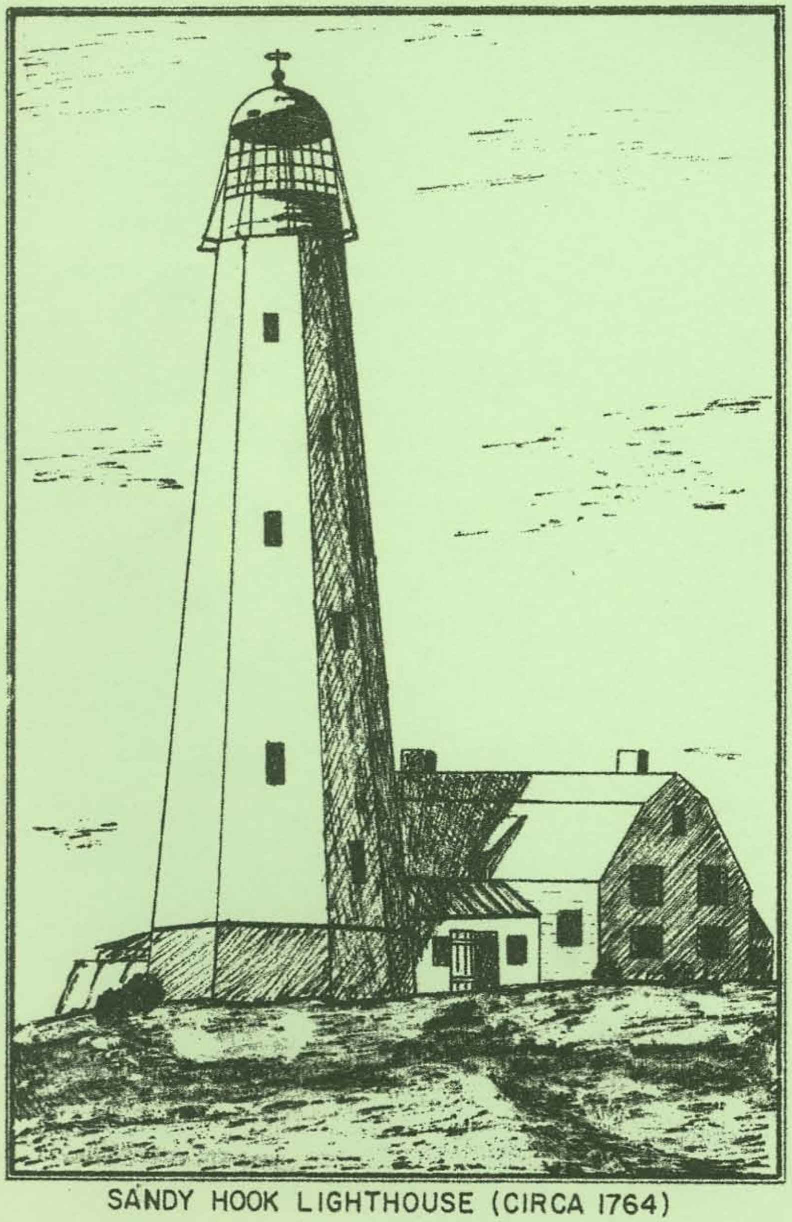
GEOLOGY
OF
MONMOUTH COUNTY
IN BRIEF



SANDY HOOK LIGHTHOUSE (CIRCA 1764)

NEW JERSEY

GEOLOGICAL SURVEY

STATE OF NEW JERSEY

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GEOLOGY OF MONMOUTH COUNTY IN BRIEF

by

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GEOLOGY OF MONMOUTH COUNTY IN BRIEF

PHYSIOGRAPHY

Monmouth County lies entirely within the Atlantic Coastal Plain, a segment of the Coastal Province of North America, which extends from Newfoundland to Central America. In New Jersey, the Coastal Plain lies southeast of a line from Trenton to Perth Amboy, covering approximately three fifths of the state.

Hills which run diagonally across the county as if forming a backbone (see Figure 1) are the most prominent topographic feature of Monmouth

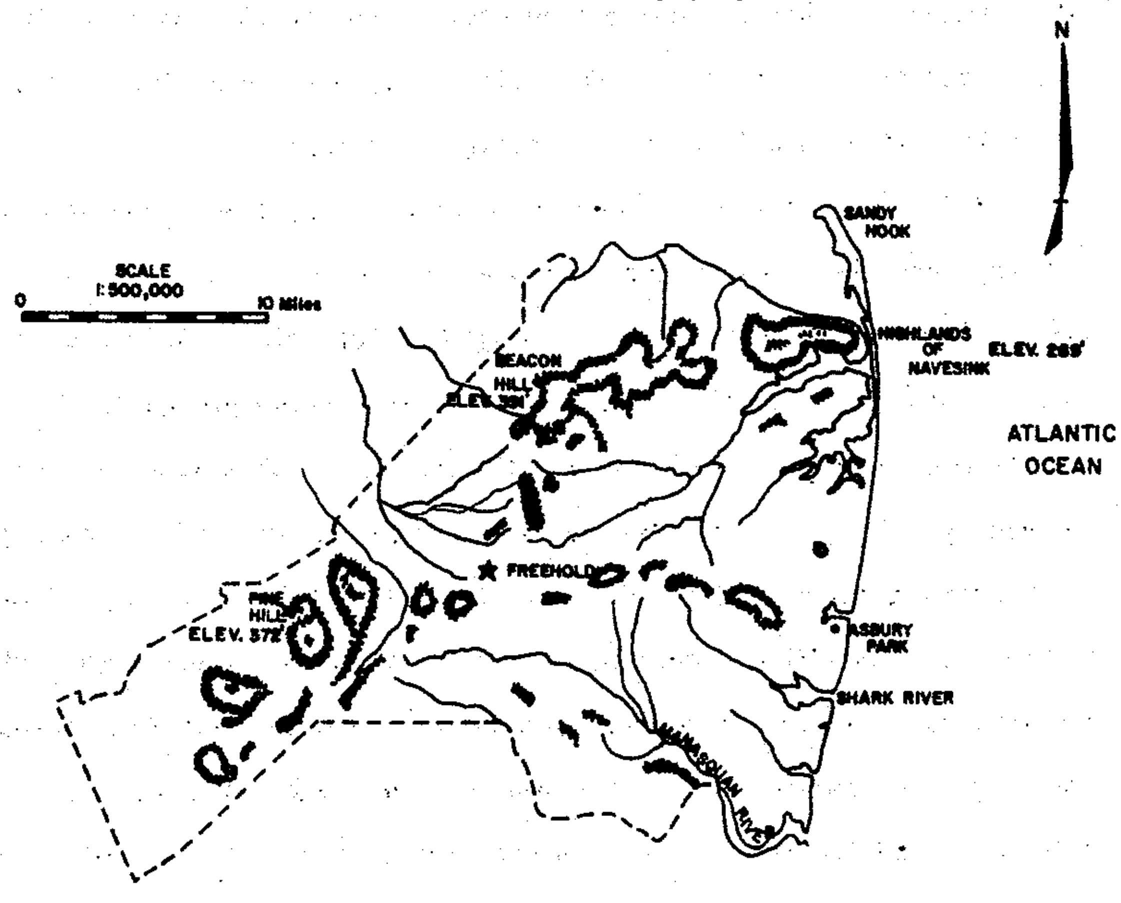


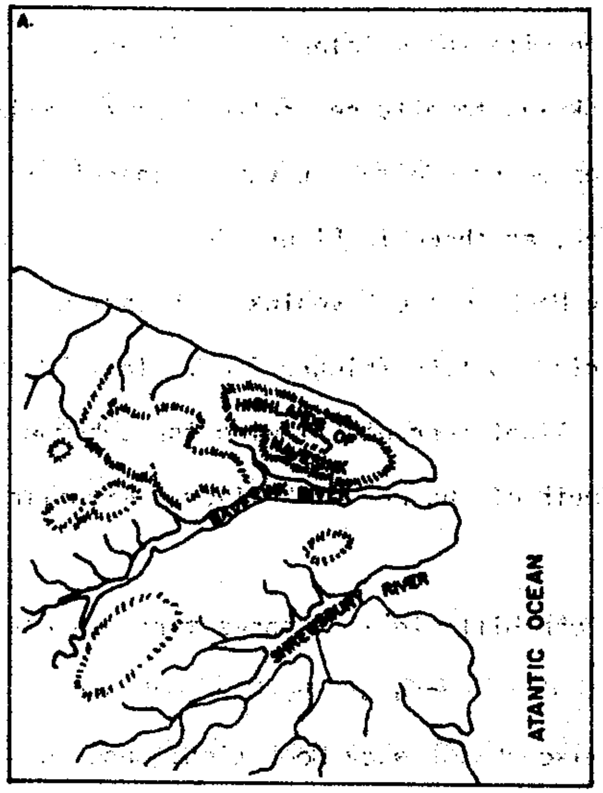
FIGURE 1. The Physiographic Features of Monmouth County.

County. This line of hills begins at the Highlands of Navesink, where steep bluffs rise as high as 269 feet above Sandy Hook Bay. Because these bluffs are the highest point on the east coast of the United States south of Maine, they were a natural landmark for mariners sailing into New York Harbor. The powerful beacons of Twin Lights, now made obsolete by modern electronic navigational systems, could be seen for many miles at sea, to guide ships safely past the shoal waters off Sandy Hook.

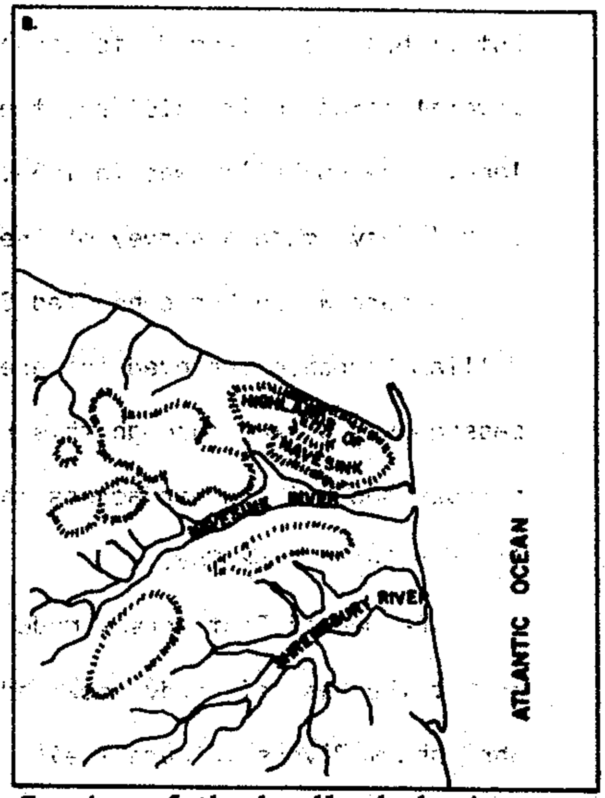
From the Navesink Highlands, the line of hills follows a curved path through the highest point in the county, 391 feet at the top of Beacon Hill, toward Freehold. Here the ridge line bends to the west, through Pine Hill (372 feet), then bends southward into Ocean County. A spur of smaller hills branches out from Freehold toward Asbury Park on the coast. Except for the hills mentioned above, most of the rest of the county has elevations of less than 150 feet. The hills of Monmouth County have been dissected by numerous branching streams into a gently rolling topography.

Sandy Hook, one of the most interesting shoreline features of the New Jersey shore, is an excellent example of the process of shoreline development. Figures 2-a and 2-b are two hypothetical stages in the development of the hook. In Figure 2-a the headlands are shown protruding from beyond their present boundaries. Both the Navesink and Shrewsbury Rivers emptied directly into the Atlantic Ocean. The erosion action of ocean waves reduced the semiconsolidated Coastal Plain sediments to loose sand, which combined with sediment carried out by the two rivers, was transported northward by currents in a process known as longshore drift, and deposited in a growing recurved spit as shown in Figure 2-b. The curving of the spit is caused by the deposition of sands swept around the end of the spit by strong flood or incoming tide currents which are generally stronger than those of the ebb or outgoing tide. The difference in tide velocities and, therefore, the ability of the current to carry sediment creates a net shoreward movement with an accompanying deposition of sands inside Raritan Bay.

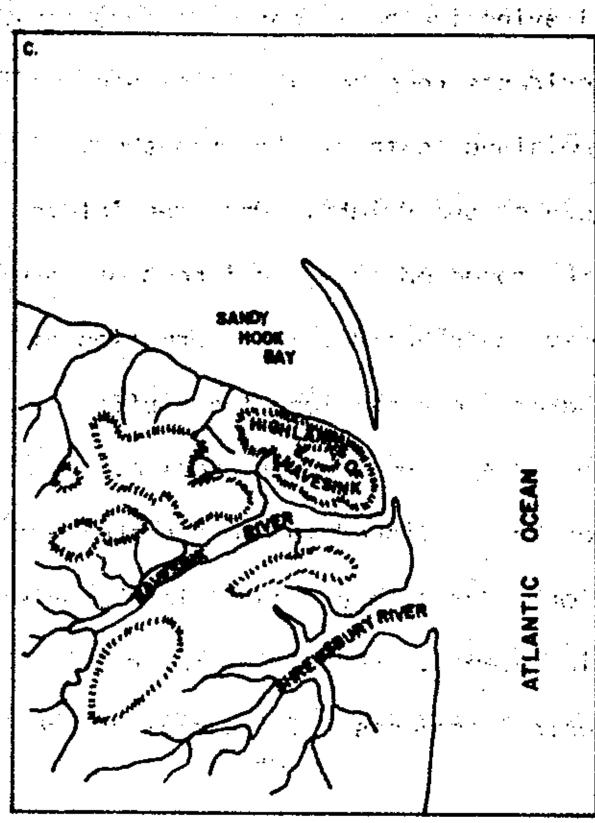
Figure 2. Stages in the Development of Sandy Hook



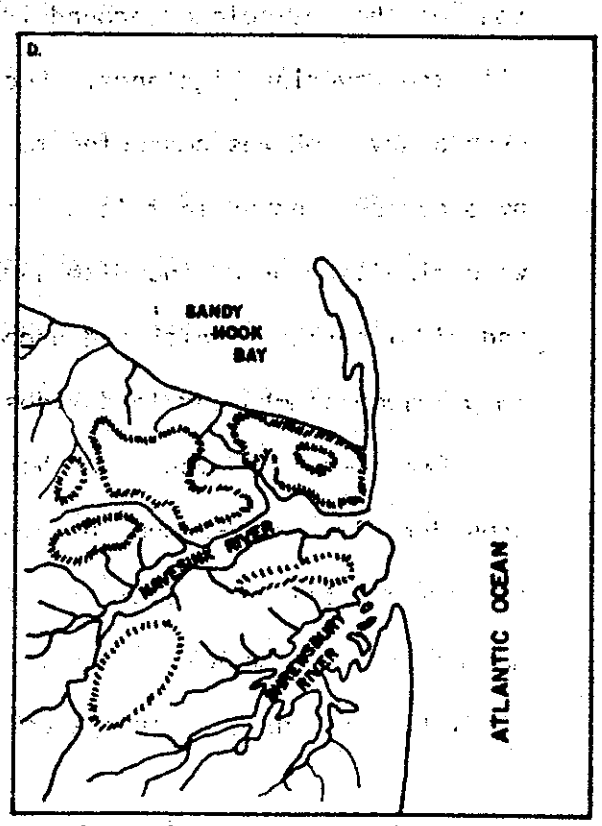
Headlands project far into the ocean.



Erosion of the headlands begins.
Several small spits begin to form.



Sandy Hook in 1685, as surveyed by George Keith, Surveyor-General of East Jersey.



Sandy Hook prior to 1764, surveyed by William Lawrence.

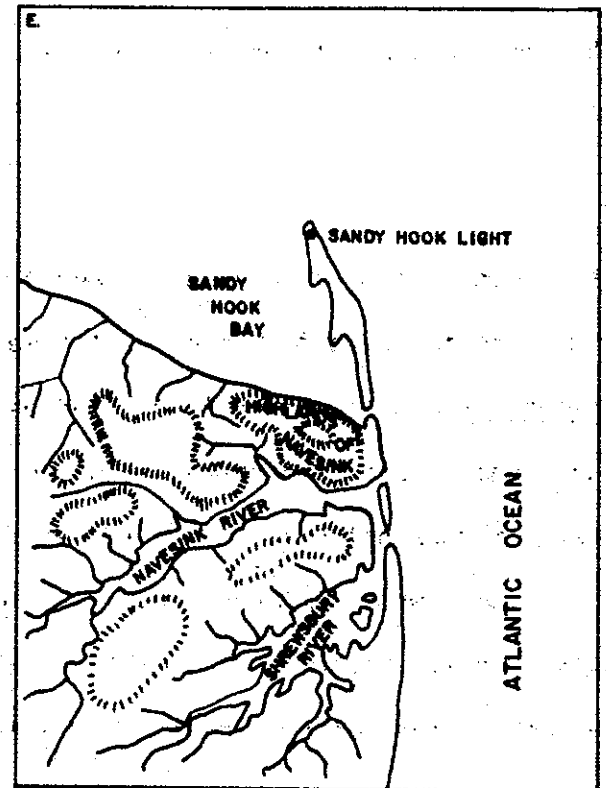
The remaining maps in Figure 2 show how much Sandy Hook has changed within historic times. Not only has the hook changed in size and shape, but it has also changed its connection with the mainland many times. At several times in its history, the hook was totally separated from the mainland. One such time was in 1685, when George Keith, Surveyor-General of East Jersey, made a survey of the hook, as shown in Figure 2-c.

A narrow sandbar connected Sandy Hook to the Navesink Highlands when William Lawrence surveyed the area prior to 1764 (Figure 2-d). In 1778 a passage was broken through this bar. Tidal currents flowing through the new passage built a bar across the mouth of the Navesink River, deflecting it into Sandy Hook Bay.

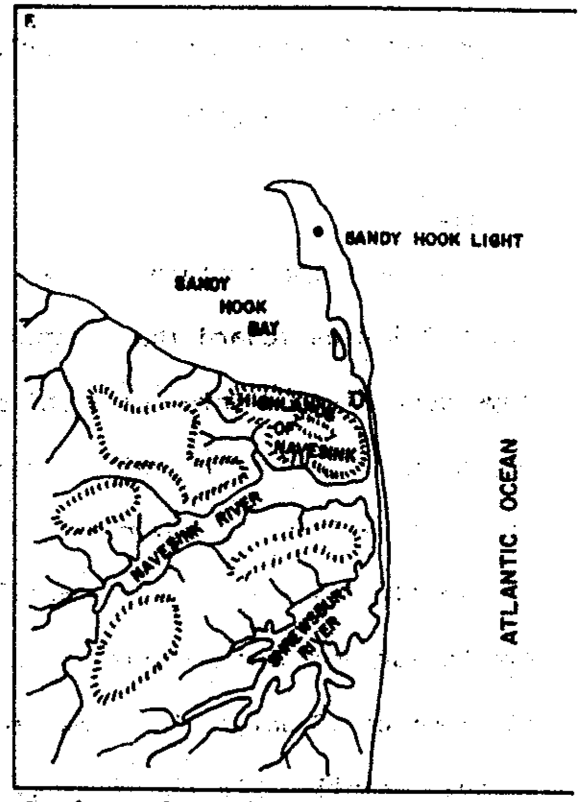
The map of East Jersey made by John Hills in 1796 shows three inlets; one at the base of Sandy Hook and two at the area of the Navesink and Shrewsbury Rivers (Figure 2-e). It also shows Sandy Hook Lighthouse, which stood at the tip of the hook when it was built in 1764. The inlet at the base of the hook closed around 1800, leaving the hook connected once again with the Navesink Highlands. Local residents reopened the inlet about 1850, when Sandy Hook was connected to the mainland south of the Shrewsbury River by a narrow sandbar that is now the town of Sea Bright. Once the inlets were finally closed, the Highlands were protected from the forces of waves and tidal currents which had undoubtedly contributed to the formation of large slump blocks and landslides at several places along the bluffs.

Beach erosion along the shore continues to be a major problem. Figures 2-f, 2-g and 2-h show how the hook has continued to grow in the last century despite efforts at stabilization. The rate of change in the development of the hook has been retarded in recent years by the construction of sea walls, groins and other erosion control projects. The northward pro-

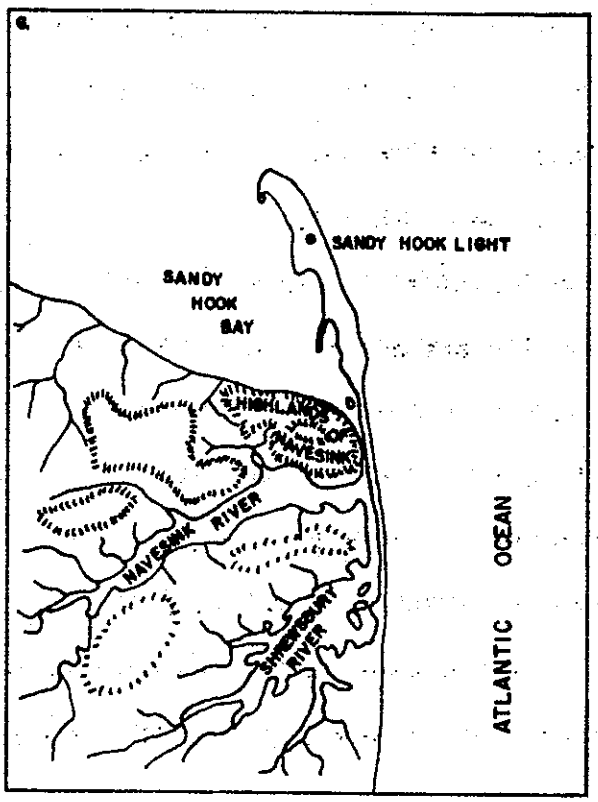
Figure 2.



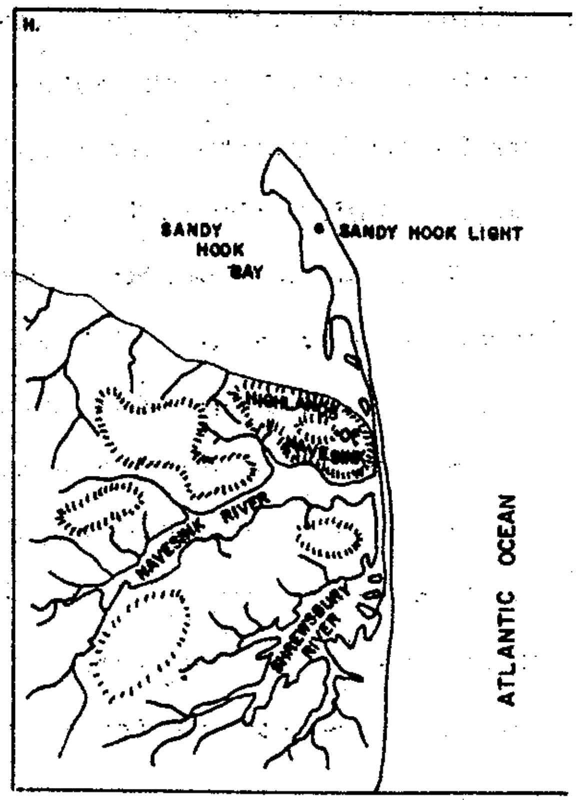
Sandy Hook in 1796, as surveyed by John Hills. Sandy Hook light was built in 1764.



Sandy Hook in 1885.



Sandy Hook in 1950.



Sandy Hook today.

gression of the hook has been effectively stopped by the maintenance of Sandy Hook ship channel. Of course, such measures do not eliminate all transport of sand along the shore. They can only modify and, to some extent, control the process.

GEOLOGY

Beneath the surface of the Coastal Plain lies a wedge of sands and clays which thickens toward the coast. The different strata that make up the wedge have been divided into units called formations. A formation is defined as a mappable stratigraphic unit. That means that it has some characteristics that can be identifed over a large area. It does not mean that a formation is exactly the same at all locations. The area where a formation is exposed at the surface of the earth is the outcrop area. Figure 3 is a geologic map for Monmouth County which shows the pattern of the outcrop areas for the different formations in the county. The cross-section in Figure 4 shows how younger formations overlie older ones. In Monmouth County, the oldest formations outcrop along the northwest border. Formations can be identified in samples obtained from deep wells. By studying samples from many wells drilled throughout the county, geologists have been able to determine that most of the formations thicken downdip to the southeast.

The Geologic Time Scale shows the units of time into which the earth's history has been divided. The units are not of equal duration in years, but rather were determined by the unraveling of geologic events that occurred at different places in the earth at different times.

The oldest of the Coastal Plain formations, deposited at about the middle of the Cretaceous Period, lies on an eroded bedrock surface known as the pre-Cretaceous "basement." Little is known about this "basement," except that under Monmouth County it slopes to the southeast at a little more than 50 feet per mile, and where it has been penetrated in deep wells, it consists of a type of rock known as gneiss. This hard crystalline rock was once composed of sediments similar to the Coastal Plain formations. The sediments were buried deep within the earth's crust where they were subjected to high temperatures and pressures for millions of years. The combination of temperature, pressure and time converted the soft sediments to hard crystalline rock. By the middle of the Cretaceous Period, the gneiss had been exposed at the earth's surface after a long period of erosion.

The Coastal Plain sediments that overlie the basement rocks were deposited in several different environments. During the 100 million years while the sediments were being deposited, sea level changed many times, so that the sea advanced and retreated across what is now Monmouth County in what are called transgressions and regressions. It is possible to document these changes by observing the sequence of sediment types in a vertical section. For example, a sequence of river deposits overlain by beach and coastal lagoon sediments overlain, in turn, by sediments deposited under several hundred feet of ocean water would represent a transgression, while the same material in the opposite order would represent a regression.

The contacts between formations are an important indicator of the geologic history of an area. If the contact is gradational from one formation to another, it is said to be conformable. A conformable contact indicates that conditions were changing gradually, with no break in sedimentary record. A sharp contact, on the other hand, indicates an abrupt change. Any break in sedimentation creates a gap in the geologic record known as an unconformity. Some unconformities are distinct, with the underlying strata at an angle to the overlying material. Others may be quite hard to detect because the strata are parallel above and below. Often there is evidence of erosion, either in the uneven form of the lower stratum or by the inclusion of re-worked material from the older formation in the younger.

While the Coastal Plain formations were being deposited, the basement was tilting gradually to the southeast, allowing even greater thicknesses of sediments to be deposited. The thickness of sediments in Monmouth County increases from about 300 feet near Raritan Bay to nearly 2000 feet at the mouth of the Manasquan River.

Cretaceous

Raritan and Magothy Formations - Kmr

Although these two formations occupy only a small area of outcrop in Monmouth County, they are of great importance because many municipalities tap them for their water supplies. The Raritan formation is the oldest and thickest of the Coastal Plain formations. Where it outcrops along Raritan Bay, it is from 150 to 300 feet thick. A deep well on Island Beach in Ocean County penetrated more than 1700 feet of the Raritan formation. The formation is made up of alternating layers of sands and clays that were deposited in river channels, flood plains, and deltas by major river systems flowing across the eroded basement surface. Fossils of brackish water and marine animals of the clam family have been found in some localities. Fragments of wood carried by the rivers were buried by the shifting sediments. During the millions of years that the wood was buried, it was transformed into a charcoal-like substance called lignite.

The Magothy formation is thinner than the Raritan, being about 175 feet near Raritan Bay and about 260 feet in the Island Beach well. Two types of evidence show that the sea was transgressing, or moving inland, while the Magothy was being deposited. Fossils found in the Magothy are of true marine animals, instead of the brackish water fossils of the Raritan formation. Also, although the lower part of the formation consists mostly of dark silty clays and light colored sands, the upper part contains some glauconite. Glauconite, or greensand, is a mineral similar to mica which forms on the ocean floor far enough from land so that land-derived sediment will not inhibit the formation of the glauconite grains. Some of the Coastal Plain formations that overlie the Magothy are composed almost entirely of glauconite. These are often referred to as greensand marls and represent a deep water marine environment.

Merchantville and Woodbury Formations - Kmv & Kwb

The contact between the Magothy and Merchantville formations is a distinct unconformity. Not only is there a change in sediment type, but the lower foot of the Merchantville contains some eroded and redeposited material from the Magothy.

In Monmouth County the Merchantville consists mostly of interstratified glauconitic sands and thin beds of clayey silt. The glauconite beds contain numerous worm borings and molds of marine fossils as well as fragments of carbonized wood. Irregularly shaped lumps of iron carbonate, called siderite concretions, are common in the silty beds.

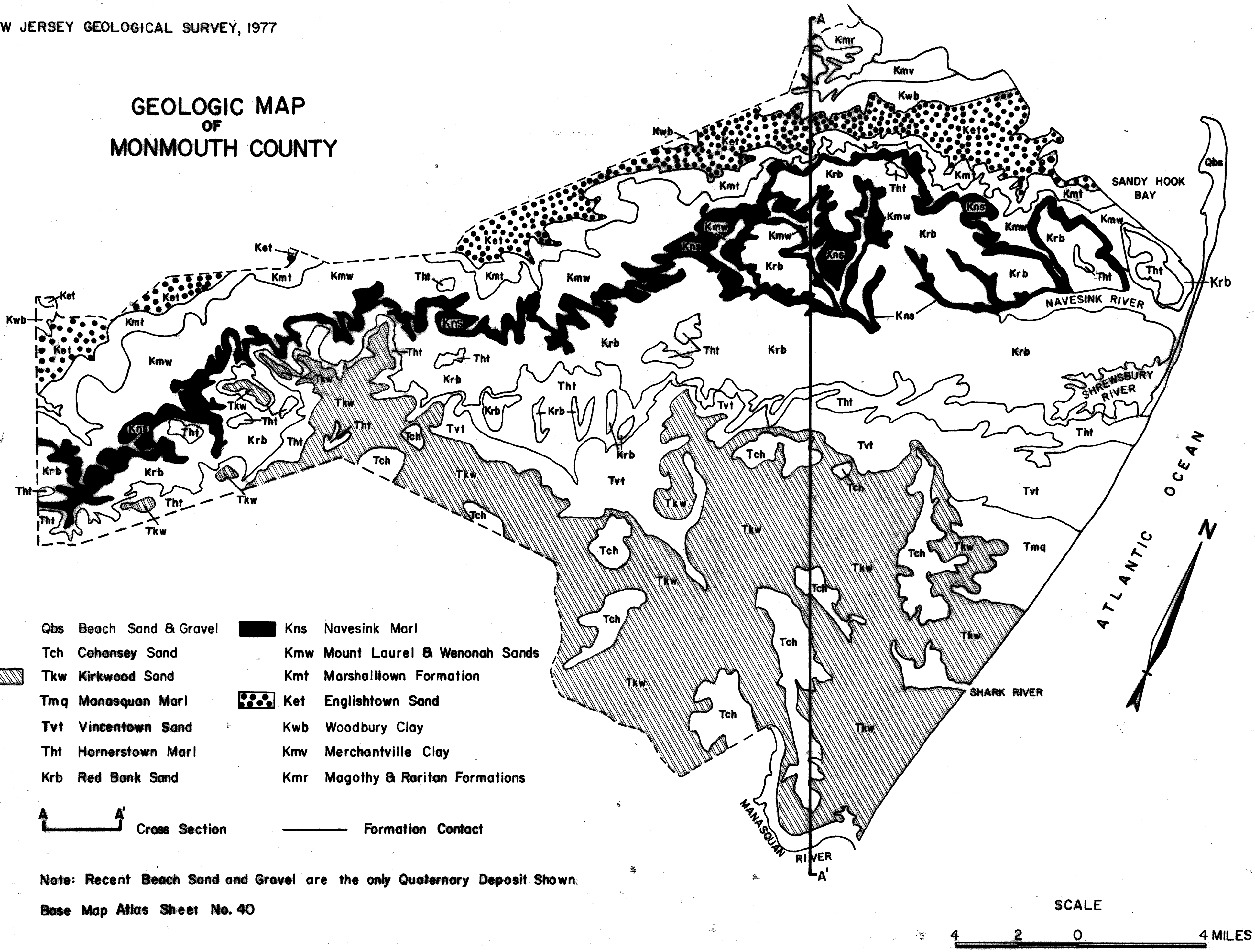
The contact between the Merchantville and the Woodbury formation is gradational, which indicates that conditions were changing without a break in the sedimentary record. In this case, the change was a lowering of sea level, or a regression, which deposited the 50 feet of dark gray clay of the Woodbury in progressively shallower water.

Englishtown Formation - Ket

Sea level continued to drop while the Englishtown formation was being deposited. In Monmouth County, the formation consists of about 140 feet of white or yellow quartz sand, with some mica, minor quantities of glauconite and some fine laminae of clay. The appearance of the sand varies from

NEW JERSEY GEOLOGICAL SURVEY, 1977

GEOLOGIC MAP OF MONMOUTH COUNTY



Qbs	Beach Sand & Gravel	Kns	Navesink Marl
Tch	Cohansey Sand	Kmw	Mount Laurel & Wenonah Sands
Tkw	Kirkwood Sand	Kmt	Marshalltown Formation
Tmq	Manasquan Marl	Ket	Englishtown Sand
Tvt	Vincentown Sand	Kwb	Woodbury Clay
Tht	Hornerstown Marl	Kmv	Merchantville Clay
Krb	Red Bank Sand	Kmr	Magothy & Raritan Formations

A—A' Cross Section

——— Formation Contact

Note: Recent Beach Sand and Gravel are the only Quaternary Deposit Shown

Base Map Atlas Sheet No. 40

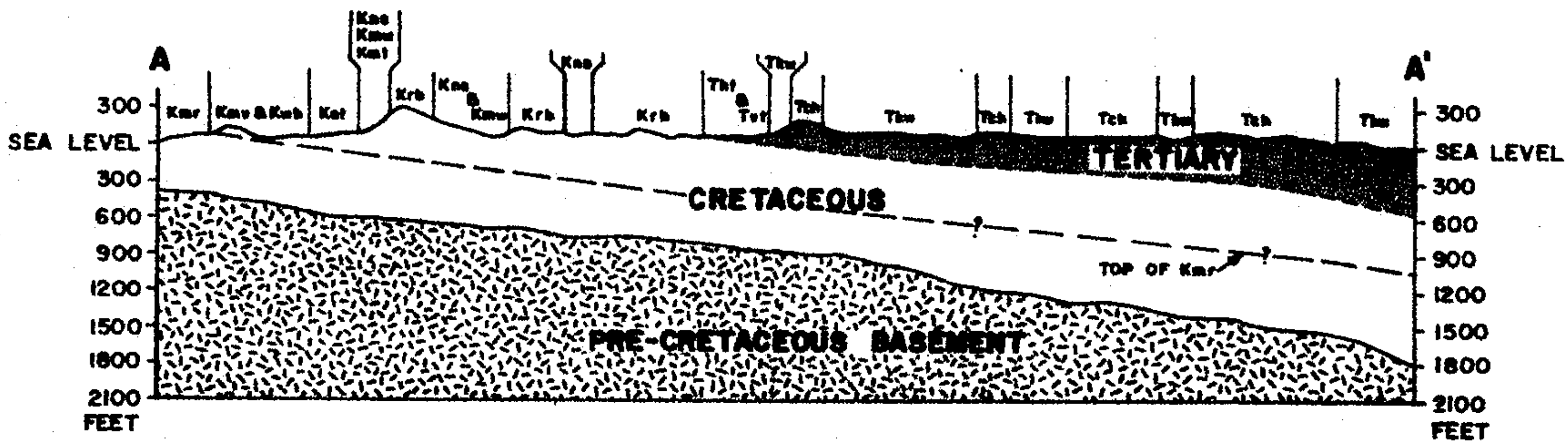


FIGURE 4. GENERALIZED CROSS-SECTION A-A'
(MONMOUTH COUNTY, NEW JERSEY)

HORIZONTAL SCALE
0 1 2 3 4
MILES

VERTICAL EXAGGERATION APPROX. 14X

well laminated and cross-bedded in some localities to a massive or uniform texture in others, especially to the south. Locally the sand is cemented by an iron oxide cement. Marine fossils are found in the Englishtown along the southern portions of its outcrop in New Jersey, although they are rare in Monmouth County. Fragments of lignite are common, some up to 4 inches long.

The interlaminated sands and clays which contain abundant lignite suggests a fluvial or deltaic environment of deposition for the Englishtown in Monmouth County. Farther south, the poorer stratification and marine fossils suggest that the formation graded into lagoon or marine sediments.

Like the Raritan and Magothy formations below it, the Englishtown is important in Monmouth County as an <u>aquifer</u>, or water-bearing formation. Both private home owners and municipal water supplies in the county tap the Englishtown with wells.

<u>Marshalltown Formation - Kmt</u>

A transgression, or rising sea level, brought about an abrupt change in the character of the sediments. As the water deepened, dark gray to black, silty, clayey glauconitic sands of the Marshalltown were deposited over the Englishtown. In outcrop the formation is only about 30 feet thick, but it thickens downdip. Casts of marine fossils and worm burrows are found in the formation. Many of the burrows are filled with glauconite, which gives the outcrop a mottled appearance.

<u>Wenonah and Mount Laurel Formations - Kmw</u>

These two formations are shown on the geologic map as a single unit because they are geologically similar and difficult to distinguish at some locations in the field. The Wenonah formation, conformable with the underlying Marshalltown, is thickest near Trenton (70 feet) but thins in

Monmouth County to about 35 feet at Atlantic Highlands. It is a uniform thick bedded to massive, medium to fine grained, micaceous, dark sand. Glauconite is a constituent at the base of the formation.

As sedimentation continued, an increase in grain size, a lighter color and more noticeable stratification mark the transition into the Mount Laurel sand. The Mount Laurel is about 35 feet thick in the north-eastern part of the county and, like the Wenonah, thickens to more than twice that figure near Trenton. Throughout most of Monmouth County, the formation consists of interbedded light-colored sands and darker clays. The clay beds contain siderite concretions and lignite fragments.

Deposition of the Wenonah and Mount Laurel formations occurred in progressively shallower water. The upper 10 feet of the Mount Laurel consists of coarse pebbly sand which marks the beginning of another transgression.

Navesink Formation - Kns

The best exposures of the Navesink formation are east of Atlantic Highlands along Sandy Hook Bay, where the entire thickness of 40 feet is exposed. The formation is a massive, poorly sorted, dark green to bluish-black clayey glauconite with some quartz sand. It is highly fossiliferous. The lower contact is abrupt. Clay becomes more abundant near the upper contact which is gradational.

Red Bank Sand - Krb

The youngest Cretaceous formation in New Jersey is found almost exclusively in Monmouth County. From a maximum thickness of about 140 feet, the Red Bank pinches out to the southwest, where it disappears in northeast Burlington County. Excellent exposures are found around the Highlands of Navesink from Red Bank along the Navesink River to the bluffs along Sandy Hook Bay.

The bulk of the Red Bank along the outcrop area is composed of coarse, yellowish to reddish brown quartz sand. It is locally cemented by iron oxide into irregularly shaped masses. The lower 15 to 30 feet consists of a dark grayish black, massive clayey sand with glauconite near the base. Fossils are rare except in the lower portion. Downdip, the sand grades into a greenish gray mixture of glauconitic clay and quartz sand.

Tertiary

Paleocene

Hornerstown Formation - Tht

A major unconformity accompanied by widespread erosion preceded deposition of the earliest Tertiary formation. Apparently erosion was most active south of Monmouth County, since the Hornerstown formation, which is exposed from Monmouth Beach to Maryland, lies on successively older formations to the south, from the Red Bank to the Mount Laurel. Over this distance, the Hornerstown changes little in either thickness or lithology. It consists of 20 to 30 feet of glauconite with some sand and clay. The formation is rich in fossils, especially near the top. In addition to many species of plecypods (clams and oysters), the remains of crocodiles and sharks' teeth have been recovered from the Hornerstown at some localities.

Vincentown Formation - Tvt

In Monmouth County, the Vincentown formation consists of about 100 feet of massive glauconitic quartz sand, similar in appearance to the Mount Laurel formation and the lower portion of the Red Bank. The similarity exists because all three were formed during regressive periods, when shallow water sediments were being deposited over deep water formations. South of

Monmouth County, the Vincentown becomes quite distinctive, being one of the most fossiliferous of the Coastal Plain formations. The area near Vincentown, in central Burlington County, consists almost entirely of foraminifera and broken bryozoa, along with the less common occurrence of remains of echinoids, corals and other marine creatures.

Eocene

Manasquan Formation - Tmq

The Manasquan formation is exposed only in a small area where the younger formations have been eroded away. The lower part of its 25 feet of thickness is mostly sand and glauconite, with some reworked fossils of the Vincentown. The upper part is mostly fine sand and greenish to white clay. Near Long Branch and Farmingdale, the Manasquan is overlain by the Shark River marl, which is about 11 feet of greensand and light colored clay.

These deposits represent a return to deeper water, after the shallow water interlude represented by the Vincentown. After deposition of the Shark River marl, the Eocene sea withdrew from New Jersey, beginning a period of erosion which continued through the middle Miocene.

Miocene

Kirkwood Formation - Tkw

The largest exposure of a single formation in Monmouth County is of the Kirkwood. As the middle Miocene seas advanced over the eroded surface of the Eocene deposits, the marginal marine to shallow nearshore sediments of the Kirkwood were deposited. A black, lignitic clay forms the base of the formation. This is overlain by fine micaceous quartz sand, which is interbedded with lens-shaped beds of clay, which vary in thickness from a few inches to several feet. Thin beds of gravel and cross-bedded sand found at some places were probably deposited on a beach. In Monmouth County, the Kirkwood averages about 100 feet in thickness, although it thickens downdip to the south to more than 1200 feet near Atlantic City.

Miocene-Pliocene

Cohansey Formation - Tch

A brief lowering of sea level recurred following deposition of the Kirkwood. Evidence of this can be seen where the lower contact of the Cohansey formation is visible in outcrop. However, the evidence of this unconformity does not persist downdip in well samples, which suggests that this break in sedimentation was not widespread.

The Cohansey is composed primarily of coarse light colored quartz sand, often with a prominent cross-bedding. Occasional discontinuous lenses of light colored clay are found from a few inches to about 10 feet thick. The depositional environment of the Cohansey varied widely from beaches and lagoons to fluvial or river deposits. Exposures of the Cohansey in Monmouth County are thin and scattered, although it is widespread in outcrop farther south in the Pine Barrens of the Coastal Plain, where the average thickness averages about 100 feet.

The age of the Cohansey is not known with certainty. The fact that it is nearly conformable with the Kirkwood suggests a late Miocene age. Some plant fossils have been identified which suggest that the formation may be as young as Pliocene. Recent analysis of pollen grains found in the Kirkwood and Cohansey formations indicates that the climate of New Jersey during the Miocene and Pliocene was humid subtropical, similar to what is found today south of Virginia.

Pliocene-Beacon Hill

After deposition of the Cohansey, an uplift of the rocks in the northern part of New Jersey began a period of increased erosion. The sands and gravels of the Beacon Hill formation were deposited by streams flowing across the Coastal Plain. Erosion since that time has reduced the formation to a few scattered remnants at the top of the highest hills which are too small to show on the geologic map. The fact that material deposited in stream valleys is now found on hill tops indicates that many hundreds of feet of sediments have been eroded since the Pliocene. Even though the largest exposures of the formation are found in Ocean County, the formation is named for Beacon Hill in Monmouth County.

QUATERNARY

Although the glaciers of the Pleistocene or Ice Age never reached Monmouth County, the changes in sea level and disruption of drainage patterns they caused played an important role in establishing our present landscape. The three formations deposited during the Pleistocene have not been shown on the geologic map because they are generally small exposures which lie on the surface of the older formations. The sands and gravels of the Bridgeton formation occur as scattered outcrops, usually less than 30 feet thick. Part of the deposition was by rivers, although some of the county was probably submerged at this time. The largest exposures of the Pensauken formation are found just west of Monmouth County, where light colored sands and gravels were deposited by a major river system flowing southwest across the state during an interglacial period. Within Monmouth County, the Pensauken is limited to thin deposits along some stream valleys. The Cape May formation is found mostly along the shore at elevations below about 50 feet, where the sands and gravels were deposited while the sea stood at a higher level than today, probably just before the start of the last period of glaciation.

MINERAL RESOURCES

Monmouth County is not richly endowed with mineral wealth. Relatively small quantities of sand and gravel are taken for building and road work. However, historically, the mineral industry in the county was once far more active than today.

The greensand marls of the Cretaceous strata were once used extensively as fertilizer. Its value as a soil conditioner was first discovered on the farm of Peter Schenck near Marlboro in 1768, after material dug from ditches was spread over the fields. When a marked improvement in yield was observed on these fields, the practice of spreading marl gained acceptance, until by the middle of the 1800's the use of marl was common throughout the Coastal Plain. It was even used to allow farming on the infertile soil of the Pine Barrens. The primary value of the marl was as a source of lime, phosphoric acid, and potassium. All the greensand formations were not of equal value. Some marls, high in sulfates of iron, were unfit for use without treatment, although even this "poison marl" was used after composting with lime. Too much clay in the marl will cause the development of a "hardpan" which is also undesirable.

Ground water in the Coastal Plain frequently contains high concentrations of iron, as is well known to homeowners with private wells. Since most of the streams in the Coastal Plain are fed by ground water, they too are frequently iron rich. Contact with the air causes the ferrous iron carried in solution to precipitate iron oxide. Because the iron oxide collects in low swampy areas, it is known as "bog iron." Most of the bog iron ore in New Jersey is found further south, where it once formed an important industry, although some was produced in Monmouth County. In fact, the first known iron works in the state was operating in 1685 at Tinton

Falls. Another iron works was started at Imlaystown, in Upper Freehold Township in 1716. The bog iron industry was made uneconomical by the development of higher grade ores many years ago. One feature of the industry is of interest in this present age of scarce resources - bog iron was a renewable resource. Ore could be "harvested" from different parts of the bogs each year. After the limonite was removed, precipitation of the iron oxide began anew and in only 20 to 30 years a new "crop" was ready for production.

In the 1950's, a new important mineral resource was discovered in the Coastal Plain. Ilmenite, or iron titanium oxide, was found in economic concentrations in parts of Ocean and Burlington Counties, where it is now being produced. Some deposits extend into southern Monmouth County, although these are not being worked. Ilmenite is used as a source of titanium, primarily for the manufacture of paint pigment.

The source of the ilmenite now found in the Coastal Plain was the Precambrian crystalline rocks now exposed in the northwestern part of New Jersey. Thousands of feet of these rocks were eroded over millions of years, providing sediment for the Coastal Plain formations. Because the ilmenite is a heavy mineral, it tends to be concentrated by wave and stream action. The ore bodies in New Jersey are found in the Kirkwood and Cohansey formations. In the Kirkwood, the ilmenite was concentrated by wave action in the retreating Miocene seas. Later, streams which deposited the Cohansey formation concentrated ilmenite in several areas along their paths.

GEOLOGIC TIME SCALE

Geologic time intervals are unequal subdivisions of the earth's history corresponding to earth's geologic events. Eras are the longest divisions of time and contain many periods which are further subdivided into epochs. Formations, which are mappable units of rock or sediments, usually have lithology or characteristic distinctions and are assigned to that period or epoch during which they are formed.

A formation's place within the stratigraphic column is determined by the predominant form of life preserved as fossils within the rocks or sediments. If fossils are lacking, a formation's location in the time scale may be determined by its relationship to previously dated units. Only recently have geologists been able to place an absolute date on these relative time units by radioactive methods.

The geologic column is used throughout the world, although some regional modifications may be used for greater clarity.

In the accompanying stratigraphic column, the rock type given after the name is the most common variety found in the county. There may be variation of lithology within the formation from place to place.

GEOLOGIC TIME SCALE OF MONMOUTH COUNTY

Era	Period	Epoch	Formation or Rock (Approx. Thickness in Ft.)	Approx. Age Million Years before Present
CENOZOIC	Quaternary	Recent	Beach sand & gravel Soil & alluvium	0-0.01
		Pleistocene	Cape May formation (0-30) Pensauken formation (0-10) Bridgeton formation (0-30)	0.01-1
	Tertiary	Pliocene	Beacon Hill formation (0-20)	1-11
		Miocene-Pliocene	Cohansey formation (0-100)	
		Miocene	Kirkwood formation (0-100)	11-25
		Oligocene	Not present in county	25-40
		Eocene	Manasquan formation (0-25)	40-60
		Paleocene	Vincentown formation (100) Hornerstown formation (20-30)	60-70
MESOZOIC	Cretaceous	Upper Cretaceous	Red Bank sand (0-140) Navesink formation (25-40) Mount Laurel formation (35-70) Wenonah formation (35-70) Marshalltown formation (30) Englishtown formation (140) Woodbury formation (50) Merchantville formation (50-60) Magothy formation (25-175) Raritan formation (150-300)	70-100
		Lower Cretaceous	Not present in county	100-135
	Jurassic		Not present in county	135-180
	Triassic		Not present in county	180-225
PALEOZOIC	Permian Carboniferous Devonian Silurian		Not present in county	225-600
	Ordovician Cambrian	?	? "basement" Gneiss, age and thickness uncertain	
PRECAMBRIAN				600+

SUGGESTIONS FOR FURTHER READING

Dietz, R.S., 1972, Geosynclines, mountains and continent-building:Scientific American,vol.226,no.3,pp.30-38. This article explains in easily understood terms how Coastal Plain sediments are added on to Continental Margins and eventually transformed into mountain belts through the processes of plate tectonics.

Jablonski, L.A., 1968, Ground-water resources of Monmouth County, New Jersey: N.J.Dept. of Cons.& Econ.Dev.,Special Rept. No.23. Although now out of print, this report may be found in libraries. The report provides technical information on the water-bearing properties of the formations in Monmouth County.

Kummel, H.B., 1940, The geology of New Jersey:Geological Survey of N.J.,Bull. 50. This reference is out of print, although it may be found in libraries.

Minard, J.P., 1969, Geology of the Sandy Hook Quadrangle in Monmouth County, New Jersey:U.S.Geological Survey Bull. 1276. This bulletin (with map) provides detailed information on the geology of the Navesink Highlands and Sandy Hook. It may be purchased through the Bureau of Geology.

________, 1974, Slump blocks in the Atlantic Highlands of New Jersey:U.S. Geological Survey Prof.Paper 898. A description of slump blocks and slumping in the hills of the northeastern N.J. Coastal Plain, and a discussion of their potential as geologic hazards.

Subtizky, S., 1969, Geology of selected areas in New Jersey and eastern Pennsylvania and guidebook of excursions:Geological Society of America and associated societies annual meeting, Atlantic City, N.J.; Rutgers University Press, New Brunswick, N.J. The interested reader will find a wealth of information in this volume. The following articles will be of particular interest to residents of Monmouth County:

Bowman, J.F. & W. Lodding, The Pensauken formation - A Pleistocene fluvial deposit in New Jersey, pp.3-6.

Enright, R., The stratigraphy and clay mineralogy of Eocene sediments of the northern New Jersey Coastal Plain, pp.14-20.

Isphording, W.C. & W. Lodding, Facies changes in sediments of Miocene age in New Jersey, pp.7-13.

Markewicz, F.J., Ilmenite deposits of the New Jersey Coastal Plain, pp.363-382.

Minard, J.P. & E.C. Rhodehamel, Quaternary geology of part of northern New Jersey and the Trenton area, pp.279-313.

Owens, J.P. & N.F. Sohl, Shelf and deltaic paleoenvironments in the Cretaceous-Tertiary formations of the New Jersey Coastal Plain, pp.235-278.

Widmer, K., 1964, The geology and geography of New Jersey:D. Van Nostrand, Princeton, N.J., v.19,193 pp. A non-technical account of the geology of the state which may be purchased from the Bureau of Geology.

Cover picture from New York magazine of August, 1790, from a New York Library figure; courtesy of Samuel Steele Smith, Sandy Hook and the Land of the Navesink; Philip Freneau Press, Monmouth Beach, N.J., 1963.

BOOKS OF INTEREST AVAILABLE
FROM THE BUREAU OF GEOLOGY

Richards, Horace G., et al, 1958, The Cretaceous Fossils of New Jersey, Parts I and II, Bulletin 61

Widmer, Kemble, 1964, The Geology and Geography of New Jersey, D. VanNostrand, Princeton, v.19, 193 p.

COUNTY SERIES:
- Geology of Bergen County in Brief, Carol S. Lucey, Sr. Geologist
- Geology of Burlington County in Brief, Carol S. Lucey, Sr.Geologist and Kemble Widmer, State Geologist
- Geology of Essex & Union Counties in Brief, Carol S. Lucey, Sr.Geologist
- Geology of Hunterdon County in Brief, Carol S. Lucey, Sr.Geologist
- Geology of Mercer County in Brief, Kemble Widmer, State Geologist
- Geology of Morris County in Brief, Carol S. Lucey, Sr.Geologist
- Geology of Passaic County in Brief, David P. Harper, Sr.Geologist
- Geology of Sussex County in Brief, Carol S. Lucey, Sr.Geologist
- Geology of Warren County in Brief, Carol S. Lucey, Sr.Geologist