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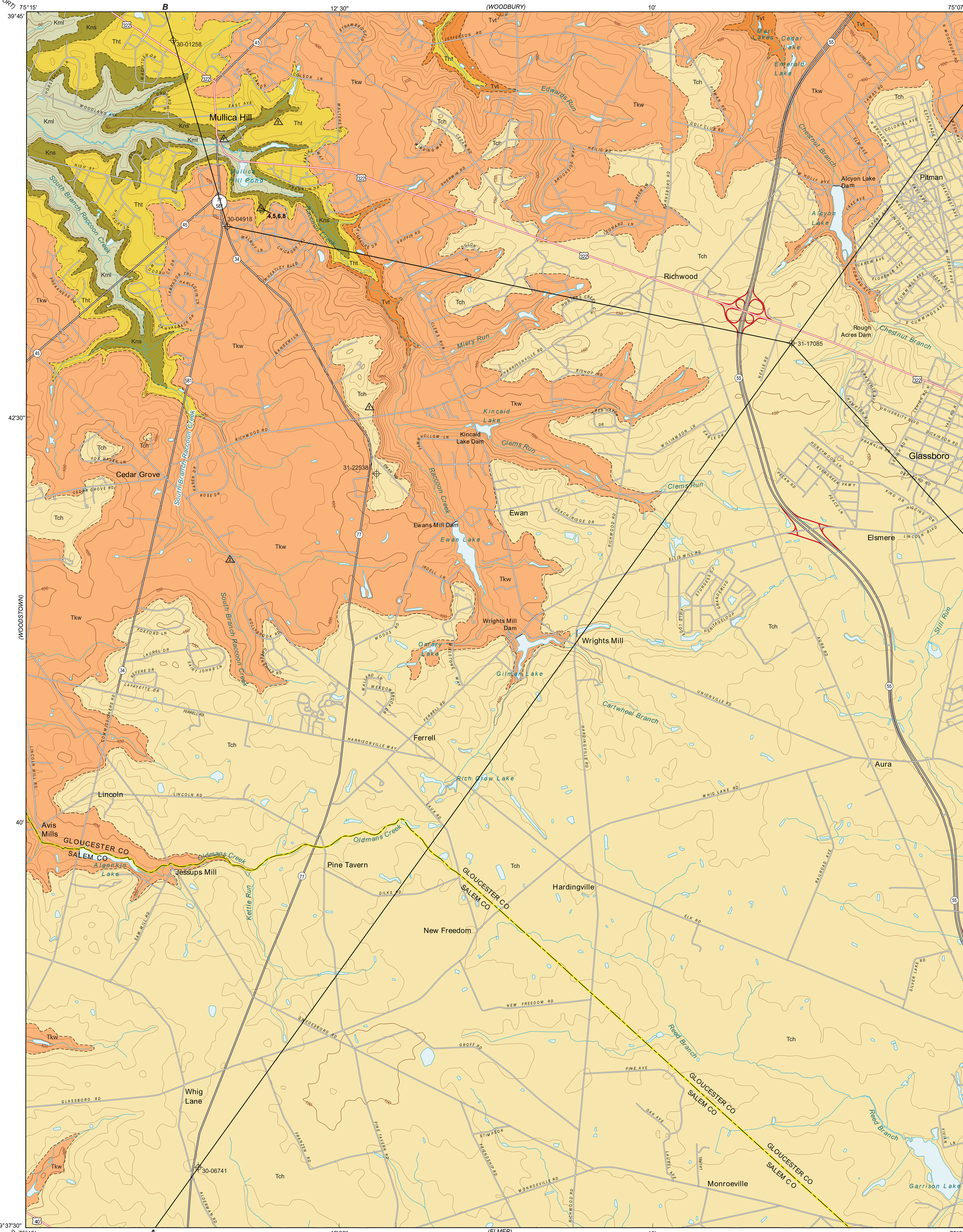

Basemap produced by the United States Geological Survey
North American Datum of 1983 (NAD83)
World Geodetic System of 1984 (WGS1984). Projection and
1000-meter grid: Universal Transverse Mercator, Zone 18S
10,000-foot ticks: New Jersey Coordinate System of 1983

Imagery..........................State of New Jersey, January 2007
Other imagery provided by DE, NY, PA
Roads... ©2006-2010 Tele Atlas
Names...GNIS, 2010
Hydrography.................National Hydrography Dataset, 2007
Contours............................National Elevation Dataset, 2001
Boundaries...........Census, IBWC, IBC, USGS, 1972 - 2010

UTM GRID AND 2011 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
MN GN 12° 8´ 216 MILS 0° 7´ 2 MILS

SCALE 1:24,000

KILOMETERS 1 0.5 0 1 2
METERS 1000 500 0 1000 2000
MILES 1 0.5 0 1
FEET 1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

CONTOUR INTERVAL 10 FEET
NORTH AMERICAN VERTICAL DATUM OF 1988

NEW JERSEY
QUADRANGLE LOCATION

Bedrock geology mapped by P.J. Sugarman,
M. Castelli, K. Kopcznski in 2019.
Digital cartography by K. Kopcznski

Prepared in cooperation with the U.S. Geological Survey,
National Cooperative Geologic Mapping Program,
under USGS award number G18AC00178.

ROAD CLASSIFICATION

Expressway — Local Connector
Secondary Hwy — Local Road
Ramp — 4WD
Interstate Route — US Route — State Route

BEDROCK GEOLOGIC MAP OF THE PITMAN WEST QUADRANGLE
GLOUCESTER AND SALEM COUNTIES, NEW JERSEY

By

Peter J. Sugarman, Michael V. Castelli, and Karen Kopcznski

2021

INTRODUCTION

Bedrock of the Pitman West quadrangle is unconsolidated Coastal Plain formations that include sand, silt, clay, and glauconite sand in varied percentages. The formations were deposited in continental shelf and marginal marine environments between approximately 90 and 12 million years ago. The lithology and age of the formations are provided in the Description of Map Units. Sections AA' and BB' show the subsurface geometry of the units along the lines of section. Extensive cover by surficial deposits in certain areas, especially the Bridgeton Formation (Fig. 1), obscure the coastal plain bedrock in much of the quadrangle. In places it is also difficult to distinguish the contact between the Bridgeton Formation and the underlying Cohansey Formation due to similar lithologies, deep weathering, and iron staining.

DESCRIPTION OF MAP UNITS

Tch **Cohansey Formation** - Quartz sand, gravelly in places, typically cross-stratified (trough and planar-tabular). Medium- to very coarse-grained sand; gravel is commonly concentrated in the base of channels. Dominantly an orthoquartzitic sand with traces of weathered feldspar and chert. Clay-silt beds present locally near the top of the formation (Minard, 1965). Detrital heavy minerals may be up to several percent and ilmenite dominates among the opaque minerals. Contains local concentrations of small to large clay-lined *Ophiomorpha nodosa* burrows. Sand is white to yellow and typically weathers to various shades of red and orange. In the adjacent Pitman East quadrangle, a core hole at Wilson Lake contained intervals of interbedded laminated sand and sandy clay with rare burrows and common organic matter and interlaminated sandy clay to clayey sand in the upper Cohansey (Miller and others, 2017). Maximum thickness 90 feet. Unconformably overlies the Kirkwood Formation.

No dateable material has been recovered from the Cohansey Formation in this quadrangle. Owens and others (1989) consider the Cohansey as middle Miocene in age, owing to the similarity of its palynomorphs to those of the Kirkwood Formation. Strontium (Sr) isotope age estimates for the upper part of the Kirkwood Formation (Sugarman and others, 1993) indicate that the Cohansey Formation is no older than middle Miocene with an age of approximately 12 million years (Ma).

Tkw **Kirkwood Formation** - Sand, silt, and clay. Where sand is the dominant lithology, it is quartz with minor feldspar, fine to very fine grained, in places medium, micaceous; with extensive iron oxide (Leisegang) banding. Commonly massive bedded, although partially preserved trough cross beds and flaser beds occur in some outcrops. *Ophiomorpha nodosa* burrows approximately 1 inch in diameter common in some beds in the adjacent Runnemede quadrangle (Sugarman, 2011). Thin weathered mollusk shells were found in an outcrop along the South Branch of Raccoon Creek. Locally can contain several percent ilmenite. Deeply weathered in outcrop to shades of orange (dark yellowish orange, grayish-orange), yellow, reddish-brown, and light gray (Fig. 2). In the subsurface, the Kirkwood grades down to a darker (grayish-brown) clayey, micaceous fine to very-fine grained organic rich clay, laminated clay silt, and shelly silty clayey fine sand (Miller and others, 2017). Maximum thickness 80 feet. Unconformably overlies the Shark River, Manasquan, Vincentown, Hornerstown, and Navesink Formations in this quadrangle.

The Kirkwood (in the Pitman West quadrangle) is assumed to be correlative with the Shiloh Marl member of the Kirkwood Formation, and is lower Miocene in age (20-21 Ma; Sugarman and others, 1993). However, Miller and others (2017) had Sr-isotope age estimates of 22.6-19.4 Ma for the Kirkwood at Wilson Lake, and correlated it with the Brigantine and Shiloh Marl Members. Miller and others (2017) also considered the Wildwood Member present at the Wilson Lake site based on sequence stratigraphic analysis, although there was no shell material and Sr-isotope age estimates to confirm this correlation.

Tsr-Tmq **Shark River and Manasquan Formations, undivided** - At the Wilson Lake corehole in the adjacent Pitman East quad, the Manasquan is approximately 17 feet thick, while the overlying Shark River Formation is 89 feet thick (Miller and others, 2017). The Shark River lithology is typically a greenish gray to light brownish gray sandy (fine quartz) clay silt, with intervals of shells and glauconite. Glauconite increases to over 20 percent in the base. The Manasquan Formation is clayey glauconite sand overlain by glauconitic clay, greenish gray to dark greenish gray, with a trace of fine quartz sand. Foraminifera are common. Since there are no observed outcrops and limited subsurface geophysical logs in the Pitman West quadrangle, the Shark River and Manasquan Formations are undivided. Maximum thickness 90 feet. Shown only on cross section.

The Manasquan is lower Eocene in age based on nannoplankton zone NP11 at Wilson Lake, while the Shark River is middle Eocene based on nannoplankton zones NP14b and NP16 (Miller and others, 2017).

Tvt **Vincentown Formation** - Quartz sand and quartz glauconite sand are the two distinct lithofacies of the Vincentown. Colors vary from greenish-gray, grayish green and yellowish-green to dusky yellow to pale yellowish orange where weathered. The quartz sand is typically medium and contains a few percent feldspar and glauconite, with minor pyrite and mica. The calcarenite (calcareous sand) facies is very fossiliferous containing foraminifera and bryozoan detritus. While not observed in the Pitman West quadrangle during this mapping, the basal 5 feet of the Vincentown is a quartz glauconite (40-90 percent) sand which may contain a bioherm composed of Oleneothyris harlani Morton and Gryphaea dissimilaris (Minard, 1965; Bernstein, 1987). This shell bed lies above the contact of the older glauconitic sands of the Hornerstown Formation, although some geologists (e.g., Miller and others, 2017) place the shell beds at the top of the underlying Hornerstown Formation. Contact can also be consolidated (to 1 ft thick) and contain quartz and phosphatic grains. Formation crops out along a thin belt along Raccoon Creek to the southeast of Mullica Hill.

In cuttings from well 30-6741, the Vincentown is dominantly a light gray to dark brownish gray clay that has a similar gamma-log signature to the Marlboro Formation described in the Wilson Lake site where the Marlboro Formation is close to 50 feet thick (Miller and others, 2017). While the authors here include this clay in the Vincentown Formation on this map, it is possible that the Vincentown is thinner than we illustrate in cross section A-A', and the upper part of the Vincentown Formation is correlative with the Marlboro Formation. Generally 20-30 feet thick, with maximum thickness 70 feet when Marlboro Formation is included.

Based on its foraminifera, the Vincentown is late Paleocene in age (Olsson and Wise, 1987). At the Wilson Lake site, the Vincentown was assigned to calcareous nannoplankton Zone NP9 (upper Paleocene; Miller and others, 2017).

Tht **Hornerstown Formation** - Glauconite sand, slightly clayey to very clayey (where weathered), dusky green to dusky blue green where fresh. Primarily fine-to medium grained glauconite sand, botryoidal shaped, with some accordion forms. Traces of quartz, mica, feldspar, and phosphatic material. No bedding seen due to extensive burrowing (fig. 3). Its dusky green clay matrix, composed mostly of glauconite, helps distinguish it from the underlying Navesink. Maximum 20 feet thick.

The underlying contact with the Navesink Formation is unconformable and heavily bioturbated, irregular, and marked by glauconite- filled burrows containing bright green glauconite from the Hornerstown Formation in the upper 1-2 feet of the Navesink. The contact is well exposed in a gully in Mullica Hill (fig. 4) where the base of the Hornerstown is deeply weathered, partly cemented clayey glauconite sand that irregularly overlies a dark, clayey glauconite sand with lighter nests of pyrite-rich burrows just below the contact.

Based on its foraminifera, the Hornerstown is early Paleocene in age (Olsson and others, 1997).

Kns **Navesink Formation** - Clayey glauconite sand, massive-bedded, bioturbated (burrows up to 1" diameter that can be pyrite-filled), olive-gray, olive-black and dark greenish-black where fresh (fig. 5); shades of gray and brown where weathered. Glauconite is botryoidal and predominantly medium to coarse grained. Clay-silt content as much as 30 percent. Accessories include pyrite, mica, quartz sand, and phosphatic fragments. Vivianite is present in places as a replacement for shell material (Weller, 1907). Maximum 20 feet thick.

The basal few feet of the Navesink contains a thick-bedded glauconitic quartz sand with granules and sand-size lignite fragments (reworked from the underlying Mount Laurel Formation), and black phosphate pebbles. This zone contained indurated iron-cemented layers in an exposure in Mullica Hill, Gloucester County (fig. 6). Weller (1907) and Richards (1962) describe a fauna from the basal Navesink Formation that is dominated by pelecypods and gastropods at a former outcrop locality in a hillside in the village (fig. 7). This same shell bed is shown at the base of a gully in Mullica Hill (fig. 8).

The contact with the underlying Mount Laurel Formation is unconformable. This contact is easily distinguished in the subsurface by the sharp positive gamma-ray response.

The Navesink is Late Cretaceous (Maastrichtian) in age based on the occurrence of the planktonic microfossils *Globotruncana gansseri* (Olsson, 1964) and *Lithraphidites quadratus* and the previously described macrofossils. The presence of the calcareous nannoplankton *Nephrolithus frequens* in the Navesink at Wilson Lake (Miller and others, 2017) also document a late Maastrichtian age.

Kml **Mount Laurel Formation** - Quartz sand, massive to crudely bedded, mostly medium, slightly glauconitic and feldspathic (5-10%), with scattered dark, ovoid-shaped medium grained phosphate pellets. Generally weathered to a light brown, pale yellowish brown or light gray. Coarser in the upper 5 feet with granules and pebbles; this interval also contains reworked glauconite (from the Navesink above) concentrated in burrows. The Mount Laurel fines downward to a clayey fine-to-medium grained quartz sand, with a noticeable increase in glauconite and mica. Burrows are common in outcrop, while fossils are rare (due to weathering); but common in the subsurface. Maximum 110 feet thick.

Where fossiliferous, fossils are preserved as poorly weathered casts although *Belemnitella americana* and *Gryphaea* have been identified. The Mount Laurel is uppermost Campanian in age. A Sr-isotope age estimate of 70.1 Ma was obtained from a shell in the Mount Laurel in the Wilson Lake corehole (Miller and others, 2017); slightly older ages of 71.1-71.6 Ma were obtained from belemnites from the Mullica Hill outcrop (Sugarman and others, 1995).

The Mount Laurel grades downward into the underlying Wenonah Formation.

Kw **Wenonah Formation** - Quartz sand, fine to very-fine grained, massive, clayey, very micaceous (muscovite and lesser chlorite), with abundant carbonaceous matter, and varying amounts of glauconite (3-20%; most abundant in the lower 3-5 feet). Colors include light olive gray, brownish-gray, and light brown where weathered; medium dark gray to dark gray where fresh. Grades down into the Marshalltown Formation. Maximum 50 feet thick. Shown only on cross section.

The Wenonah is late, but not latest, Campanian based on ammonites (Owens and others, 1998).

Kmt **Marshalltown Formation** - Quartz glauconite sand, massive, fine- to medium-grained, and clayey. Glauconite is very abundant in the lower few feet but increases upward to a nearly equal mixture of quartz and glauconite. Greenish black weathering to a greenish-gray, moderate olive-brown and light brown. While quartz and glauconite constitute the bulk of the formation, feldspar, mica, finely disseminated pyrite, and phosphatic fragments are present. Macrofossil assemblages containing *Exogyra ponderosa* and *Ostrea falcata* (Minard, 1965) are abundant locally. Maximum 20 feet thick. Shown only on cross section.

The Marshalltown is the basal transgressive unit of an unconformity-bounded cycle of sedimentation that includes the overlying Wenonah and Mount Laurel Formations.

The Marshalltown has been assigned to the middle Campanian nannofossil Zones CC 20-21 in southeastern New Jersey (Sugarman and others, 1995).

The Marshalltown unconformably overlies the Englishtown Formation; along the contact, the Englishtown is extensively bioturbated with burrows filled with glauconite sand from the overlying Marshalltown.

Ket **Englishtown Formation** - Quartz sand, fine to coarse grained, locally interbedded with thin to thick beds of dark clay and silt. Medium-dark gray to dark gray. Sand contains considerable carbonaceous matter, feldspar, mica and glauconite; carbonaceous matter and pyrite are common in the clays (giving them a dark-gray color where unweathered). Maximum 20 feet thick. Shown only on cross section.

Wolfe (1976) assigned an early Campanian age to the Englishtown based on a distinctive assemblage of palynomorphs.

Kwb **Woodbury Formation** - Clay, grayish-black to black, massive, and sandy (very fine-grained quartz). Conspicuously micaceous with major amounts of finely dispersed pyrite and carbonaceous material; locally contains several percent glauconite . Iron oxides fill fractures and occur in layers in most weathered beds. Maximum 50 feet thick. Shown only on cross section.

The Woodbury is lower Campanian in age (Owens and others, 1998).

Kmv **Merchantville Formation** - Intercalated, thick-bedded sequence of glauconitic sand and silt and micaceous clayey silt. The glauconitic sand is grayish-olive, greenish-black, or dark greenish-gray; the clay-silt is shades of black and gray. Quartz and glauconite are the major sand components; feldspar, mica (colorless and green), and pyrite are minor constituents. Siderite- cemented layers are common. The formation is highly bioturbated. Maximum 60 feet thick. Shown only on cross section.

The Merchantville is the basal transgressive bed of the unconformity-bounded coarsening-upward cycle which includes the overlying Woodbury and Englishtown formations.

The Merchantville is lower Campanian in age based on the ammonite *Scaphites hippocrepis* III (Owens and others, 1977).

Kmg **Magothy Formation** - Intercalated quartz sand and clay, thin- to thick-bedded. Sand is light- to medium-gray or brownish-gray; clay is olive-black to grayish-black. Bedding is horizonta (laminated) and cross-stratified. The sand is fine to very coarse, well sorted within each bed, predominantly quartz, and includes minor feldspar and mica. Pyrite-cemented and pyrite-coated sand concretions are common. Carbonaceous material is abundant.

The Magothy is Upper Cretaceous (Santonian) in age based on pollen (Christopher, 1977).

Kp_3 **Potomac Formation, Unit 3** - Sand, fine to coarse, light colored, cross-bedded, somewhat gravelly, interbedded with clays that are white or variegated red and yellow. Beds of dark gray woody clays are less common. Maximum thickness 300 feet. Shown only on cross section.

The pollen from the Potomac unit 3 is assigned to Zone III (early Cenomanian in age; Doyle and Robbins, 1977).

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CORRELATION OF MAP UNITS

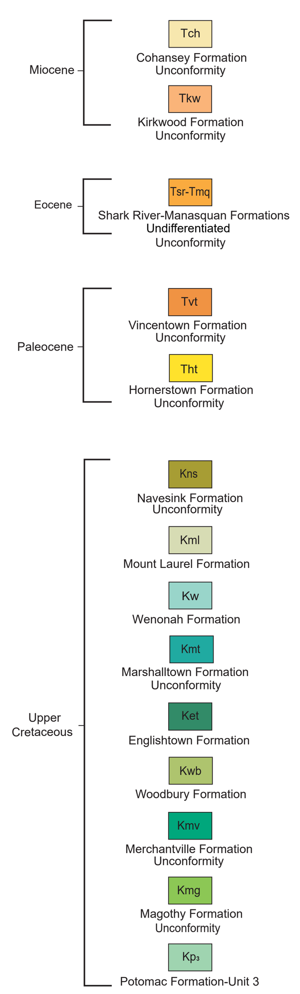


Figure 5. Navesink Formation outcrop.

Figure 6. Weathered iron cemented layers located in the lower part of the Navesink Formation.

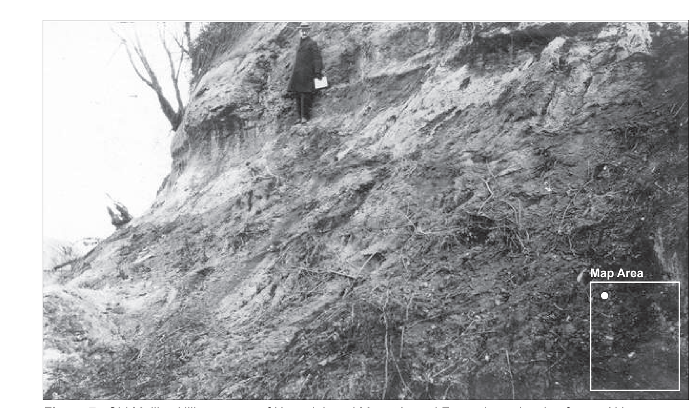


Figure 7. Old Mullica Hill exposure of Navesink and Mount Laurel Formations showing former NJ Geological Survey State Geologist Henry B. Kummel at the fossil shell bed at the base of the Navesink Formation (11/14/1918).

Figure 8. Shell bed at base of the Navesink Formation.

EXPLANATION OF MAP SYMBOLS

Contact - Approximately located

Gamma-ray log - On sections, vertical line shows well location and depth of penetration. Gamma intensity increases to right.

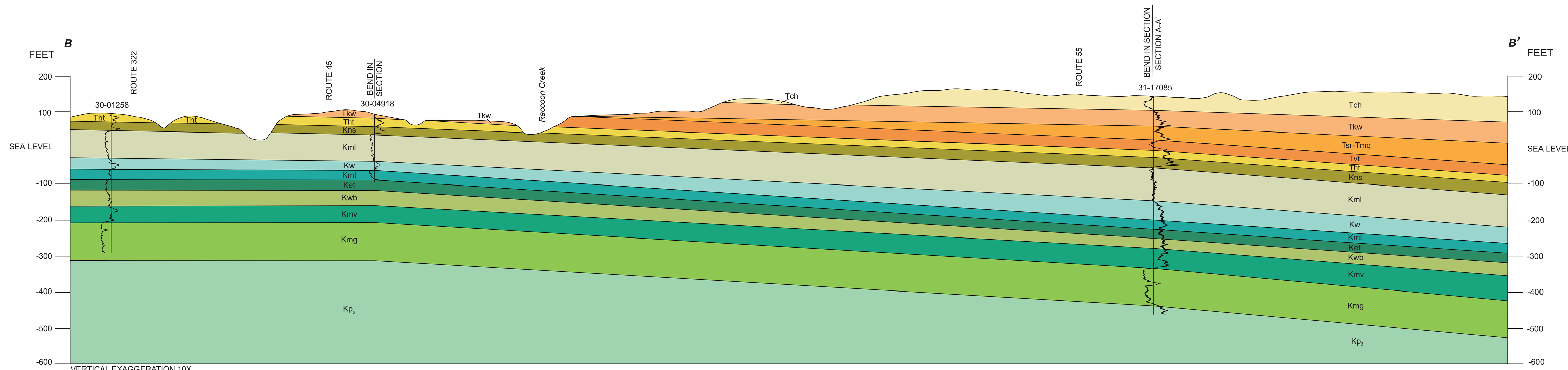
Well with geophysical log - Location accurate to within 500 feet. Identifiers of the form 30-xxxxx and 31-xxxxx are New Jersey Department of Environmental Protection well permit numbers.

Approximate photograph location, number corresponds to figure number.

Table 1. Selected well records (gamma).

Identifier[1]	Depth (ft.)	Formations Penetrated	Notes
30-06741	330	Tch, Tkw, Tsr-Tmq, Tvt, Tht, Kns, Kml	A-A' first well
31-17085	607	Tch, Tkw, Tsr-Tmq, Tvt, Tht, Kns, Kml, Kw, Kmt, Ket, Kwb, Kmv, Kmg, Kp_3	A-A' second well B-B' third well
30-01258	385	Tht, Kns, Kml, Kw, Kmt, Ket, Kwb, Kmv, Kmg	B-B' first well
30-04918	202	Tkw, Tsr-Tmq, Tht, Kns, Kml, Kw, Kmt	B-B' second well
31-22538	280	Tkw, Tsr-Tmq, Tvt, Tht?	Not on cross-sections

[1]New Jersey Department of Environmental Protection well permit numbers.



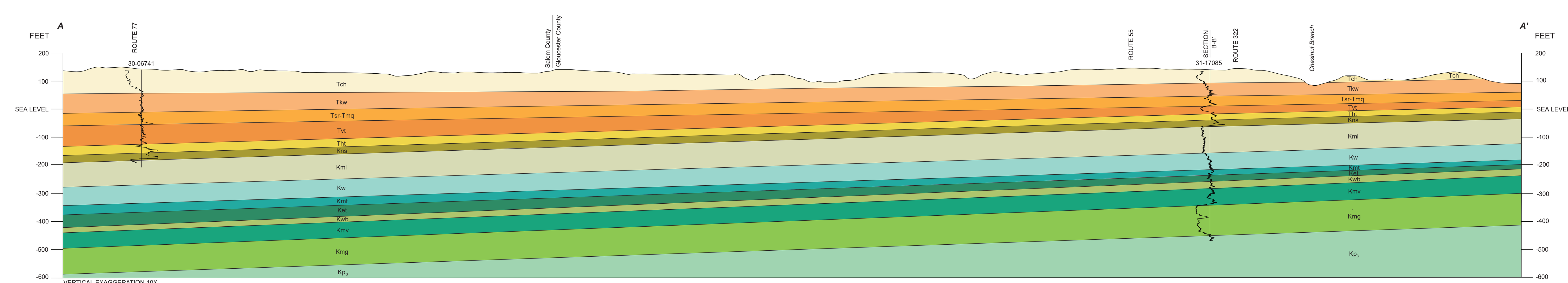


Figure 1. Bridgeton Formation with alternating beds of gravelly sand, clayey gravel, and cross-bedded sand.

Figure 2. Kirkwood Formation outcropping in Raccoon Creek.

Figure 3. Hornerstown Formation greensand outcropping along the Mullica Hill bypass.

Figure 4. Paleogene deeply weathered Hornerstown Formation (above red line) unconformably overlying Upper Cretaceous dark glauconite sands of the Navesink Formation (below red line) in a gully in Mullica Hill.