PLATE 1 of 2

Bedrock of the Lakehurst quadrangle consists of unconsolidated sand, silt, clay, and glauconite sand, deposited in fluvial, coastal, nearshore-marine, and continental-shelf settings between 95 and approximately 12 million years ago. These coastal plain sediments are classified into 16 formations above pre-Cretaceous basement rock, but only 2 formations - the Cohansey and Kirkwood - crop out in the quadrangle. The other 14 formations are mapped in the subsurface and shown on cross-section only. Lithology and age of the formations are provided in the Description of Map Units. Cross sections AA', BB', and CC' show

In many locations in the Lakehurst quadrangle, bedrock outcrops of the Kirkwood and Cohansey Formations are overlain or covered by surficial deposits. These deposits include alluvial and wetland sediments of Holocene age laid down in modern floodplains and areas of groundwater seepage; fluvial and colluvial sand and gravel of Pleistocene age forming terraces in valleys; and fluvial and colluvial sand and gravel of late Miocene to early Pleistocene age capping hilltops and divides between valleys. They are generally less than 20 feet thick. Their approximate extent is shown on Newell and others (2000) and Stanford and

DESCRIPTION OF MAP UNITS

Tch Cohansey Formation - Sand, quartz, light brown to dark-yellowish-orange and yellowish-gray to light-gray, medium- to very coarse-grained, with pebbles. Commonly cross-bedded (trough and planar-tabular). Carter (1978) identified two depositional sequences for the Cohansey Formation: 1) barrier beach, and 2) protected barrier or tidal flat facies. Most of the facies within these depositional sequences were observed in the Lakehurst quadrangle and include: 1) a burrowed, massive sand with rare to abundant Ophiomorpha borrows as much as 1 inch in diameter (fig. 1); 2) interbedded sand and grit (fig. 2); 3) laminated sand (fig. 3); 4) burrowed, laminated sand (fig. 4); 5) peat (fig. 5); 6) laminated clay; 7) cross-bedded sand (fig. 6); and 8) burrowed cross-bedded sand (fig. 7) (Carter, 1978).

Typically weathered Cohansey sand is dominantly an orthoguartzite with traces of feldspar. There are locally high concentrations of heavy minerals (fig. 4). In these concentrations, ilmenite dominates the opaque minerals; to a lesser extent zircon and sillimanite dominate the nonopaque minerals. Kaolinite is predominant in the laminated clay facies and among the clay-sized minerals in the sandy facies.

Exposures of the Cohansey Formation are poor except in excavations because of the loose sandy nature of the formation. Maximum thickness of the formation is approximately 100 feet in the Lakehurst guadrangle. The basal contact of the formation is placed at the unconformity between cross-bedded, medium- to coarse sand of the Cohansey and massive, fine-grained micaceous sand of the Kirkwood Formation (Sugarman and others, 1991). The contact was not observed when mapping the Lakehurst quadrangle.

No datable material has been recovered from the Cohansey in this quadrangle. Cores taken near Mays Landing, New Jersey (Owens and others, 1988) show Cohansey and Kirkwood palynomorphs very similar to those reported by Rachele (1976) and Greller and Rachele (1983) from the Legler lignite (fig. 5) found in the Cohansey Formation in this quadrangle, and indicate that the two formations are close in age. As the upper part of the Kirkwood is middle Miocene, the Cohansey is also middle Miocene. Pollen in the Legler lignite is dominated by oak and pine, and suggests a warmer, wetter climate than at present (Rachele,

Tkw Kirkwood Formation - Sand, typically orange, yellow, or gray, overlying dark-gray or brown lclay-silt. Sand is cross-bedded, laminated, or massive, very fine- to fine-grained quartz, micaceous, with occasional gravel and heavy minerals concentrated on bedding planes (fig. 8). Sand consists mostly of quartz, with small amounts of feldspar and mica (mostly muscovite). Detrital heavy minerals are dominated by the opaques, especially ilmenite, with lesser amounts of nonopaques including zircon, staurolite, garnet, rutile, and tourmaline. Ore grade ilmenite deposits have been identified in the Kirkwood as well as the Cohansey. Ilmenite concentrations in the ore grade Kirkwood range from 3 to 10 percent (Markewicz, 1969). The clay-silt facies, that dominates the lower half of the formation in the quadrangle, is known as the Asbury Clay where it outcrops in Monmouth County, north of the quadrangle (Ries and others, 1904). It is dark, peaty, and laminated with lenses of massive to locally cross-bedded fine sand. Finely dispersed clay minerals include kaolinite, illite, and illite/ smectite. Pyrite is common in the lower dark, clayey, organic-rich beds. A reworked section typically 2 to 3 feet thick at the base of the Kirkwood consists of coarse glauconite-quartz sand with granules and occasional shark teeth. The re-worked material rests unconformably upon the Shark River Formation.

The Kirkwood, in the subsurface, has been revised by Owens and others (1998) to include in ascending order, an unnamed lower member (equivalent to the Brigantine Member of Miller and others, 1997), the Shiloh Marl Member, the Wildwood Member, and the Belleplain Member. Both the unnamed lower member and the Shiloh Marl Member are clayey at the base and sandy at the top, a pattern that is also reflected on gamma-ray geophysical logs. The unnamed lower member and Shiloh Marl Member are approximately 21-19 million years old, the Wildwood member 18-15 million years old, and the Belleplain Member 13 million years old (Miller and others, 1997). Previous mapping of these members illustrates that the older unnamed lower and Shiloh Marl members are present in the northern New Jersey coastal plain to the north and northeast of Lakehurst (Sugarman and others, 1991; Sugarman, 1994), while the Wildwood and Belleplain Members are not present in Lakehurst quadrangle, but only to the south of this region (Sugarman and others, 1993). Due to a lack of age control for outcropping or subsurface material in the Lakehurst quadrangle, members were not assigned to the Kirkwood Formation in this quadrangle. Maximum thickness of the Kirkwood Formation is 110 feet in the Lakehurst quadrangle.

While no datable material has been recovered from the Kirkwood Formation in the Lakehurst quadrangle, the formation is known to be early Miocene to early middle Miocene in age (Andrews, 1987; Sugarman and others, 1993).

Shark River Formation - Clay-silt, calcareous, grayish-olive-green to olive-gray, pale-olive, and moderate-olive-brown; massive to thick-bedded and extensively burrowed. Grades upward into slightly glauconitic quartz sand (informally termed the Upper Shark River Formation; Browning and others, 2011). In the Double Trouble corehole (Browning and others, 2011), in the Toms River quadrangle southeast of the Lakehurst quadrangle, the sand was poorly sorted ranging from very fine to coarse with granules. Calcareous microfossils are abundant in lower half of the formation; small, broken mollusk shells are present in upper half. Glauconite, botryoidal, fine to medium, comprise as much as 10 percent in some intervals, is disseminated in dominantly clay-silt matrix. Glauconite is the dominant sand component in the lower 10 feet. Clay minerals include illite, illite/smectite, kaolinite, and minor amounts of the zeolite clinoptilolite.

The Shark River Formation crops out in the Manasquan River valley unconformably below the Kirkwood Formation in the Farmingdale quadrangle (Sugarman and others, 1991) northeast of the Lakehurst quadrangle, but does not crop out in the Lakehurst quadrangle. The contact with the underlying Manasquan Formation is unconformable and is placed at the boundary of the lower glauconite sand of the Shark River and the pale-olive clay-silt of the Manasquan (Browning and others, 2011). It is marked by a sharp positive gamma-ray response on geophysical logs. Maximum thickness is 140 feet in the quadrangle.

Calcareous nannofossils in core samples from the NJGS Allaire State Park corehole (Sugarman and others, 1991) and the Double Trouble corehole (Browning and others, 2011) indicate the Shark River is middle Eocene in age (nannozones NP 14-16). Shown in cross-section only.

Manasquan Formation - Clay-silt, dusky-yellow-green to pale-olive and grayish-green,

extensively burrowed, massive to thick-bedded, calcareous, grading upward into very fine quartz sand. Cross-bedded laminae of very fine sand occasionally present. Fine glauconite sand is commonly dispersed throughout the dominantly clayey matrix. Clay minerals include illite, illite/smectite, and minor amounts of the zeolite clinoptilolite. In the Double Trouble corehole, porcellanite zones up to 10 feet thick were common (Browning and others, 2011).

The contact with the underlying Vincentown Formation is marked by a sharp positive response of the gamma-ray log. Otherwise the formation, in general, has a neutral response on the gamma-ray log, not reflecting the dominant clay-silt lithology. Maximum thickness is 80 feet in the quadrangle.

Calcareous nannofossils in core samples from the NJGS Allaire State Park corehole indicate that the Manasquan is early Eocene in age (nannozones NP 10-13; Sugarman and others, 1991). Shown in cross-section only.

Vincentown Formation - Clay-silt, massive, slightly micaceous, finely laminated where not burrowed, grayish-olive-green, with thin beds of very fine quartz and glauconite sand. The basal 20 feet of the formation is a massive slightly quartzose glauconite sand. Maximum thickness 80 feet in quadrangle.

Calcareous nannofossils from the NJGS Allaire State Park corehole, and borings at the Manasquan Reservoir in Monmouth County, indicate zones NP 5, 6, and 8 (late Paleocene age) in the Vincentown (Sugarman and others, 1991). At the Double Trouble corehole, zones NP 9 and 10a were present (Browning and others, 2011). Shown in cross-section

Hornerstown Formation – Glauconite sand, clayey, massive-bedded, dusky-yellowish-green to dusky-green and greenish-black where unweathered. Glauconite grains are mainly medium to coarse in size and botryoidal. Contains 1 to 2 percent fine- to very coarsegrained quartz sand, phosphate fragments, pyrite, and lignite. Matrix contains minor glauconite clay. Locally cemented by iron oxides and siderite. Good exposures occur in the Manasquan River valley and its northern tributaries to the northeast in the Adelphia quadrangle. Maximum thickness 15 feet in quadrangle.

and others, 1991). Shown in cross-section only.

Calcareous nannofossils from the NJGS Allaire State Park corehole indicated that the Hornerstown falls within zones NP 3 and NP 4, of early Paleocene (early Danian) age (Sugarman

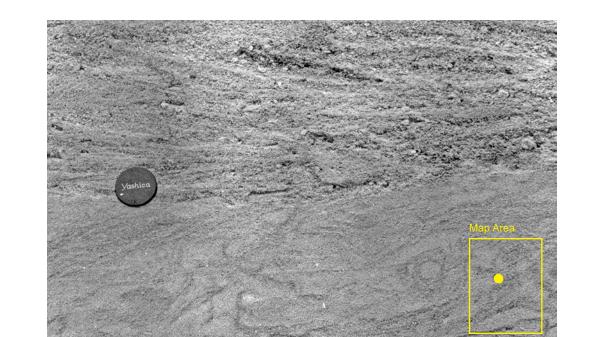


Fig. 2. Interbedded sand and grit facies within the Cohansey Formation (from Carter, 1978).

Navesink-Red Bank Formations, Undivided - Glauconite sand, slightly quartzose, clayey, greenish-black. Unconformably overlies the Mount Laurel Formation and underlies the Hornerstown Formation. These contacts are easily distinguished in the subsurface by sharp positive gamma-ray responses.

(Navesink Formation), a middle silt (Red Bank Formation), and an upper quartz sand (Red Bank Formation). In the subsurface the sand pinches out and the silt changes facies to glauconite sand. Maximum thickness is 60 feet in the quadrangle.

In outcrop the Navesink Formation and the Red Bank Formation form an unconformi-

ty-bounded, coarsening-upward sedimentary sequence consisting of basal glauconite sand

The nannofossils Nephrolithus frequens and Lithraphidites quadratus indicate the Navesink-Red Bank is late Maastrichtian in age. Shown in cross-section only.

Mount Laurel Formation - Quartz sand, fine- to coarse-grained, glauconitic (2 to 5 percent), extensively burrowed, slightly micaceous and feldspathic, commonly interbedded with thin layers of dark clay and silt. Olive-gray to dark-greenish-gray where unweathered. Conformably overlies the Wenonah Formation. The transition from the Wenonah to the Mount Laurel is generally marked by an increase in grain size, a decrease in mica (Owens and Sohl, 1969), and the appearance of alternating thin beds of clay and sand in the Mount Laurel (Minard, 1969). Maximum thickness of 60 feet in the quadrangle.

The Mount Laurel is Upper Cretaceous (late Campanian) in age based on calcareous nannofossils and Sr-isotope age estimates (Miller and others, 2006). Shown in cross-section

Marshalltown-Wenonah Formations, Undivided - Glauconite sand, greenish-black, exensively burrowed, with fine-grained quartz sand and silt (Marshalltown), grading upward into a thick, very silty, micaceous sand (Wenonah). The Marshalltown-Wenonah is recognized in the subsurface by a small gamma spike at the base of the Marshalltown passing into a relatively flat, positive pattern above. Undivided due to the thinness of the Marshalltown Formation (approximately 10 ft) and its lithologic similarity to the lower Wenonah Formation. The lower contact is extensively burrowed; lignite and locally coarse sand from the Englishtown are reworked into the basal Marshalltown. Maximum thickness is 100 feet in

The Marshalltown has been assigned to the Globotruncana calcarata zone of late Campanian age on the basis of its foraminifera (Olsson, 1964). Shown in cross-section only.

Englishtown Formation, Upper - Clay-silt to very fine quartz sand, glauconitic, dark-greenh-gray, micaceous, and lignitic. Grades upward into a fine- to coarse-grained sand interbedded with thin, dark-gray, micaceous, woody, clay-silt. The sand is dominantly quartz: less than 10 percent consists of feldspar, rock fragments, and glauconite. Defined on gamma-ray logs by a thick (~50 foot), high-intensity clayey unit at its base and a thick (~80 foot) low-intensity sand at its top. Equivalent to the Kc2 cycle of Owens and others (1998). In southeastern Monmouth and northeastern Ocean counties, the Englishtown Formation has been subdivided into an upper and lower sand facies divided by a clay-silt facies (Nichols, 1977; Zapecza, 1989). The clay-silt facies and upper sand facies are shown here as the Upper Englishtown Formation. Maximum thickness is 135 feet in the quadrangle.

The Upper Englishtown Formation is middle-late Campanian in age based on nannofossils at the Sea Girt corehole site (Miller and others, 2006). Shown in cross-section only.

Ketl Englishtown Formation, Lower - Quartz sand, feldspathic, micaceous and lignitic, fine- to medium-grained, medium to dark-gray, and typically cross-bedded. Maximum thickness 40 feet. Contact with the underlying Merchantville-Woodbury Formations is gradational.

Wolfe (1976) assigned an early Campanian age to the Lower Englishtown on the basis of a distinctive assemblage of palynomorphs. Shown in cross-section only.

Merchantville-Woodbury Formations, Undivided - Clay-silt, very fine sand with mica, and occasional lenses of finely disseminated pyrite, lignite, and siderite. Color ranges from dark gray to olive black. Bedding is massive to finely laminated with alternating layers of very fine sand and clay-silt (Woodbury Formation). Grades downward into an intercalated, thick-bedded sequence of glauconite sand and silt and micaceous clayey silt (Merchantville Formation). 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 contains zones of broken calcareous mollusks. Maximum thickness is 200 feet in the guadrangle.

The Merchantville-Woodbury ranges in age from Santonian to mid-Campanian based on nannofossils (Miller and others, 2006). Shown in cross-section only.

Magothy Formation - Intercalated quartz sand and clay, thin- to thick-bedded. Sand is ght- to medium-gray or brownish-gray; clay is olive-black to grayish-black. Bedding is horizontal (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 in beds as much as 0.5 feet thick. Description of the Magothy lithology, as observed in the Sea Girt corehole, is in Miller and others (2006). Recognized on gamma logs as a series of thick sands showing negative responses and interbedded clay-silts showing positive responses. Maximum thickness is 150 feet in the quadrangle.

The Magothy is upper Cretaceous (Turonian-Santonian) age based on Zone V pollen in the Sea Girt corehole (Miller and others, 2006). Shown in cross-section only.

Raritan Formation - Subdivided into two members: the upper Woodbridge Clay Member and the lower Farrington Sand Member. The Raritan is assigned to the late Cenomanian-early Turonian (Upper Cretaceous age) based on pollen Zone IV – the Complexiopollis-Atlantopollis zone (Christopher, 1979), and the occurrence of the ammonite Metoicoceras bergquisti (Cobban and Kennedy, 1990). Shown in cross-section only.

Woodbridge Clay Member - Clay and silt, dark gray, massive, with mica, pyrite, lignite, and siderite. Siderite forms layers 0.25 to 0.50 inch thick. Maximum thickness 150 feet (in well 29-23401) in the quadrangle.

Farrington Sand Member - Fine- to medium-grained quartz sand, white, yellow, red, light ray, commonly interbedded with thin gravel beds and thin to thick dark gray silt beds. Maximum thickness is 40 feet in the quadrangle.

Potomac Formation, Unit 3 - Clay, thin-to-thick bedded, overlying interbedded fine-tocoarse quartz sand and silty clay, mottled red, white, and less commonly dark gray. Maximum thickness is 300 feet in the quadrangle.

The age of the Potomac Formation, Unit 3 is lowermost Upper Cretaceous; lower Cenomanian based on pollen (Sugarman and others, 2010). Shown in cross-section only.

Potomac Formation, Unit 2 - Fine- to-coarse quartz sand with sparse gravel, interbedded with white, red, yellow-brown, and less commonly dark grey clay (Owens and others, 1998). More than 180 feet in quadrangle; base not penetrated. The Potomac Formation, Unit 2 is lower Cretaceous based on pollen (Barremian) in age (Sugarman and others, 2010). Shown in cross-section only.

ECONOMIC GEOLOGY

Ilmenite (titanium-iron oxide) concentrations measure as high as 19 percent in the Lakehurst area (Markewicz, 1969), high enough that mining of sand bodies was carried out by the Glidden Company at its Lakehurst mine. The main use of titanium in the late 1940's was in pigments due to the high opacity of the white dioxide. It was also used in steel manufacturing both as an alloying metal and a scavenger and deoxidizer (California Dept. Natural Resources, 1948). By the early 1950's titanium was highly desirable in jet plane construction due to its strength at high temperatures and corrosion resistance, and various news stories were naming it the wonder metal and the Cinderella metal (The Ore-Bin, 1953).

In October of 1956, Frank J. Markewicz of the New Jersey Geological Survey found high concentrations of heavy minerals in an excavation near Colliers Mills, New Jersey. State tion and assigned a second staff member, Daniel G. Parrillo, to assist with the investigation. Markewicz and Parrillo during the next few weeks, drilled fourteen boreholes over an area of about one square mile. On November 23, 1956, a news release by the Department of Conservation and Economic Development announced this important discovery of commercial-grade ore bodies by the New Jersey Geological Survey.

As a result of the news release a number of mining companies began exploration in southern New Jersey and by late 1957 four potential ore bodies, each over a thousand acres, had been identified (Markewicz and Parrillo, 1957). Eventually two of the deposits were mined, both near Lakehurst. A mine owned by the Glidden Company, about two miles north of Lakehurst, consisted of about 1,400 acres and operated from 1962 to 1978 producing approximately 100,000 tons of ilmenite concentrate a year (New Jersey Geological Survey files). The ilmenite was used in pigments for lead-free paints. The other deposit, owned by American Smelting and Refining Company, was located on a 4,000 acre site adjacent to Lakehurst Quadrangle about two miles southwest of Lakehurst. Mining began in late 1973 and continued until 1982. The mine produced up to 180,000 tons of ilmenite concentrate a

At the Glidden mine the sand was excavated by a large walking dragline with a 4-to 6.5-cubic yard bucket. The material was dumped into a hopper with a wobbler feeder that removed iron stone pieces, roots, and clay balls greater than 1.25 inch, then mixed it with water. The resultant slurry was pumped through a pipeline to a separation plant. Tailings were then pumped back to previously mined areas. At the Glidden mine the mining depth ranged from 20 to 40 feet and averaged about 25 feet (Markewicz, 1969).



Fig. 3. Laminated sand facies within the Cohansey Formation (from Carter, 1978).

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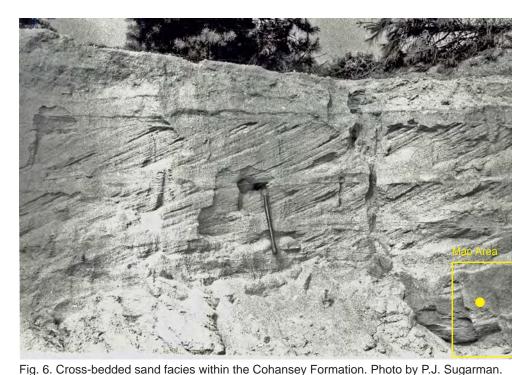
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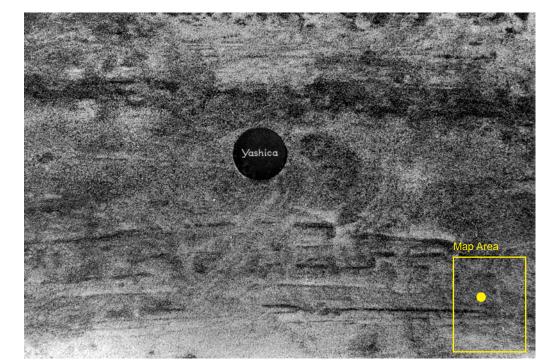
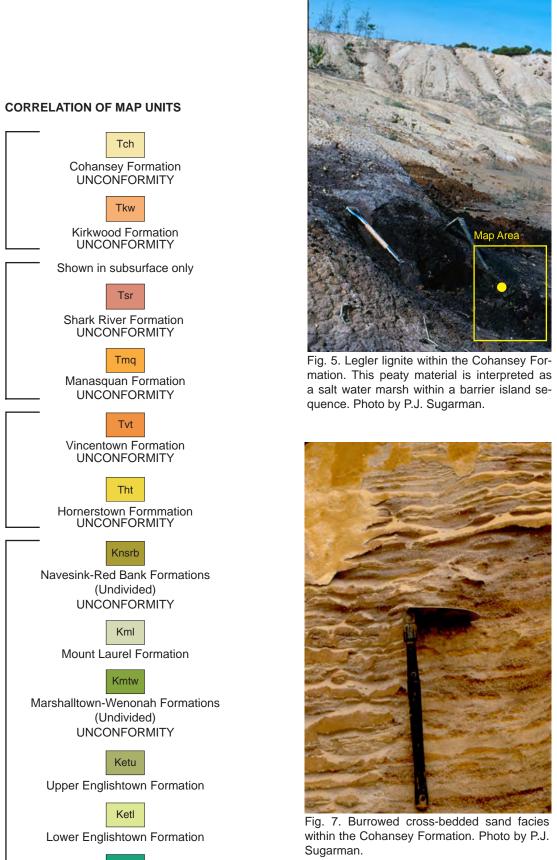


Fig. 4. Burrowed, laminated sand facies within the Cohansey Formation. Dark sand grains are heavy minerals (from Carter, 1978).



Merchantville-Woodbury Formations

UNCONFORMITY

Magothy Formation

UNCONFORMITY

Raritan Formation

Woodbridge Clay Member

Raritan Formation

Farrington Sand Member

UNCONFORMITY

Potomac Formation, Unit 3

UNCONFORMITY

Potomac Formation, Unit 2

within the Cohansey Formation. Photo by P.J. Fig. 8. Kirkwood Formation from the former Glidden sand quarry showing sand with heavy

mineral laminations and thin lenses of fine gravel concentrated along bedding planes. Bedding consists of planar parallel laminations and low-angle cross beds deposited in high energy beach or tidal channel environments. Photo by J.P. Owens.

Well Permit No.	Latitude (ddmmss)	Longitude (ddmmss)	Elevation (feet)	Total Depth (feet)
29-08936	400700	741713	140	1660
29-39030	400033	741940	65	1473
29-00429	400007	741927	65	1038
29-23406	400016	741543	74	1004
29-23401	400039	741514	36	1471
29-48781	400143	741929	75	1041
29-03726	400327	741940	100	1728



Contact – approximately located in outcrop.

Well with geophysical log – Location accurate to within 500 feet. Identifiers of the form 29-xxxxx are N. J. Department of Environmental

figure 7 Approximate photograph location

Protection well permit numbers.

Geophysical log – On sections. Gamma-ray log is shown by black line, intensity increasing to right. Information on wells given in Table 1.





Base from U.S. Geological Survey, 1957.

North American Datum of 1927.

Photo revised 1971.

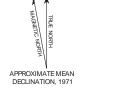
Peter J. Sugarman, Michael V. Castelli, Richard F. Dalton, and Nicole L. Malerba

Bedrock Geologic Map of the Lakehurst Quadrangle

Ocean County, New Jersey

1 1/2 0

1000 0 1000 2000 3000 4000 5000



Bedrock geology mapped by P.J. Sugarman and M. Castelli in 2015.

The views and conclusions contained in this document are those of the

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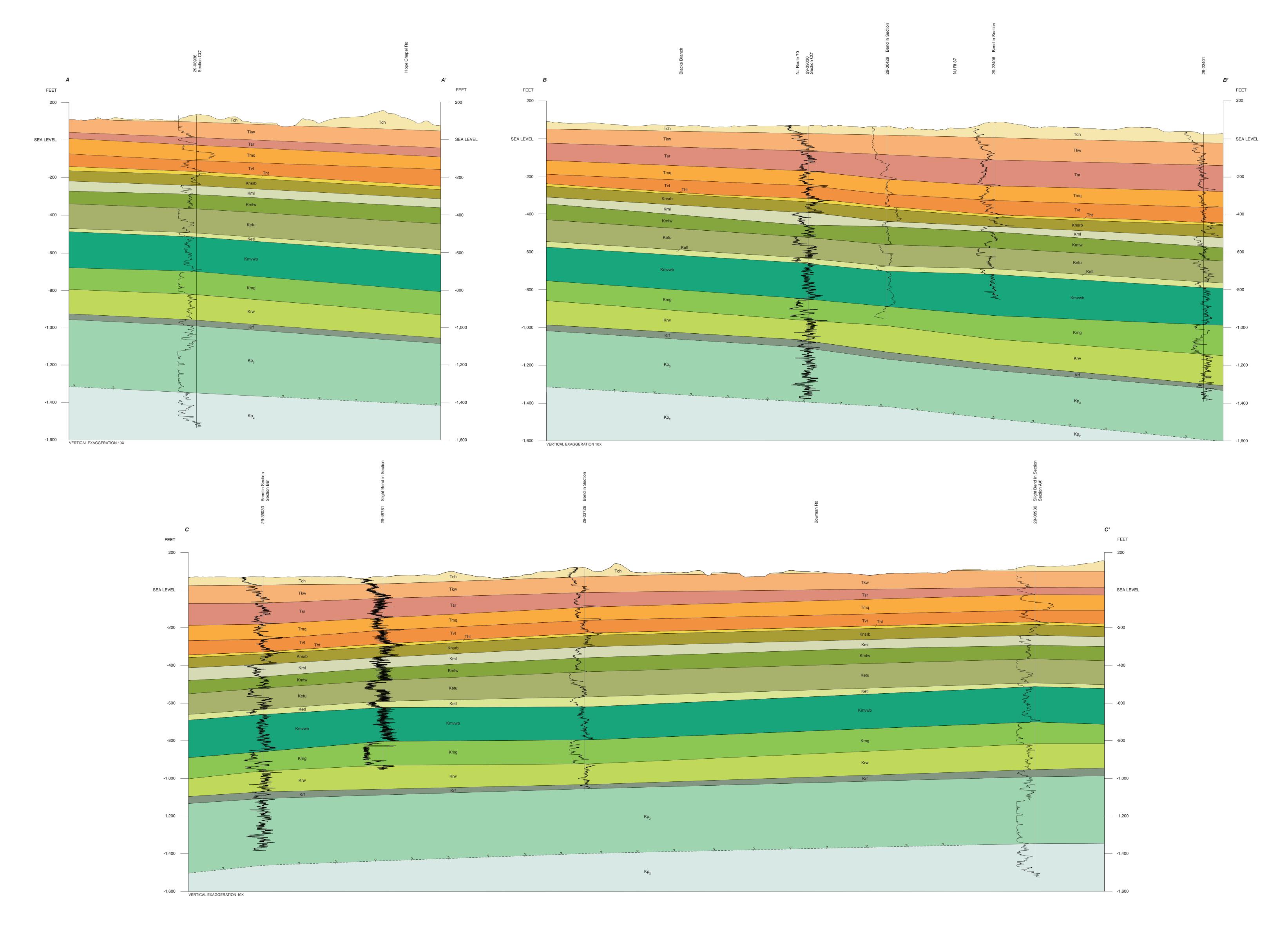
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Digital cartography by N.L. Malerba.

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Bedrock Geologic Map of the Lakehurst Quadrangle Ocean County, New Jersey



