800 ka)) led to another period of valley incision. Groundwater seepage and channel and slope erosion reworked both the Beacon Hill and Upland gravels and deposited the Upland Gravel, Lower Phase (TQg) in shallow valleys 20 to 50 feet below the Upland Gravel, High Phase. These deposits today cap low interfluves and, on the western edge of the quadrangle, form more extensive mantles in head-of-valley areas and upper slopes. The base of these deposits descends from an elevation of 150 to 160 feet on the west to an elevation of 60 to 80 feet on the east edge of the quadrangle. Stream drainage at this time, inferred from interfluve deposits, is shown by red arrows on figure 1.

Continuing stream incision in the middle and late Pleistocene (about 800 to 20 ka) formed the modern valley network. Sediments laid down in modern valleys include Upper and Lower Terrace Deposits (Qtuo, Qtu, and Qtl), inactive deposits in dry valleys (Qald), and active floodplain and wetland (Qals) deposits in valley bottoms. Like the upland gravels, the terrace and floodplain deposits include 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 formed by accumulation of organic matter in swamps and bogs.

Upper Terrace Deposits form terraces and pediments 5 to 25 feet above modern wetlands and are the most widespread deposit in modern valleys. They include sediments laid down during periods of cold climate, and during periods of temperate climate when sea level was high, in the middle and late Pleistocene. During cold periods, permafrost impeded infiltration of rainfall and snowmelt and this, in turn, accelerated groundwater seepage and slope erosion, increasing the amount of sediment entering valleys. During periods of high sea level, the lower reaches of streams in the quadrangle were close to sea level, favoring deposition.

The Upper Terrace Deposits include higher, older, more-eroded sediments (Upper Terrace Deposits, older phase, Qtuo) capping the divides between Cedar Creek and Davenport Branch and between Davenport Branch and Wrangel Brook. These sediments form terraces as much as 20 feet higher than the lower, younger, less-eroded upper terrace deposits (Qtu) that border the modern floodplain. The older terraces decline eastward from elevations of about 110 feet to an elevation of 65 to 70 feet, where they grade to the Cape May Formation, unit 1, marine terrace (see below). This relationship indicates that the older terrace deposits are fluvial sediments laid down during the sea-level highstand recorded by the Cape May Formation, unit 1. Similarly, the younger upper terraces grade eastward to the Cape May Formation, unit 2, marine terrace east of the quadrangle, indicating that the younger terraces were laid down, in part, during the sea-level highstand at about 125 ka, when the Cape May Formation, unit 2, was laid down.

The Cape May Formation, unit 1 (Qcm1) consists of sand and gravel deposits forming erosional remnants of a marine terrace at a surface elevation of 60 to 70 feet in the eastern part of the quadrangle (east of the blue line on figure 1), in the Wrangel Brook, Davenport Branch, and Cedar Creek valleys. This terrace was laid down during a middle or early Pleistocene highstand when sea level was 60 to 70 feet higher than at present in this area. Global records show a period of sea level this high about 400 ka (Olson and Hearty, 2009). The Qcm1 deposits may have been laid down at this time, or possibly earlier.

During the period of lowered sea level following deposition of units Qcm1 and Qtuo, streams incised into the terraces, and drainage on the terraces reoriented from southeasterly to east-northeast. Headwaters of Davenport Branch and, possibly, Wrangel Brook, have a southeasterly trend suggesting that they drained into the Cedar Creek valley during deposition of unit Qtuo (orange arrows on fig. 1). This southeasterly to east-northeast drainage reorientation is evident in many of the valleys along the northern New Jersey coast. It is likely a consequence of the expansion of the Atlantic Ocean into the lower Hudson valley, eventually forming what is now the New York Bight, through the early and middle Pleistocene due to fluvial erosion by the Hudson River during periods of low sea level and marine erosion during periods of high sea level. This expansion brought sea level closer to the northeast, gradually shifting stream drainage in that direction, particularly where streams could establish new routes on the Cape May marine terraces. In the quadrangle this reorientation, began in the transition from Qtuo terraces to the Qtu terraces after the Qcm1 highstand, continued after the highstand at 125 ka, as recorded in the transition from deposition of Qtu (pink arrows on fig. 1) to a more northeasterly flow during deposition of the lower terraces (Qtl) and the modern floodplain (Qals). Active incision along present streams (green arrows on fig. 1), marked by ingrown meanders and embayed seepage scarps at the edge of the modern floodplain, record the steeper gradients of northeast-trending stream reaches.

Lower Terrace Deposits (Qtl) form low, generally wet, terraces less than 10 feet above modern floodplains. They are of much smaller extent than the upper terraces. They generally form narrow, discontinuous, wet terraces along modern streams, or low islands within modern floodplains. In two locations: in the headwaters of Jakes Branch and Green Brook, lower terraces cross divides (green arrows on fig. 1). Here, groundwater seepage eroded the low divides, allowing east-flowing tributaries to capture former south-flowing drainage.

The lower terraces formed from stream and seepage erosion of the Upper Terrace Deposits, probably during or slightly after the last period of cold climate around 25 ka. Braided channels scribe the lower terraces in two places along Cedar Creek (symboled on map). These braided networks indicate that streams were choked with sand and gravel during deposition of the terraces, causing channels to aggrade and split. The high sediment supply indicates increased erosion by groundwater seepage and runoff, most likely when permafrost impeded infiltration. Dry-valley alluvium (Qald), which grades to the lower terraces in places, was likely also laid down at this time.

Windblown deposits (Qe) form narrow, linear dune ridges as much as 1.5 miles long (yellow lines on fig. 1). They are as much as 15 feet high but are commonly 3 to 6 feet high. Their long axes are oriented east-west to northwest-southeast. A few have crescentic form, and the crescents open to the east. If these are longitudinal dunes formed parallel to the prevailing wind direction, they indicate that winds were blowing from the west and northwest during their deposition. Most occur on the upper terraces or the Qcm1 marine terrace but a few are on lower terraces and on upland surfaces above the upper terraces. Based on this distribution, the windblown deposits were laid down after deposition of the upper terraces, and continuing during deposition of the lower terraces, during the period of intermittently cold climate about 80 to 15 ka known as the Wisconsinan. 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 Pine Barrens (Buell, 1970; Florer, 1972; Stanford, 2000).

During periods of cold climate in the middle and late Pleistocene, permafrost formed in the Pine Barrens region (Wolfe, 1953; French and others, 2003). During thaws, permafrost at depth acted as an impermeable layer and supported the water table at a higher elevation than in temperate climate. Seepage features, including inactive scarps and amphitheater-shaped hollows, developed in landscape positions that are dry today. These are indicated by special symbols on the map. Other permafrost-related features include thermokarst basins and cryoturbation structures. Thermokarst basins are shallow depressions that form when subsurface ice lenses melt (Wolfe, 1953). These basins (shown on map) typically form in sandy deposits in lowlands with high water table, or, more rarely, in upland settings where shallow clay layers impede groundwater drainage. A few basins, for example, those bordering eolian deposits in the Sunken Branch valley, were likely formed or enlarged by wind erosion (French and Demitroff, 2001). A few others along modern floodplains (for example, in the Michaels Branch valley) may have been created or enlarged by seepage erosion. Cryoturbation structures are folds and involutions in the upper several feet of surface materials. These structures formed by density flow of waterlogged sediment during melting of permafrost (French and others, 2005). They are common throughout the quadrangle, especially on older surficial deposits (units TQg, Tg, and Tbh) where clayey soil horizons provide cohesion and water retention.

DESCRIPTION OF MAP UNITS

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

afm MINE TAILINGS—Fine-to-medium quartz sand, minor coarse sand, very pale brown to light gray. As much as 50 feet thick. Consists of waste sand from the Cohansey Formation, placed in fills after being processed to remove titanium-bearing minerals.

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 and black peat and gyttja (gel-like organic mud). Peat is as much as 8 feet, but generally less than 4 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 floodplains and 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 consist of quartz. In dry valley bottoms forming headwater reaches of streams. These valleys lack channels or other signs of surface-water flow. They may have formed under cold-climate conditions when permafrost impeded infiltration, increasing surface runoff. The deposits are therefore largely relict.

Qe EOLIAN DEPOSITS—Fine-to-medium quartz sand; very pale brown, white. As much as 15 feet thick. Form long, linear dune ridges and, less commonly, crescentic or elliptical areas of multiple dune ridges. Sand is from the Cohansey Formation, upper terrace deposits, and, less commonly, lower terrace deposits.

Qtl LOWER TERRACE DEPOSITS—Fine-to-medium sand, pebble gravel, minor coarse sand; light gray, brown, dark brown. As much as 10 feet thick. Sand and gravel consist of quartz. Form terraces and pediments in valley bottoms with surfaces 2 to 10 feet above modern floodplains. Include both stratified stream-channel 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 where there is poor drainage. Gravel is more abundant in lower terrace deposits than in upper terrace deposits 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 20 feet thick, generally less than 10 feet thick. Sand and gravel are quartz. Form terraces and pediments with surfaces 5 to 25 feet above modern floodplains. Include stratified stream-channel deposits and poorly stratified to unstratified deposits laid down by groundwater seepage on pediments.

Qtuo UPPER TERRACE DEPOSITS, OLDER PHASE—Sand and pebble gravel as in unit Qtu, forming eroded terraces as much as 20 feet higher than adjacent upper terraces.

Qcm1 CAPE MAY FORMATION, UNIT 1— Fine-to-medium sand, pebble gravel, minor coarse sand; yellowish-brown, yellow, very pale brown. Sand and gravel consist of quartz. As much as 20 feet thick. In erosional remnants of a marine terrace with surfaces up to 75 feet in elevation in the Cedar Creek, Davenport Branch, and Wrangel Brook valleys. These are the inland edge of a marine terrace formed during a middle or early Pleistocene sea-level highstand.

TQg UPLAND GRAVEL, LOWER PHASE—Fine-to-medium sand, minor coarse sand, slightly clayey in places, and pebble gravel; yellow, very pale brown, reddish-yellow. Sand and gravel consist of quartz and a trace (<1%) of white weathered chert in the coarse sand-to-fine pebble gravel fraction. Clay is chiefly from weathering of chert. As much as 10 feet thick, generally less than 5 feet thick. Occurs as erosional remnants on lower interfluves and hilltops 70 to 150 feet in elevation, and as more continuous deposits in headwater valleys, above 150 feet in elevation, on the western edge of the quadrangle. Includes stratified stream-channel deposits, poorly stratified deposits laid down by groundwater seepage on pediments, and pebble concentrates formed by winnowing of sand from older surficial deposits, and from 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. Sand and gravel consist of quartz, and as much as 5 percent 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. As much as 15 feet thick. Occurs as erosional remnants on hilltops on the western edge of the quadrangle, from 140 to 180 feet in elevation. Includes stratified and cross-bedded stream-channel deposits and poorly stratified to unstratified pebble concentrates formed by washing of sand and clay from the Beacon Hill Gravel by groundwater sapping or surface runoff.

Tbh BEACON HILL GRAVEL—Medium-to-very coarse sand, some fine-to-medium sand, clayey to very clayey in places, pebble gravel; reddish-yellow, yellow, brownish-yellow, red, very pale brown. Clay-size material chiefly is from weathering of chert and feldspar. Sand and gravel consist of quartz and as much as 15 percent brown and dark gray chert; gravel includes red and gray sandstone and siltstone and white granite and gneiss as rarities; sand includes traces of weathered feldspar. Rarely, chert pebbles contain fossil molds of brachiopods, pelecypods, and corals of Paleozoic age. Most chert is weathered to white and yellow clay-size material. As much as 15 feet thick. Generally unstratified, or poorly stratified, owing to weathering, cryoturbation, and bioturbation. Tabular, planar cross-bedding is locally preserved (fig. 2). Caps highest hills in the quadrangle, above 190 feet in elevation.

COHANSEY FORMATION—Fine-to-medium quartz sand, and 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. Divided into two map units: a sand facies and a clay-sand facies. Total thickness in the quadrangle is as much as 220 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 of fine-to-medium pebbles; very pale brown, brownish-yellow, white, reddish-yellow, rarely reddish-brown. Well-stratified to unstratified; stratification varies from thin, planar, subhorizontal beds to large-scale trough and planar cross-bedding (fig. 3). Sand consists of quartz; coarse-to-very coarse sand may include as much as 5 percent 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 consist chiefly of quartz and minor gray chert and rare gray quartzite. 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, and where iron-bearing heavy minerals are abundant, 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 resembling the clay-sand facies described below. The sand facies is as much as 130 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 0.25 to 3 inches thick, rarely as much as 3 feet thick, sand beds are commonly 1 to 6 inches thick but are as much as 2 feet thick (fig. 4). Clays are white, yellow, very pale brown, reddish-yellow, light gray; sands are yellow, brownish-yellow, very pale brown, reddish-yellow. Rarely, clays are brown to dark brown and contain organic matter. As much as 25 feet thick.

Tkw KIRKWOOD FORMATION—Fine sand, fine-to-medium sand, sandy clay, and clay, minor coarse sand and pebbles; gray, dark gray, brown. Sand consists of quartz with some mica and lignite. Contains mollusk shells in places. In subsurface only. As much as 200 feet thick in central and southern part of quadrangle, thins to 100 feet in northern part. Kirkwood sediments in the quadrangle are in the "lower Kirkwood sequence" of Sugarman and others (1993) and in the lower and Shiloh Marl members of Owens and others (1998). These members are of early Miocene age, based on strontium stable-isotope ratios and diatoms (Sugarman and others, 1993).

Tsr SHARK RIVER FORMATION—Clayey glauconitic quartz sand, gray to dark green. In subsurface only. Approximately 280 feet thick in the Double Trouble corehole, about 2 miles east of the east edge of the quadrangle, on the north bank of Cedar Creek (Browning and others, 2011). Middle Eocene in age based on dinoflagellates, foraminifers, calcareous nannofossils, and strontium stable isotope ratios from mollusk shells, in the Double Trouble corehole (Browning and others, 2011).

MAP SYMBOLS

Contact of surficial deposits—Solid where well-defined by landforms visible on 1:12,000 stereo airphotos and LiDAR imagery; long-dashed where approximately located; short-dashed where gradational or featheredged; dotted where covered by water, where exposed in excavations, or where deposit has been leveled or removed by urbanization. Contacts in urban areas and beneath large areas of mine tailings based on 1961 stereo aerial photography. Some deposits beneath mine tailings may have been removed before emplacement of the tailings.

Contact of Cohansey facies—Approximately located. Dotted where concealed by surficial deposits.

3 / Qe3/Qtu Material penetrated by hand-auger hole, or observed in exposure or excavation. Number indicates thickness of surficial material, in feet, where penetrated. Symbols without a thickness value within surficial deposits indicate that the 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. Number next to lower unit indicates total depth of observed section, if deeper than 6 feet. Unit "Tchc" indicates isolated clay within Cohansey Formation, Sand Facies. "Tchco" indicates organic clay within Cohansey Formation.

Material formerly observed—Recorded in N. J. Geological and Water Survey files. Abbreviations as above.

figure 2 Photograph location

47 Well or test boring—Location accurate to within 200 feet. Log of formations penetrated shown in table 1.

105 Well or test boring—Location accurate to within 500 feet. Log of formations penetrated shown in table 1.

Geophysical log—On sections. Gamma-ray log is indicated by red line, with radiation intensity increasing to right. Resistivity log is indicated by blue line, with resistance increasing to right.

Paleocurrent direction—Arrow indicates direction of streamflow, as inferred from dip of planar, tabular cross-beds observed at point marked by x.

Head of seepage valley—Line at top of scarp, ticks on slope. Marks head of small valleys and hillslope embayments formed by seepage erosion. Scarps that do not occur above active seeps are relict. They mark valleys formed during times when the water table was higher than at present.

Active seepage scarp—Line at foot of scarp. Water drains downhill from this position.

Abandoned channel—Line in channel axis. Marks braided-channel network on lower terraces in Cedar Creek valley.

Iron-cemented sand—Extensive iron cementation or hardening in Cohansey Formation, sand facies.

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

Excavation perimeter—Line encloses excavated area. Topography within these areas differs from that on the base map. Contacts show units as exposed in 2013.

Sand pit—Active in 2013.

Sand pit—Inactive in 2013.

c Clay pit—Inactive in 2013.

Ti Titanium pit—Inactive in 2013.

Water—Dredge ponds of former titanium pit. Contacts within these ponds show the pre-mine outcrop pattern.

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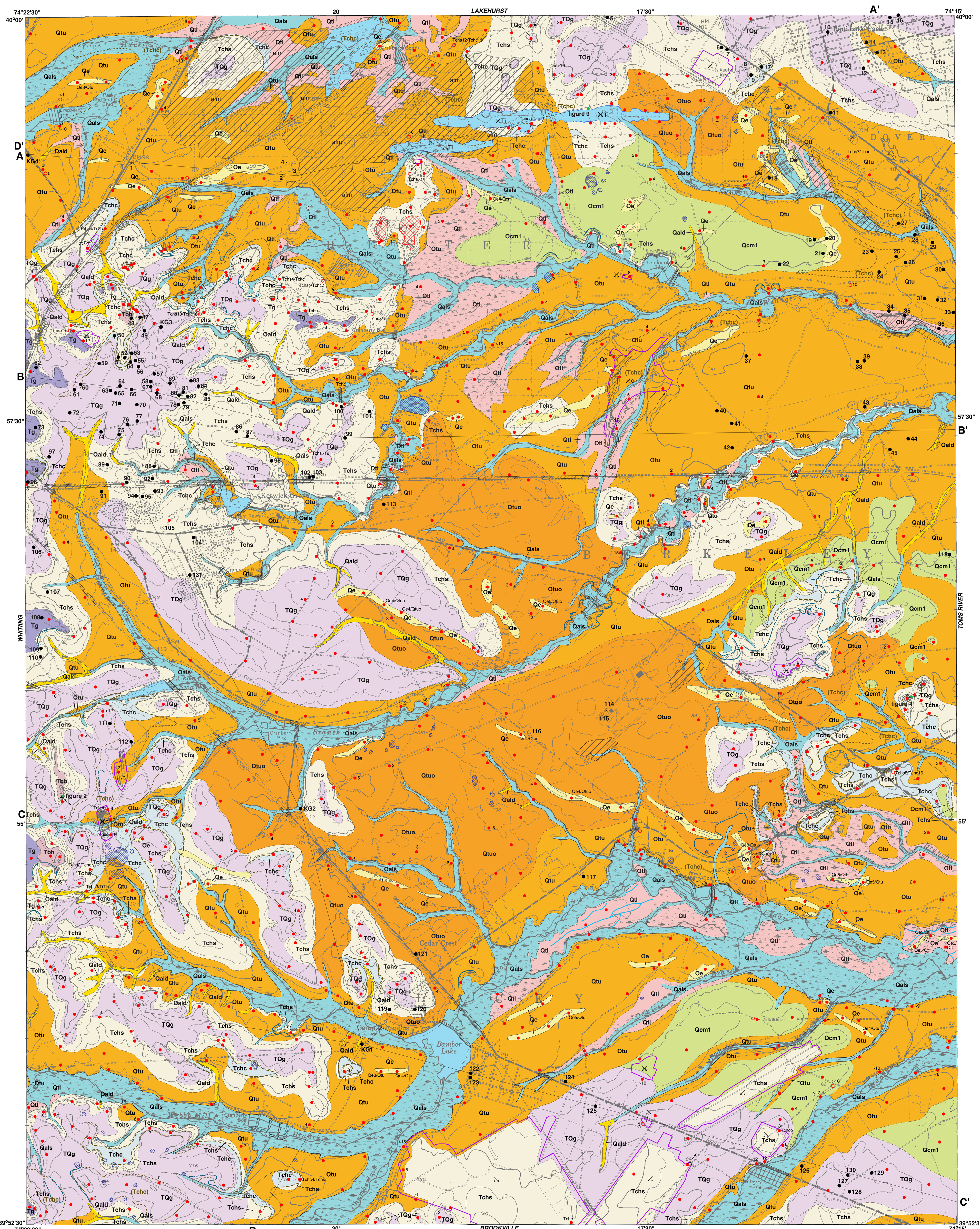


Base from U. S. Geological Survey, 1957
Photorevised 1971
North American Datum of 1927

APPROXIMATE MEAN DECLINATION, 1971

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

LOCATION IN NEW JERSEY

Geology mapped 2012-13
Drilling by G. Steidl and J. Curran
Geophysical logging by J. Curran and M. Gagliano
Drilling assistance by I. Snook, M. French, M. Castelli, M. Gagliano
Cartography by S. Stanford

Research supported by the U. S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number G12AC20227.
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.

GEOLOGY OF THE KESWICK GROVE QUADRANGLE OCEAN COUNTY, NEW JERSEY

by
Scott D. Stanford
2013

CORRELATION OF MAP UNITS

Map units	Epoch	
afm, Qals	Holocene	
5-10 feet of stream incision		
Qald, Qtl, Qe	late	Pleistocene
10-20 feet of stream incision		
Qtu	middle	Pleistocene
10-20 feet of stream incision		
Qtuo, Qcm1	middle	Pleistocene
20-40 feet of stream incision, extensive erosion		
TQg	early / Pliocene	Pleistocene / Pliocene
20-50 feet of stream incision, extensive erosion		
Tg	late	Miocene
20-50 feet of stream incision, extensive erosion		
Tbh	late	Miocene
UNCONFORMITY?		
Tchs, Tchc	middle	Miocene
UNCONFORMITY?		
Tkw	early	Miocene
UNCONFORMITY		
Tsr	middle	Eocene

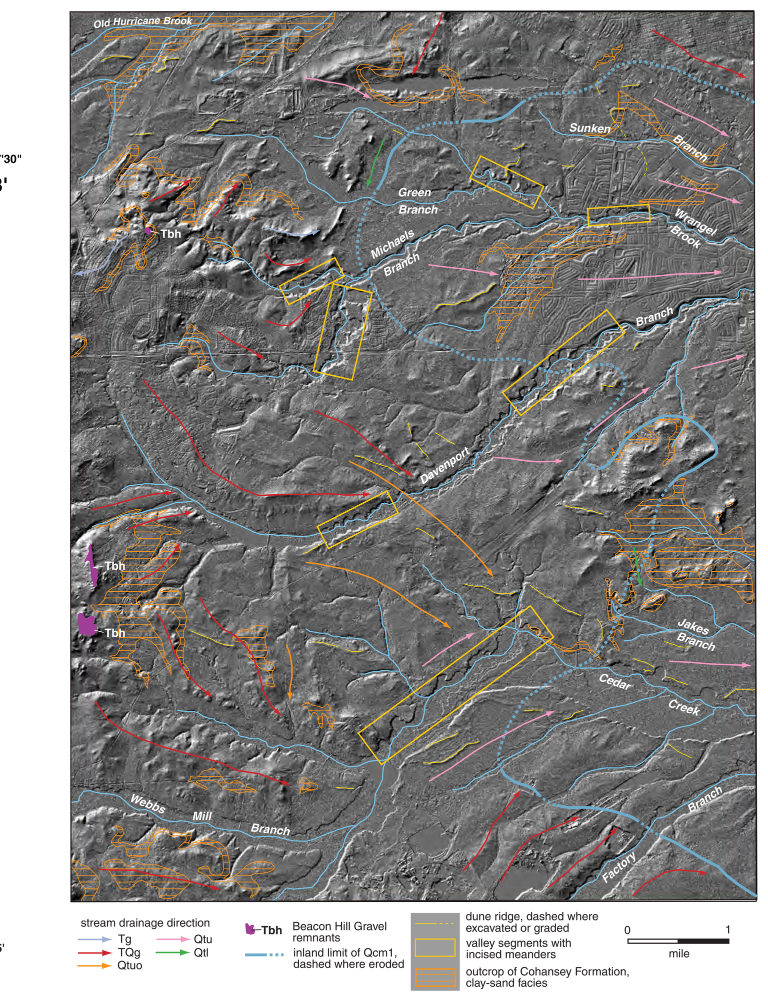


Figure 1. Geomorphic features and outcrop area of clay-sand facies of the Cohansey Formation in the Keswick Grove quadrangle. Shaded relief image from N. J. Department of Environmental Protection LiDAR data.

Figure 2. Coarse sand and fine gravel of the Beacon Hill Gravel (above line) overlying fine-to-medium sand of the Cohansey Formation, sand facies. Tabular, planar cross-bedding in the Beacon Hill indicates streamflow to left. Dot on inset shows location.

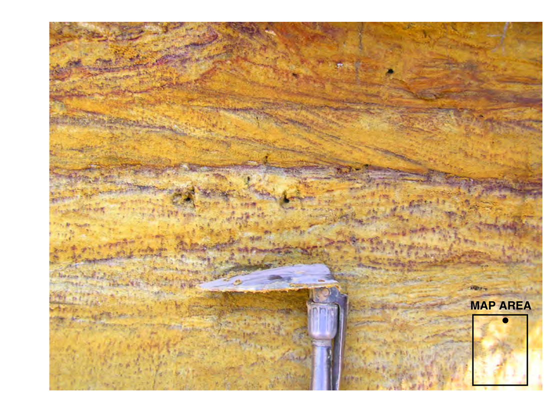


Figure 3. Plane bedding (below shovel head) and low-angle cross-bedding (above shovel head) in Cohansey Formation, sand facies. Weathering of heavy minerals to red and purple oxides highlights bedding features. Dot on inset shows location.

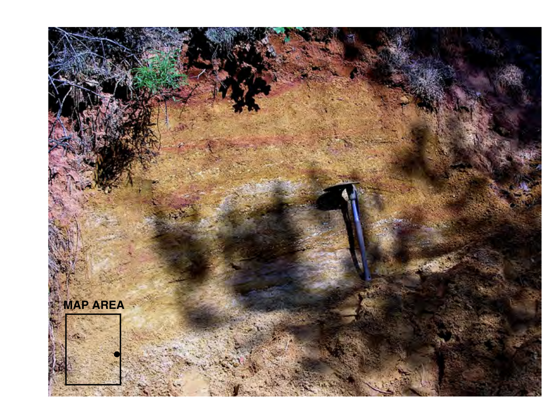
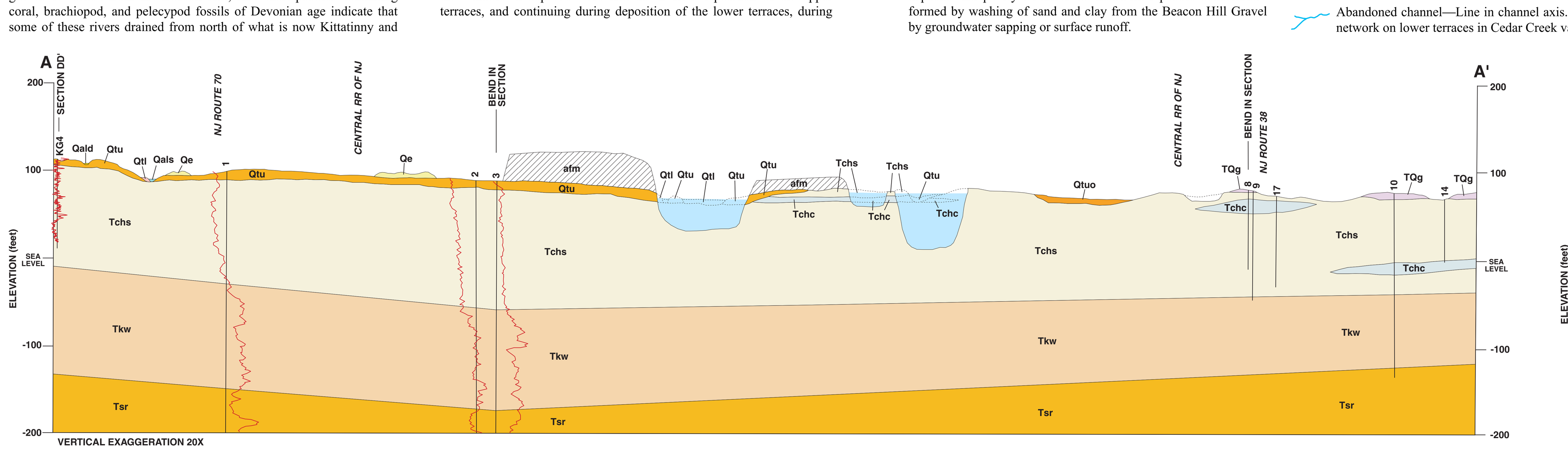
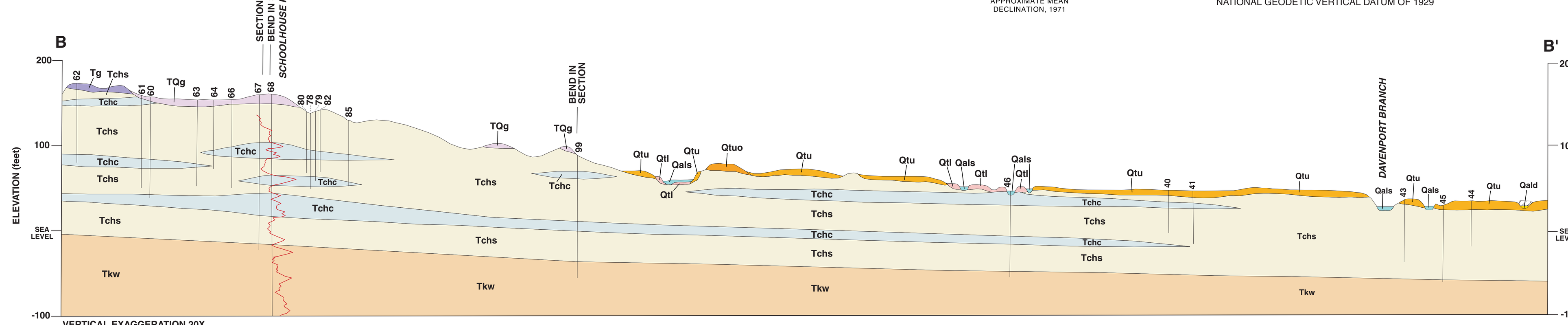


Figure 4. Interbedded clay laminas (thin white layers) and sand beds (red, yellow, and grayish-white layers) of the Cohansey Formation, clay-sand facies. Dot on inset shows location.



VERTICAL EXAGGERATION 20X



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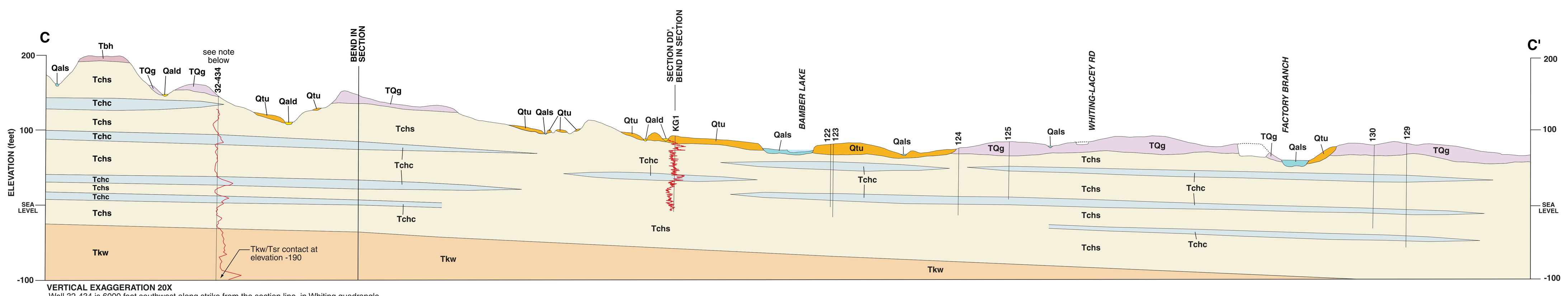
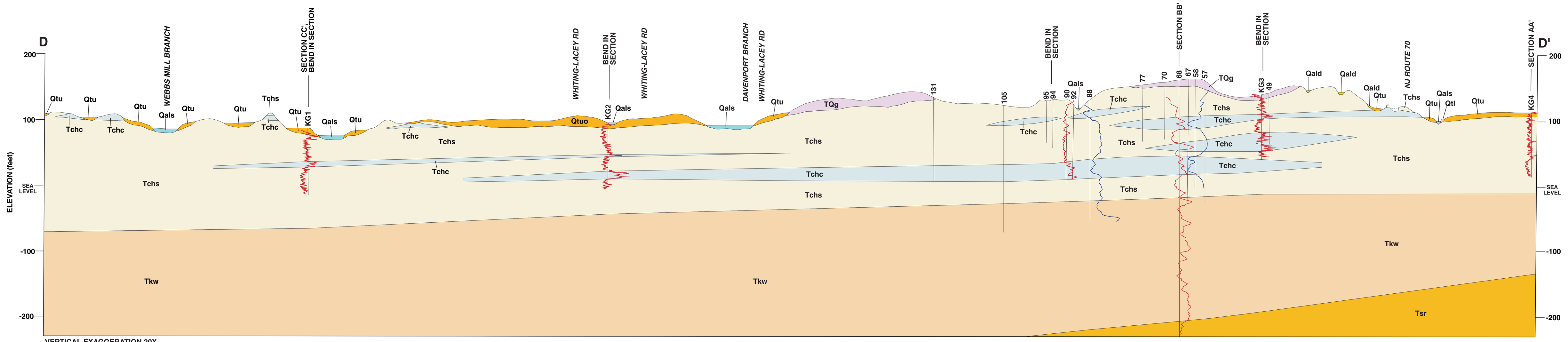


VERTICAL EXAGGERATION 20X
Well 32-434 is 6000 feet southwest along strike from the section line, in Whiting quadrangle.



VERTICAL EXAGGERATION 20X

Geology of the Keswick Grove Quadrangle
Ocean County, New Jersey

New Jersey Geological and Water Survey
Open-File Map OFM 100
2013

pamphlet with tables 1 and 2 to accompany map

Table 1. Selected well and boring records.

Well Number	Identifier[1]	Formations Penetrated[2]
1	32-1342, G	92 Tchs 110 Tchc 122 Tchs 235 Tkw 1621 TD
2	33-1341, G	35 Tchs 150 Tchs+Tchc 235 Tkw 1700 TD
3	33-1343, G	150 Tchs 235 Tkw 1653 TD
4	32-5701	43 Tchs 50 Tchc 71 Tchs
5	33-12531	10 Q 21 Tchs 29 Tchc 37 Tchs 53 Tchc 72 Tchs 73 Tchc
6	33-27513	19 Tchs 22 Tchc 77 Tchs
7	33-27512	16 Tchs 20 Tchc 70 Tchs
8	33-22726	25 Q over Tchs, Tchc at base 90 Tchs
9	29-6137	10 Tchc 95 Tchs 98 Tchc 120 Tchs or Tkw
10	33-23246	80 Tchs 95 Tchc 110 Tchs 195 Tkw 210 Tsr
11	33-27673	9 Tchs 13 Tchc 25 Tchs+Tchc
12	33-12372	51 Tchs 63 Tchs+Tchc 80 Tchs 83 Tchs+Tchc
13	33-24392	71 Tchs+Tchc 98 Tchs 110 Tchs+Tchc 207 Tkw 210 Tsr
14	33-24797	10 Q 36 Tchs 38 Tchc 70 Tchs 71 Tchc
15	33-20931	17 Q 25 Tchs+Tchc 47 Tchs 49 Tchc 63 Tchs 66 Tchc 112 Tchs
16	33-573	12 Q 33 Tchs 49 Tchc 68 Tchs+Tchc 76 Tchs
17	33-26272	25 Tchc 30 Tchs 40 Tchco 58 Tchs 70 Tchc 98 Tchs 102 Tchco
18	33-10169	28 Tchs 30 Tchc 87 Tchs 90 Tchc
19	33-7603	2 Tchs 27 Tchs+Tchc 64 Tchs 70 Tchc
20	33-25327	10 Tchs 20 Tchs+Tchc 22 Tchs 27 Tchc 64 Tchs
21	33-19089	47 Tchs 54 Tchc 60 Tchs 65 Tchc 78 Tchs 80 Tchc
22	33-11936	8 Tchs 19 Tchc 65 Tchs 80 Tchc
23	33-7890	6 fill over Q over Tchs 18 Tchc 33 Tchs 45 Tchs+Tchc 67 Tchs 70 Tchc+Tchs
24	33-7748	11 Tchc 60 Tchs 70 Tchc+Tchs
25	33-7749	9 Q over Tchc 19 Tchc+Tchs 70 Tchs 80 Tchc+Tchs
26	33-8573	27 Tchs 34 Tchc 52 Tchs 55 Tchc
27	33-12269	6 Q 16 Tchc 21 Tchs+Tchc 54 Tchs 58 Tchc
28	33-12917	11 Tchs 24 Tchc 60 Tchs
29	33-11633	5 fill 9 Tchs 39 Tchc 62 Tchs 80 Tchc
30	33-12560	10 Tchs 22 Tchs+Tchc 65 Tchs 70 Tchc
31	33-26008	10 Tchs 20 Tchc 40 Tchs 50 Tchc 69 Tchs
32	33-22721	8 Q 15 Tchs+Tchc 60 Tchs
33	33-20731	45 Tchs 55 Tchc 78 Tchs
34	33-26102	41 Tchs 42 Tchc
35	33-12049	3 Q 47 Tchs 50 Tchc
36	33-10430	7 fill 11 Qals 27 Tchs 48 Tchc 65 Tchs
37	33-22744	10 Tchs 15 Tchc 50 Tchs 55 Tchc 69 Tchs
38	33-7960	15 Tchs 25 Tchc 95 Tchs 195 Tkw 260 Tkw over Tsr
39	33-7755	23 Tchs+Tchc 58 Tchs 60 Tchc 97 Tchs 160 Tkw
40	33-11428	3 fill 22 Tchs+Tchc 50 Tchs
41	33-10480	2 fill 15 Tchs+Tchc 41 Tchs 47 Tchc 60 Tchs, minor Tchc

Well Number	Identifier[1]	Formations Penetrated[2]
42	33-26308	32 Tchs 37 Tchc 65 Tchs 68 Tchc
43	33-21138	10 Tchc 47 Tchs 49 Tchc 78 Tchs
44	33-28000	14 Q 52 Tchs
45	33-24453	16 Q 18 Tchc 73 Tchs 75 Tchc 95 Tchs 100 Tkw
46	33-835	14 Tchc 52 Tchs 63 Tchc 94 Tchs 100 Tkw
47	32-15029	12 Tchs 15 Tchc 60 Tchs 80 Tchc 90 Tchc+Tchs 104 Tchs
48	32-7523	6 Q or fill 12 Tchc 30 Tchs+Tchc 42 Tchs 82 Tchs+Tchc 96 Tchs+Tchco 120 Tchs+Tchc
49	32-12887	10 Tchs 25 Tchs+Tchc 40 Tchs 42 Tchc 75 Tchs 80 Tchc+Tchs
50	32-12691	20 Q over Tchc 70 Tchs 95 Tchc 110 Tchs
51	32-14695	30 Tchs+Tchc 35 Tchc 70 Tchs 85 Tchc 105 Tchs
52	32-10059	5 Q 17 Tchc+Tchs 65 Tchs 66 Tchco 120 Tchs
53	32-10550	62 Tchs 67 Tchc 82 Tchs+Tchc 110 Tchs
54	32-7585	33 Tchs 45 Tchc 52 Tchs 65 Tchc+Tchs 79 Tchs 81 Tchc
55	32-8625	3 fill 13 Tchs 20 Tchc 35 Tchs+Tchc 52 Tchs 57 Tchs+Tchc 61 Tchco 90 Tchs
56	32-13451	30 Tchs 55 Tchs+Tchc 60 Tchco 62 Tchc 80 Tchs
57	32-2890, E	10 Tchs 29 Tchs+Tchc 38 Tchc 65 Tchs 70 Tchc 113 Tchs 114 Tchc 120 Tchs 133 Tchc 175 Tchs 184 Tkw
58	32-2892, E	32 Tchs 58 Tchc 66 Tchs 75 Tchc 118 Tchs 136 Tchc 169 Tchs
59	32-13495	20 Tchs+Tchc 60 Tchs 70 Tchc 80 Tchs+Tchc 100 Tchs
60	32-9458	5 Q 12 Tchc 45 Tchs 65 Tchs+Tchc 78 Tchs 82 Tchc 97 Tchs 118 Tchs+Tchc 120 Tkw
61	32-11353	15 Q over Tchc 47 Tchs 75 Tchs+Tchc 95 Tchs 98 Tchc 109 Tchs 110 Tchc
62	32-5631	22 Q over Tchs 26 Tchc 70 Tchs 75 Tchc 85 Tchs 95 Tchc
63	32-9665	2 fill 77 Tchs 81 Tchc 101 Tchs+Tchc
64	32-13511	60 Tchs 62 Tchc 80 Tchs
65	32-13914	60 Tchs 62 Tchc 80 Tchs
66	32-6229	45 Tchs 52 Tchco 62 Tchc 105 Tchs
67	32-2893, E	32 Tchs 33 Tchc 43 Tchs 46 Tchc+Tchs 71 Tchc 113 Tchs 117 Tchc 124 Tchs 129 Tchc 136 Tchs+Tchc 177 Tchs 185 Tkw
68	32-28003, G, E	62 Tchs 66 Tchc 73 Tchs 77 Tchc 178 Tchs 365 Tkw 1245 TD
69	32-14202	20 Tchs 40 Tchs+Tchc 50 Tchs 55 Tchco 90 Tchs
70	32-12926	55 Tchs 60 Tchco 65 Tchc 70 Tchs 75 Tchc 89 Tchs
71	32-8782	35 Tchs+Tchc 41 Tchs 50 Tchc 62 Tchco 79 Tchs 80 Tchc 94 Tchs
72	32-11531	10 Tchs+Tchc 15 Tchc 55 Tchs 60 Tchc 85 Tchs
73	32-13750	20 Tchs+Tchc 75 Tchs 100 Tchc 120 Tchs
74	32-12821	20 Tchs+Tchc 30 Tchs 40 Tchc 55 Tchs+Tchc 62 Tchc 78 Tchs
75	32-14104	39 Tchs+Tchc 52 Tchs 58 Tchc 76 Tchs 80 Tchs+Tchc
76	32-15197	40 Tchs 50 Tchc 55 Tchs 70 Tchco 89 Tchs
77	32-8403	30 Tchs 50 Tchs+Tchc 65 Tchco 86 Tchs
78	32-7339	6 Tchs 24 Tchc 52 Tchs 55 Tchc 75 Tchs+Tchc 90 Tchc
79	32-7929	11 Tchc 32 Tchs 55 Tchs+Tchc 81 Tchs
80	32-7397	8 Q 48 Tchs 55 Tchc 65 Tchs+Tchc 75 Tchs
81	32-9062	20 Tchs 23 Tchc 33 Tchs+Tchc 63 Tchs
82	32-6080	50 Tchs 60 Tchc 75 Tchs
83	32-7521	4 fill 41 Tchs 47 Tchc 80 Tchs
84	32-6382	4 Tchc 35 Tchs 42 Tchc 56 Tchs+Tchc 77 Tchs 80 Tchs+Tchc
85	32-9443	6 Tchs 25 Tchc 47 Tchs+Tchc 48 Tchco 80 Tchs
86	32-8143	4 Tchs 15 Tchc+Tchs 75 Tchs 80 Tchc
87	32-9808	3 fill 18 Tchs 44 Tchs 47 Tchc 65 Tchs
88	32-1985, E	17 Tchs 24 Tchc 88 Tchs 115 Tchc 150 Tchs 184 Tkw
89	32-13441	40 Tchs 45 Tchc 50 Tchs+Tchc 58 Tchco 79 Tchs
90	32-1072, G	33 Tchs 37 Tchc 47 Tchs 54 Tchc 59 Tchs 62 Tchco 105 Tchs 134 Tchs+Tchc
91	32-5954	11 Q 22 Tchs+Tchc 52 Tchc 79 Tchs 80 Tchc
92	32-874	16 Tchs 28 Tchc+Tchco 72 Tchs+Tchc 92 Tchc 107 Tchs+Tchc 113 Tchco
93	32-7399	4 fill 41 Tchs 47 Tchc 80 Tchs
94	32-11315	30 Tchs 53 Tchs+Tchc 57 Tchco 71 Tchs
95	32-14941	10 Tchc 15 Tchs 40 Tchc 69 Tchs
96	32-4174	12 Tchs 15 Tchc+Tchs 73 Tchs 94 Tchc+Tchs 96 Tchs 100 Tchco 171 Tchs 215 Tkw

Well Number	Identifier[1]	Formations Penetrated[2]
97	32-7718	3 fill 56 Tchs 74 Tchs+Tchc 89 Tchs 91 Tchc
98	32-12070	20 Tchs 25 Tchc 35 Tchs
99	32-7287	2 fill 4 Tchs+Tchc 18 Tchs 28 Tchc 56 Tchc+Tchs 63 Tchs 83 Tchs+Tchc 124 Tchs 146 Tkw
100	32-12768	40 Tchs 62 Tchs+Tchc 64 Tchc 79 Tchs+Tchc
101	32-11626	55 Tchs 63 Tchco 80 Tchs
102	32-12787	8 Tchs 25 Tchs+Tchc 52 Tchs+Tchc 69 Tchs 72 Tchc
103	32-7931	13 Tchc 27 Tchs 34 Tchc 50 Tchs+Tchc
104	32-489	155 Tchs (? anomalous depth) 250 Tkw 257 Tsr
105	32-748	13 Tchs 25 Tchs+Tchc 36 Tchc 75 Tchs 76 Tchc 167 Tchs 198 Tkw
106	32-9581	23 Tchs+Tchc 39 Tchs 48 Tchs+Tchc 60 Tchs 67 Tchc 75 Tchs 90 Tchc+Tchco 100 Tchs
107	32-15406	20 Tchc 40 Tchs+Tchc 55 Tchs 75 Tchc+Tchs 80 Tchco 85 Tchc
108	32-13368	12 Q 35 Tchs+Tchc 85 Tchs 90 Tchs+Tchc
109	32-7111	90 Tchs 95 Tchc
110	32-12049	3 Q 47 Tchs 50 Tchc
111	32-14045	3 Tchs 20 Tchs+Tchc 31 Tchs 34 Tchc 190 Tchs+Tchc 200 Tkw
112	32-14854	11 Q+Tchc 60 Tchs 64 Tchc 120 Tchs
113	33-19295	47 Tchs 50 Tchc
114	33-25594	96 Tchs 100 Tchc
115	33-2983	20 Tchs 25 Tchc 60 Tchs 90 Tchc 115 Tchs 116 Tchc 138 Tchs 173 Tkw
116	33-20130	40 Tchs 47 Tchs+Tchc 62 Tchs
117	33-13421	25 Tchs 35 Tchc 80 Tchs
118	33-26334	10 Tchs 15 Tchc 68 Tchs
119	33-27484	60 Tchs 70 Tchs+Tchc 100 Tchs
120	33-21674	15 Tchs 25 Tchc 50 Tchs
121	33-11536	20 Tchs 50 Tchs+Tchc 110 Tchs
122	33-18102	27 Tchs 35 Tchc 64 Tchs 67 Tchco 86 Tchs
123	33-24110	23 Tchs 26 Tchc 32 Tchs 56 Tchc 67 Tchs 74 Tchco 100 Tchs
124	33-3692	69 Tchs 70 Tchc 90 Tchs
125	33-24671	35 Tchs 40 Tchc 80 Tchs
126	33-19793	40 Tchs+Tchc 60 Tchs 70 Tchs+Tchc 90 Tchs
127	33-7780	11 Q 21 Tchs+Tchc 32 Tchc 95 Tchs+Tchc 112 Tchs
128	33-17686	20 Q+Tchs 45 Tchs 50 Tchc 85 Tchs 105 Tchc+Tchs 130 Tchs
129	33-16635	12 Q 40 Tchs 46 Tchc 90 Tchs 96 Tchc 128 Tchs 129 Tchc 140 Tchs
130	33-7200	21 Q+Tchs 43 Tchs+Tchc 60 Tchc 90 Tchs+Tchc 112 Tchs
131	32-15103	105 Tchs+Tchc 129 Tchc

[1]Identifiers of the form “33-xxxx and 32-xxxx” are N. J. Department of Environmental Protection well-permit numbers. A “G” following the identifier indicates that a gamma-ray log is available for the well; an “E” indicates that an electric log (resistivity and spontaneous potential) is available.

[2]Number is depth (in feet below land surface) of base of unit indicated by abbreviation following the number. Final number is total depth of well rather than base of unit. For example, “12 Tchs 34 Tchc 62 Tchs” indicates Tchs from 0 to 12 feet below land surface, Tchc from 12 to 34 feet, and Tchs from 34 to bottom of hole at 62 feet. Formation abbreviations and the corresponding drillers’ descriptive terms used to infer the formation are: f=fill, Q=yellow and white sand and gravel, and brown to black peat, surficial deposits (units Tg, TQg, Qtu, Qtuo, Qcm1, Qtl, Qals). Bedrock formations are: Tchs=white, yellow, gray, brown (minor red, orange) fine, medium, and coarse sand (and minor fine gravel) of the Cohansey Formation; Tchc=yellow, white, gray (minor red, orange, black) clay, silty clay, and sandy clay of the Cohansey Formation; Tchco=gray, black, brown clay with organics, “bark”, or lignite. Tkw=gray and brown clay, silt and sand of the Kirkwood Formation. Tsr=green, glauconitic clay of the Shark River Formation. A “+” sign indicates that units are mixed or interbedded. “TD” indicates total depth of deep wells for which units below Tkw are not listed. Units are inferred from drillers’ or geologists’ lithologic descriptions on well records filed with the N. J. Department of Environmental Protection, or from geophysical well logs. Units shown for wells may not match the map and sections due to variability in drillers’ descriptions and the thin, discontinuous geometry of many clay beds. In most well logs, surficial deposits cannot be distinguished from Cohansey sands; thus, the uppermost Tchs unit in well logs generally includes overlying surficial deposits.

Table 2.—Lithologic logs of test borings. Gamma-ray logs provided on sections AA’ and BB’.

N. J. permit number and identifier	Lithologic log	
	Depth (feet below land surface)	Description (map unit assignment in parentheses) Color names from Munsell Soil Color Charts, 1975
E20136418 Keswick Grove 1	0-11	brown, dark yellowish-brown, brownish-yellow fine-to-medium sand with a few quartz pebbles (Qtu)
	11-51	yellow to reddish-yellow fine sand, minor fine-to-medium sand, trace coarse sand (Tchs); gamma-ray log is elevated from 11-17, suggesting a clayey bed similar to 51-58 but no clay was recovered from augers
	51-58	white to light gray fine-sandy clay (Tchc)
	58-103	yellow fine sand (Tchs)
E20136419 Keswick Grove 2	0-10	yellowish-brown fine-to-medium sand (Qtuo)
	10-49	yellow to yellowish-brown medium-to-coarse sand, some very coarse sand and very fine quartz pebbles (Tchs)
	49-51	laminated to thinly bedded white to light gray clay and yellow to yellowish-red fine sand (Tchc)
	51-74	yellowish-brown medium-to-coarse and, some very coarse sand and very fine quartz pebbles (Tchs)
	74-83	white, very pale brown clay with yellow to brownish-yellow fine-to-medium sand (Tchc)
	83-103	brownish-yellow to yellowish-brown fine-to-medium sand, minor coarse sand (Tchs)
E20136420 Keswick Grove 3	0-10	brownish-yellow to yellow medium sand , medium-to-coarse sand, with a few fine quartz pebbles (TQg)
	10-20	reddish-yellow fine sand (Tchs)
	20-33	brownish-yellow to yellow fine sand (Tchs)
	33-37	dark gray, dark grayish-brown, very dark gray, very dark grayish-brown organic clay with laminae of light-gray clay (Tchco)
	37-50	brownish-yellow fine-to-medium sand (Tchs)
	50-57	brown to yellowish-brown fine-to-medium sand (Tchs)
	57-86	gray, dark gray, very dark gray clay to fine-sandy clay, with interbeds of dark brown to very dark brown organic fine sand to clayey fine sand (Tchco)
	86-103	brown fine-to-medium sand (Tchc)
E20136421 Keswick Grove 4	0-10	yellowish-brown fine-to-medium sand, a few fine quartz pebbles (Qtu)
	10-40	brownish-yellow, yellowish-brown, strong brown fine-to-medium sand, some coarse sand (Tchs)
	40-90	brownish-yellow fine-to-medium sand, trace coarse sand (Tchs)
	90-103	yellow, very pale brown fine sand (Tchs)