BULLETIN 63

Geologic Series

PETROGRAPHY AND GENESIS OF THE NEW JERSEY BEACH SANDS

By

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STATE OF NEW JERSEY
DEPARTMENT OF CONSERVATION
and ECONOMIC DEVELOPMENT

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Division of Planning and Development
WILLIAM C. COPE, *Director*

TRENTON, N. J.
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WILLIAM C. COPE, *Director*

BUREAU OF GEOLOGY AND TOPOGRAPHY

MEREDITH E. JOHNSON, *State Geologist*

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COUNCIL OF THE DIVISION OF PLANNING AND DEVELOPMENT

LETTER OF TRANSMITTAL

Dr. William C. Cope, Director
Division of Planning and Development

Sir:

I am transmitting with this letter, and recommend for publication, a report describing the composition of the beach sands of New Jersey as determined by detailed microscopic examination of 144 beach samples, and 26 additional samples collected in bay bottoms, offshore, and from headlands. This is the first thorough study of our beach sands and it is of value, therefore, to residents of all our shore communities in showing the derivation of their beaches and how man can work with Nature to preserve them. Also, it is of value to the economic geologist and to companies interested in the production of such minerals as ilmenite, zircon and monazite in showing the percentages of those minerals present in our beach sands. And finally, it should be of great value to this Department and to the Corps of Engineers, U. S. Army, which annually spend millions of dollars in the protection of our shore communities and in the maintenance of channels.

Respectfully submitted,

Meredith E. Johnson
State Geologist

PREFACE

The writer is pleased to acknowledge the debt of gratitude owed those whose generous aid and cooperation made this investigation possible. Space will not permit mention of all those to whom he is indebted, but their help is deeply appreciated.

He is particularly indebted to Professor James H. C. Martens for his valuable counsel and encouragement throughout the study, and to Doctor Helgi Johnson for permission to use the laboratory facilities and equipment of the Rutgers University Bureau of Mineral Research.

Special thanks are due Mr. William Lodding whose constant willingness to furnish valuable information on technical matters has been extremely helpful.

Acknowledgement is made to the United States Army, Corps of Engineers, Office of the District Engineer at Philadelphia, Pennsylvania, for making available valuable information from their files.

The writer sincerely appreciates the aid and cooperation of his many Rutgers University friends, especially Doctor Mitchell A. Light and Messrs. Russell H. Michel and Joseph E. Patchett.

Finally, particular gratitude is due my wife, Edith P. McMaster, whose tireless assistance and encouragement made possible the completion of this study.

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1. New Jersey Coastal Area .... ENVELOPE

INTRODUCTION

Introductory Statement

Along the eastern margin of New Jersey, the ravenous waters of the Atlantic Ocean lap the gently dipping land surface of the Atlantic Coastal Plain for a distance of some 125 miles. Although the stability of the shore area is subject to the workings of nature and the fulfilment of its laws, this narrow belt of shifting sediment serves as an enormous recreational attraction and thereby nourishes one of the largest businesses of the state.

A detailed sedimentological study of the sandy beaches in particular, and certain off-shore and mainland areas in the immediate vicinity of the shoreline, was limited to the region of New Jersey between Sandy Hook on the north and Reeds Beach on Delaware Bay, a distance of almost 150 miles. This region lies along the landward margin of the Coastal Plain and its relief does not exceed 60 feet except at Atlantic Highlands, near Sandy Hook, where the elevation reaches almost 300 feet.

In this region, the coastline reveals a variety of interesting physiographic features. Between Sandy Hook and Monmouth Beach the shoreline is characterized by a spit and bay bar which offset the sandy beaches from the mainland. From Monmouth Beach to Bay Head, the shore is developed along the truncated structure of the mainland. South of Bay Head, the shoreline is nearly a continuous barrier bar, broken only by a number of tidal inlets. Between this series of bars and the mainland, a lagoon, reaching a maximum width of about five miles, protects the headlands from wave attach. At Cape May and along Delaware Bay, the mainland again forms the bulwark against the sea.

During the years 1950-1951, the writer devoted the bulk of his time to the investigation of this region of New Jersey. Most of the field work was completed during the summer of 1950. The laboratory work was conducted at the Bureau of Mineral Research at Rutgers University and was made possible by a research assistantship. This report presents the results of field and laboratory study of the sands of the coastal region of New Jersey.

Purpose of the Investigation

It was the purpose of this research to describe the New Jersey beach sands as to texture and mineral composition and, as far as possible, to interpret the origin and movements of these sands. These objectives can be more specifically stated as follows:

(1) The determination of any compositional differences of the New Jersey beach sands which may indicate possible source differences.

(2) The general relationship of the beach sands to adjacent bottom sediments.

(3) Locations of ultimate and immediate source materials for the beach sands.

(4) Movement of sand from the source areas to the littoral zone.

A technique of comparing the mineral contents of the various beach samples is closely related to the first of these aims. Rittenhouse (39) developed the use of hydraulic ratios in correlating the heavy minerals in river sands. It is Rittenhouse's belief that material derived from the same source should have the same hydraulic ratios regardless of the present nature of its textural composition and amount of heavy minerals. As a corollary objective, this study will endeavor to test the validity of the hydraulic ratio principle as applied to the littoral sediment of the New Jersey beaches.

The results obtained in this study may have valuable applications in problems of erosion control along the New Jersey shore.

Recently, Mason (32, p. 287) and Krumbein (21, p. 196) publicized the contributions which geology may make to the solution of engineering problems in beach preservation. It is their belief that an important geological contribution lies in the study of the source areas and movement of beach material.

THE NEW JERSEY SHORE

General Description

In New Jersey, the Coastal Plain forms the eastern margin of the continent. Its surface, developed on late Cretaceous to Quaternary gravels, sands, marls, and clays, slopes gently to the southeast. Various shoreline features separate the submerged plain from the subaerial portion of this typical emerged coastal plain.

There are many internal and external features which characterize the New Jersey coastal region. Near the north end of the shore, in the vicinity of Raritan Bay, many marshes border the stream courses. Between Sandy Hook and Long Branch the shoreline displays a compound and complex recurved spit with its distal terminus in Raritan Bay and its base attached to a bay bar which connects with the mainland at Long Branch. Drowned courses of the Navesink and Shrewsbury Rivers and the cliffed Highlands to the west are internal elements which are associated with the spit and bay bar. From Long Branch to Bay Head, exposed headlands are the major feature, with bay bars closing the Shark and Manasquan Estuaries (inlets are artificially maintained for these streams). South of Bay Head, the coast consists of a number of offshore bars or barrier bars which are separated from the mainland by a series of lagoons, marshes, and thoroughfares. In this area, the mainland shoreline is quite irregular due to the submergence of the numerous stream courses. At Cape May the Atlantic shoreline again touches the mainland. Toward the north, along the Delaware Bay shore, marsh bars are numerous and cuffed head-. lands are well developed. Delaware Bay is the drowned lower part of the Delaware River.

Development of a Coastal Plain Shoreline

As the logical expression of natural evolution, Johnson (17, pp. 258-262) has briefly summarized the general pattern of development of a typical coastal plain shoreline.

During the earliest state of development, a significant feature to make its appearance is a continuous narrow ridge of sand lying some distance out from the shore, which is referred to under the various names of barrier beach, sand reef, offshore barrier, and offshore bar. Slow retrogression marks its normal evolution. This results from either grinding of the beach materials to fine silt and its removal in suspension to deep water, or from the loss of coarser debris from the bar by the drag of sea bottom currents. However, material freshly cut from the sea bottom or new debris brought from an adjacent source of supply by longshore currents may compensate for the sediment lost, but at best this is only a temporary respite. Landward building is accentuated by storm waves hurling debris over the crest of the bar, and by overwash waves and wind carrying additional material down the back side of the bar. As Johnson (17, p. 261) writes:

> "All these factors combined may be sufficient to build up the inner side of the bar as fast as the outer side is cut away, in which case the bar will retreat bodily toward the coast without any marked change in its average width."

When the offshore bar is formed, a narrow strip of shallow water, called a lagoon, is enclosed between the bar and the mainland. Deposition of fine debris is favored in the quiet waters of the lagoon. These sediments are derived from: (1) wind-blown sands of the beaches and dunes of the bar, (2) stream deposits of mainland material, and (3) finer sediment particles transported from the beaches to inlets by longshore currents and carried into the lagoon by tidal currents. In time, these sediments may build up the floor of the lagoon to such a level that salt marsh vegetation can take possession.

The last stages of development are described by Johnson (17, p. 261) when he states:

> "As the retrograding of the offshore bar continues, its sands and gravels are driven in over the marsh surface. The enormous weight of the bar compresses the peat and other marsh deposits, which later outcrop on the seaward side of the bar near or below low-tide level, and thus bear witness to the retrograde movement of the outer shoreline."

When the bar has been forced back to the mainland, the lagoon is completely eliminated and the waves begin their relentless attack on the mainland itself. Longshore currents carry eroded material along the shore, closing bays and rivers, and forming spits in the offshore areas. When sea level rises in relation to the land masses, regression of the shoreline is accelerated and river courses and bays become drowned beneath the advancing sea.

Beaches and Beach Sands

System of Terminology

The system of nomenclature of the coastal area shown in Figure 1 has been adopted by the Beach Erosion Board. (8, Figure 1)

General Description of New Jersey and Northern Delaware Beaches

Beaches of New Jersey and northern Delaware are composed essentially of sand with only small amounts of shell and pebbles. These beaches may be placed in two broad categories. One has a relatively narrow shore with a gentle to moderate dipping foreshore and contains medium to coarse laminated sands. The second type is a wide nearly flat beach composed of fine sand.

The coast of New Jersey was subdivided into smaller areas which do not have physiographic or geologic

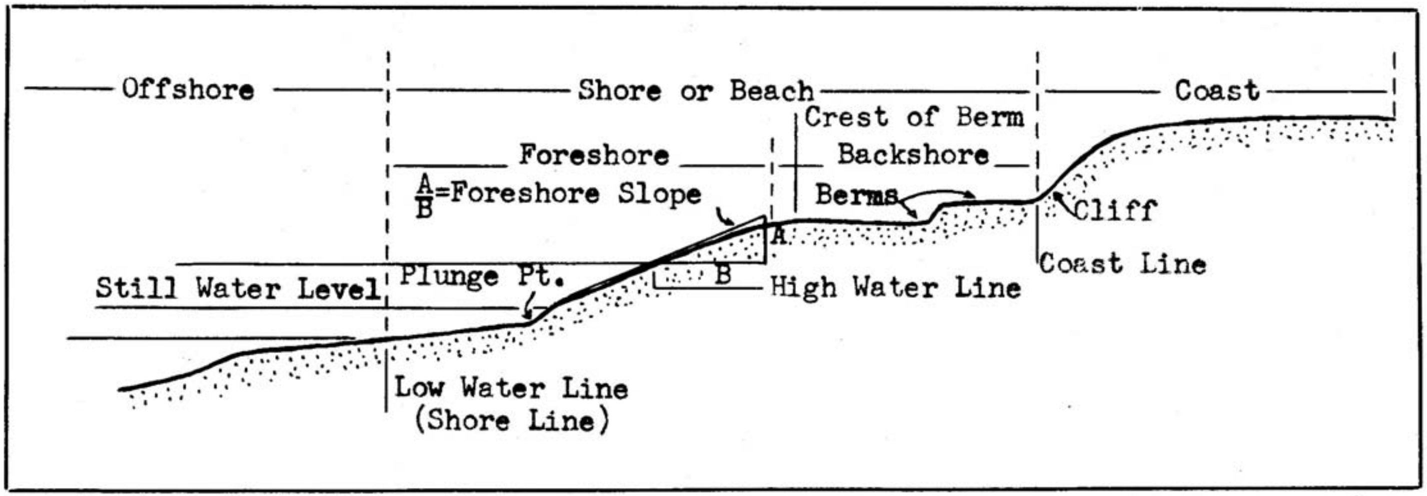


Figure 1 Nomenclature of Coastal Area

Adapted from the Beach Erosion Board (8, Figure 1) boundaries, but which have some common attribute that sets them apart from one another.

Sandy Hook to Point Pleasant.

Most of the beaches in this area are not an expression of natural shore conditions. Their development and configuration is artificially controlled and maintained by the groins and sea walls which line the beach.

In general, the foreshore is 50 to 100 feet broad and is inclined from 5 to 12 degrees. Lower foreshore slopes level off to 2 or 3 degrees. When a backshore is developed, it is over 100 feet wide and has a slope of 1 to 2 degrees toward the cliff or dunes.

Where natural conditions are allowed to develop the beaches, as at Sandy Hook and Spring Lake, several different types of beach profile were noted. One type of profile features a double berm on the backshore zone in which the lower berm was cut longitudinally by a shallow trough (Figure 1). Another type of profile showed an upper foreshore of 15 to 20 feet, with a greater inclination than the mean slope of the foreshore zone. Coarse and medium sands[1] occur along this type of beach (Plate 1) and streaks of well-rounded

[1] Classification based on Wentworth scale. See Table 3.

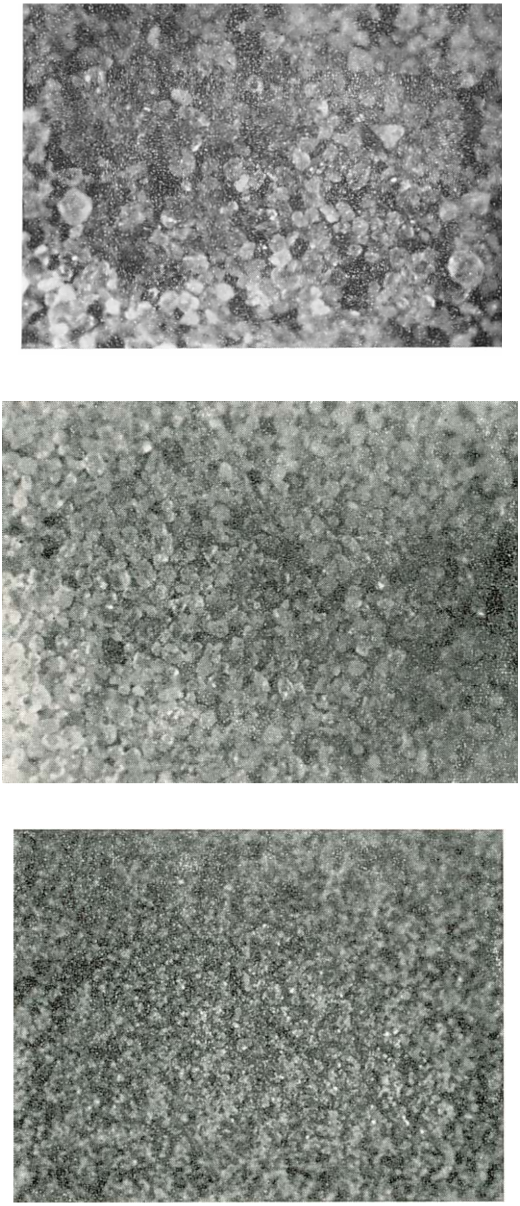


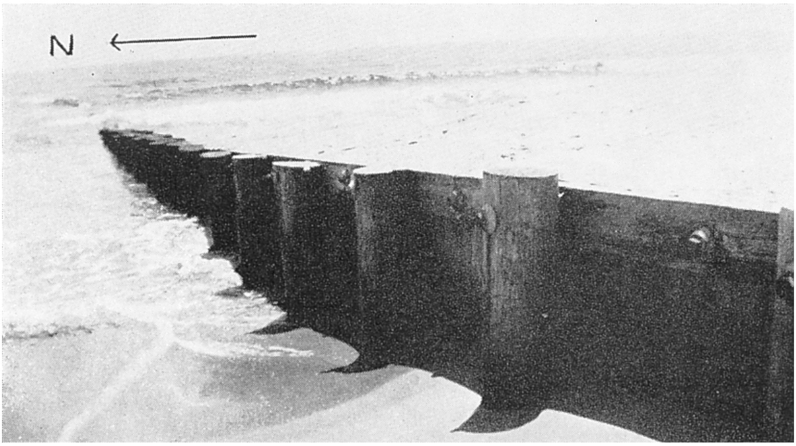
PLATE 1—New Jersey beach sands. Top: Asbury Park. Center: Long Beach Island. Bottom: Atlantic City

quartz pebbles and granules and shells of various kinds are a common feature.

The composition of those sands is not the same over the entire area. From Sandy Hook to Shark River Inlet the sands contain over 10 percent well-rounded glauconite grains in addition to quartz, which is the most abundant mineral. Iron-stained grains are common and the resulting color of these sands is dusky yellow. South of Shark River Inlet there is a reduction in the number of glauconite grains to less than 5 percent and this, coupled with the decrease in iron-stained grains, results in a color change to grayish-yellow.

In this area beach drifting is definitely toward the north (Plate 2). Almost every groin shows an accretion of sand on its south side. In addition, the extension of Sandy Hook spit toward the north over the years proves, without a doubt, that the beach material is migrating toward the north.

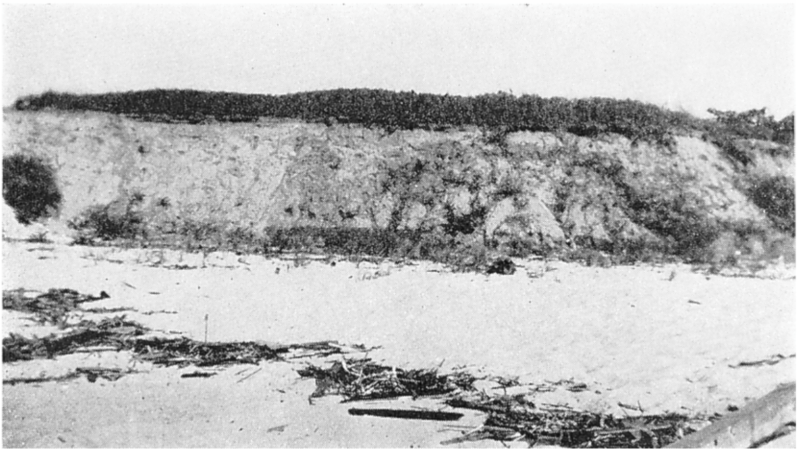
Wave erosion in this area is a major problem. The many groins and sea walls are evidence of the fury of wave attack and erosional features are all too obvious. Sharply truncated dunes, and brushwood at the waters edge, can be seen at many places on Fort Hancock (Plate 2). Wave-cut cliffs, some over 15 feet in height (Plates 3 and 4) exist at various localities between North Long Branch and Allenhurst.



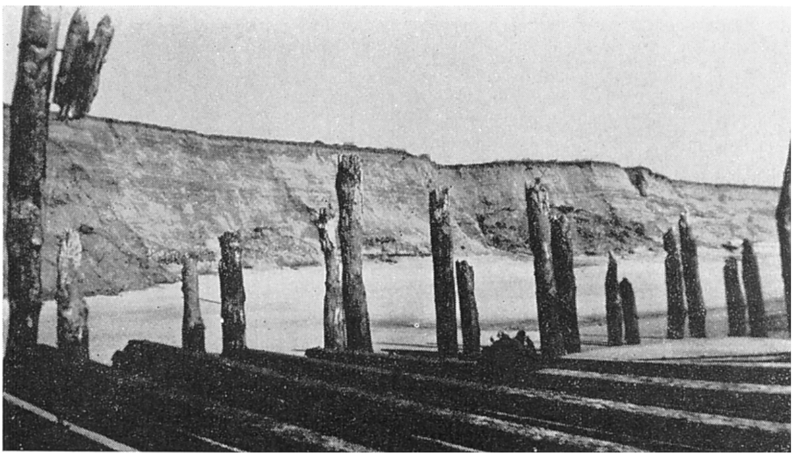
A. Beach accretion in the direction of longshore transportation at Manasquan.

B. Dune scarp on Sandy Hook.

PLATE 2



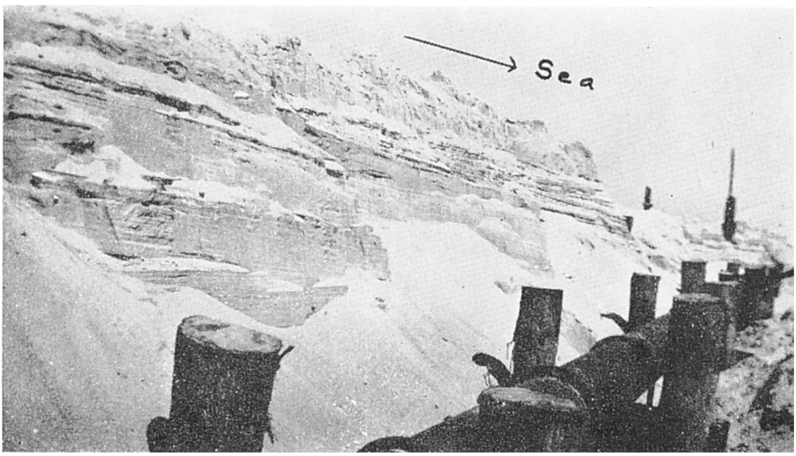
A. Twelve foot wave-cut cliff at Deal.



B. Wave-cut cliff along the beach at Deal. Notice the broken sea wall in the foreground.

PLATE 3

A. Headlands at North Long Branch. Notice overlying dune.



B. Transverse section across the beach at Spring Lake.

PLATE 4

A section across the sandy beach at Spring Lake shows interesting stratification (Plate 4). Close inspection of this 6-foot section reveals both landward and seaward dipping laminae. Laminae of landward dip are truncated by an erosional surface of seaward dip and this surface is the floor of deposition of laminae of seaward dip. Similar observations were previously reported by Thompson (45, p. 733) on California beaches. In this section certain layers are composed of coarse sand and pebbles; others of medium sand or shells, or black opaque minerals; and some of shells, and coarse and medium sand. Most shell fragments show a preferred orientation of the convex side upward.

Point Pleasant to Pullen Island.

From Point Pleasant to Pullen Island, the foreshore has the greatest inclinations of any area along the New Jersey coast-line. The slopes of this zone vary between 7 and 12 degrees, but lower foreshore inclinations level off to 2 to 3 degrees. The foreshore width measures as much as 100 feet at several places but averages closer to 75 feet from berm crest to low tide line. When natureally developed, the backshore is well over 100 feet wide and slopes at 1 degree toward the bordering dunes.

A transverse profile with two berms is a common feature on this stretch of beach. Concave and convex foreshore profiles observed in some places are controlled by the inclination of the upper foreshore. If the slope of this area is greater than the mean slope of the foreshore, then the profile is concave. If the reverse is true, then the profile is convex.

Beach scarps are a regular feature of the foreshore (Plate 5). Since the slopes of the foreshore are moderate, almost every storm and gale produces some kind of scarp. Large and small cusps are also common along the beach. These cusps are much more prominent than these developed on beaches with small inclinations. Stone and wooden groins are an uncommon feature over most of the area.

Texture and composition may be briefly summarized. Coarse and medium sands are associated with the beach slopes (Plate 1). Streaks of well-rounded quartz pebbles and granules and pieces of shell are common along this stretch of the beach. Although iron-stained grain are less abundant toward the south, grayish-yellow is most descriptive of these sands. Dark grains make up only a very small part of these sands except where wave action is actively reworking former sand dune material or where wind action has removed the fine lighter material. A few grains of glauconite appear in those sands near Point Pleasant, but only traces of this mineral can be found near Beach Haven. Quartz makes up over 98 percent of the sands.

Evidence of beach drift are not readily apparent. Several groins on Long Beach Island show that material is being added to their south sides. These indications are contrary to the evidence furnished by inlet migrations which seem to show a southward movement.

Active wave erosion seems to be at a minimum in this area. Sharply truncated dunes can be observed south of Barnegat Inlet and between Beach Haven and Holgate (Plate 6). A few pieces of salt peat[1] were noted in back-shore areas at several places.

Pullen Island to Cape May.

In this area of the New Jersey coast, the beaches are widest and most gently inclined (Plate 6). The fore-shore width is almost 150 feet in most places and the backshore is over 100 feet wide when naturally developed. Slopes on the foreshore vary between 2 and 5 degrees, but 3 degrees is the most common reading. Between the berm crest and the dunes, the backshore shows a 1 degree slope, but very often there is a constant inclination from the dunes to the low tide line. Dunes of varying height bor-der the backshore in many places. In some localities the beach contains numerous stone groins, this being especially true in and around inlets.

Laminated beach structure was noted on Pullen Island (Plate 7), where a longitudinal section was

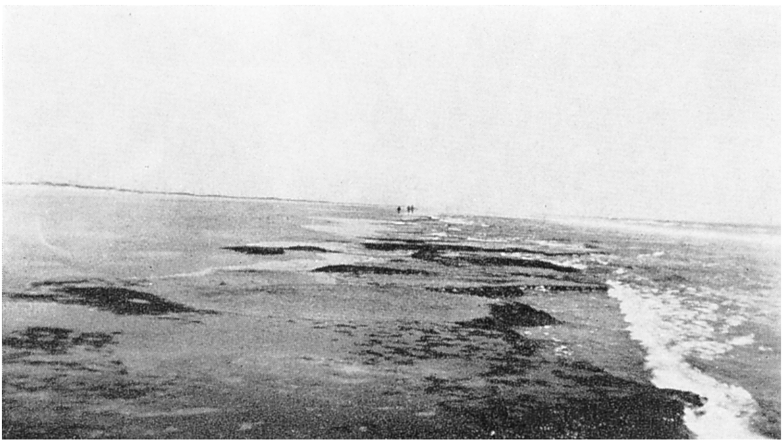
[1]Salt peat is partially decomposed salt water vegetable matter.

A. Beach scarp on the south side of Tucker Island. Notice the salt peat scattered along the beach.

B. Beach scarp on Island Beach.

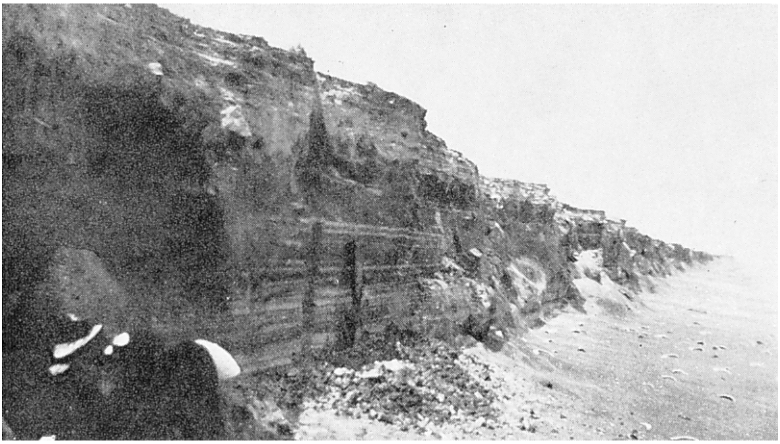
PLATE 5

A. Dune scarp near Barnegat Light.



B. Marsh deposits uncovered on the beach at Brigantine at low tide. Notice the width of the shore.

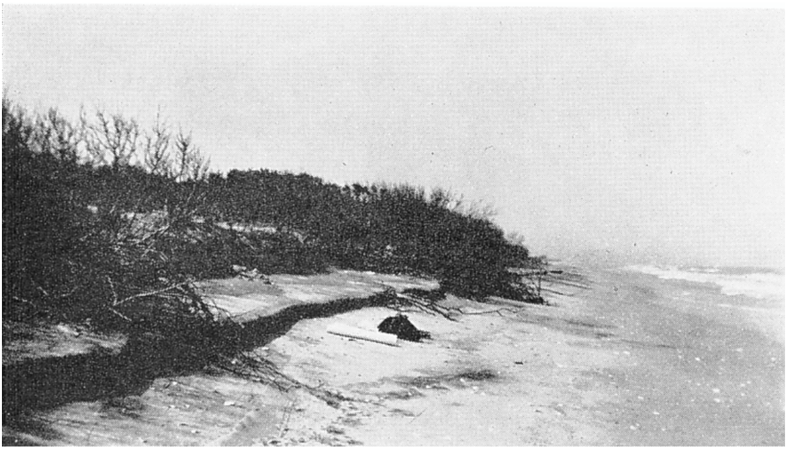
PLATE 6



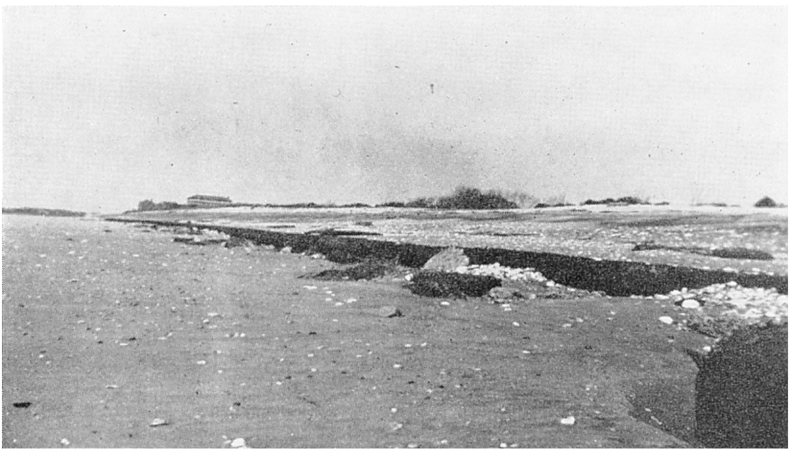
A. Beach scarp on Pullen Island. Note the stratification.

B. Wave erosion at Ocean City.

PLATE 7



A. Brushwood along the beach on Pullen Island.



B. Marsh deposits exposed on the beach at Sewell Point near Cape May.

PLATE 8

exposed by wave action as a beach scarp. The unusual concentration of dark layers in the section is due to recent reworking by the waves of nearby dune material.

Flat, irregularly developed cusps and sand dunes can be found at many places along this stretch of beach.

The texture and composition of these sands are quite different from those in the adjacent areas. Fine sand dominates in this area and few pebbles can be found on the beach (Plate 1). However, streaks of shells are common. Although quartz is the most abundant mineral, dark grains of hornblende and black opaques make up about 5 percent of these sands. Feldspar is also an important constituent. The presence of significant amounts of dark grains deepens the color of these sands to yellowish-gray. At a number of places the surface of the backshore zone is covered by a concentration of these black grains as a result of wind action.

The dominant direction of beach drift is apparently toward the south in this area. This is evident by the migration of inlets. However, the successive offsets of the barrier bars toward the north clearly indicate that more complex factors are involved (Map I).

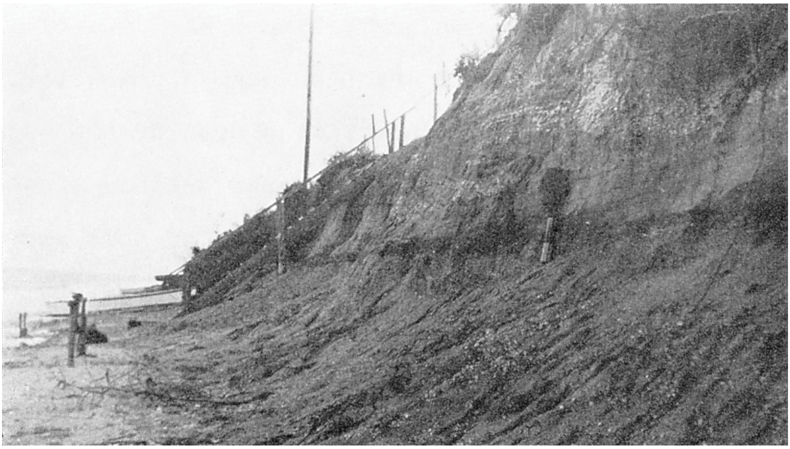
Active erosion by waves can be viewed at many places (Plate 7). On Pullen Island stumps of brushwood are found on the foreshore (Plate 8). Salt peat is exposed in the beach and south side of inlets at several points (Plates 6 and 8), and many loose pieces can be found strewn over the backshore. Dune scarps are common on Pullen island and Brigantine. Numerous stone groins at Atlantic City, Ocean City, and Cape May indicate too clearly that active wave erosion is at work.

The recent evolution of Sewell Point near Cape May can be interpreted from a section of a sharply truncated wave scarp (Plate 9). In this exposure fine sand is overlain by almost two feet of lagoon deposits. The upper 1 foot of these deposits is not uniform but shows alternating layers of light colored fine sand, dark colored silt and clay, and coarse sand with shells. Dune sand overlies the marsh deposits for a depth of 16 inches (note the cross bedding.) It is believed that at one time this part of Sewell Point was completely separated from the open ocean and that this interval may be represented by the lower foot of marsh deposits. The upper foot of these deposits (alternating layers) suggests that the lagoon was subject to influences of wind-blown sands and wave-borne sediments (coarse sand and shells). The last phase of the cycle is represented by the dune sands which completely buried the lagoon.

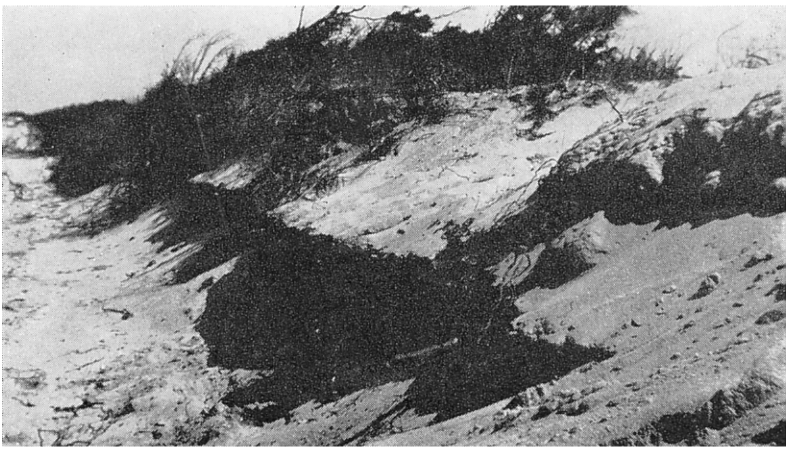
A. A wave-cut scarp at Cape May. Section shows dune material overlying lagoon deposits. Notice the layer of sand at the bottom.

B. Partially inundated flats at low tide near Town Bank.

PLATE 9



A. Wave-cut cliff in the Cay May formation at Town Bank.



B. Dune sand overlying the Cape May formation at Higbee Beach.

PLATE 10

South Cape May to Reeds Beach.

North of Cape May on the Delaware Bay side of the cape, the beaches show a sharp change in character. In place of the wide, relatively flat shores of the adjacent Atlantic Coast, narrower and steeper beaches appear. The upper foreshore and backshore together of this stretch of beach range from 40 to 60 feet in width. However, at low tide large areas of partially inundated flats are exposed in front of the upper foreshore (Plate 9). The inclination of the lower foreshore ranges from 1 to 3 degrees. The upper foreshore shows a variable slope of 5 to 8 degrees and in many places this slope is constant from the bordering dunes, or wave cliff, to the lower foreshore. When a backshore is developed, it slopes away from the berm crest at 1 to 2 degrees. From North Cap May to Town Bank a 10- to 15-foot wave cliff is exposed behind the beach (Plate 10). At several points along the beach wind-blown sand overlies a headland scarp (Plate 10). Numerous small wooden groins are a common feature of the beach and sand deposits adjacent to them indicate that the beach drift is toward the north in this area.

Evidences of active wave erosion are not difficult to find. Salt peat is uncovered on the foreshore at many places. Sharply truncated sand dunes and wave-cut scarps are common. Trees and brushwood at the water's edge can be found at several places.

The fine-textured sands of the Atlantic Coast give way to sands of medium to coarse texture. Streaks of well-rounded pebbles and granules are common along this stretch of beach. Iron-stained grains increase in abundance and the sands are grayish-yellow. The mineral composition is dominated by quartz and the proportion of heavy minerals and feldspar is very small.

Cape Henlopen to Rehoboth, Delaware.

The ocean beaches in the Cape Henlopen area are strikingly similar in texture and composition to those north of Cape May on Delaware Bay. These beach sands are yellowish-gray, medium-textured sands, with a large number of iron-stained grains. Streaks of well-rounded pebbles, granules, and shells are also common along this stretch of beach. Quartz is the dominant mineral, and feldspar and dark minerals occur only as minor constitutents.

The foreshore varies from 50 to 75 feet in width and the inclinations range from 5 to 10 degrees. Along this stretch of beach prominent cusps are well developed and at Rehoboth numerous groins have been built.

In this area beach drifting is toward the north as Evidenced by the constant accumulation of material on the south sides of the groins and the growth of Cape Henlopen.

FIELD METHODS

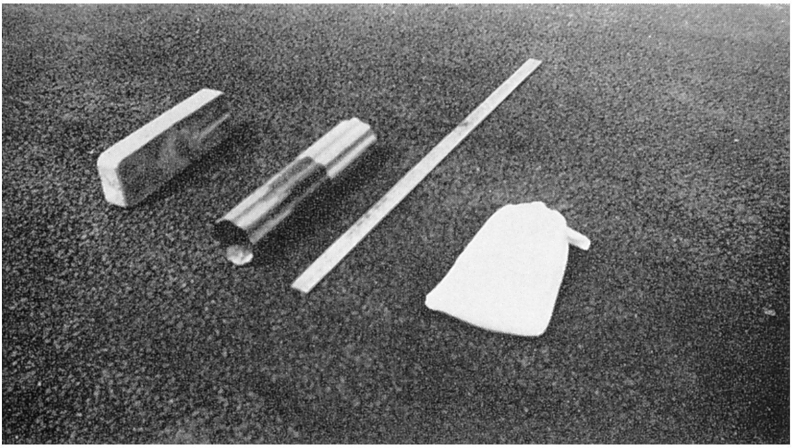
Sampling of Beach Sands

It would be highly desirable to sample a coastal area on the same day, at the same time in relation to the tide, at the same relative position on the beach, and utilizing the same technique of sampling. Thus, the effect of various environmental factors, such as storms, tides, currents, and winds would be greatly reduced. However, as the coastal strip investigated was almost 150 miles long, this approach could not be followed in all details.

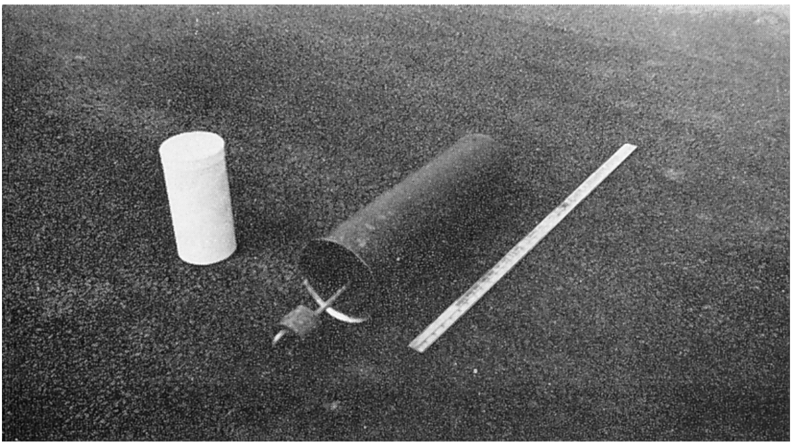
Each 1-mile sample was collected along the latest high tide line on the beach„ By following this procedure, it was hoped that a degree of uniformity could be maintained for all samples. The reasons for selecting this position on the beach follow. First, the high tide line secures a position which is available for sampling during most of the tidal cycle, yet it maintains a direct expression of oceanic processes. Second, Rasmussen (35, p. 100) found that there is a greater percentage of heavy minerals of a given size on the upper part of the beach than on the lower. As the velocity of the water returning on the ebb is much less because of friction and volume losses, lighter minerals of a given size will be removed on return more easily than heavy minerals of that size.

A 14-inch corrugated downspout pipe has been described by Krumbein (22, p. 207) as a satisfactory device for collecting beach sand samples. The writer improved this by painting the outside wall to a distance of 8 inches from the top and by making two small vents near the top to free any trapped air (Plate 11). In operation this sampler was forced into the sand to a depth of 6 inches (to the painted section of the tube), with the aid of a short piece of wood. Then the sand around the tube was removed and a trowel was pushed beneath the pipe to preserve the core.

Krumbein pointed out (22, p. 212) that compound samples, prepared by combining four closely-spaced samples, reduce the sampling error approximately one-half. In addition, Krumbein and Rasmussen (24, p.17) suggest that when sampling heavy minerals, the collection include a mixture of at least four samples for each location. This procedure was adopted with the variation that at each 1-mile station, three substations were established 15 feet apart along the high tide line. After removing the surface layer of sand, individual cores were collected from these sites and these were combined into a composite sample of about 2,000 grams.



A. Beach sand sampler.



B. Sea bottom sampler.

PLATE 11

After the compound sample was collected, the slope of the beach was determined with a Brunton compass. Information was also noted on the size, form, and structure of the beaches; evidence of wave erosion; and direction of beach drifting.

Sample locations between Sandy Hook and Reeds Beach on Delaware Bay were determined prior to beginning any field work. In an arbitrary manner, a line was constructed which delimited the beach area exposed to the direct influence of the ocean. Along this line sample sites were plotted at 1-mile intervals (Map I).

The location of each station in the field was determined by topographic expression or culture with pacing of distance to reference points where necessary. Detailed information concerning each sample location is presented in Appendix I.

Sampling of Bottom Sediments

To supplement the study of beach sands, bottom samples were obtained at various points offshore and in Barnegat and Delaware Bays. Sampling was limited to areas close to shore and to shallow depths (less than 10 fathoms) because of the lack of equipment and personnel needed for large-scale offshore sampling.

A drag-bucket device to sample the sea bottom at shallow depths was designed and assembled. It was designed so as to be light enough for one man to handle, and so that it could be constructed with available tools and materials. Plate 11 shows the sampler completed assembled. The cylinder is a piece of brass tubing 19 inches long, with an inside diameter of 6 inches and an outside diameter of 6-1/8 inches. The forward end is flared to an angle of 20 to 30 degrees over a distance of 3/4 of an inch. The rear end is closed with a 2-inch wood block which is held fast to the cylinder by brass screws. A 30-inch piece of brass rod, looped on one end, is secured by double nuts to the wood block, through a hole drilled in its center. A lead weight is molded on a section of the brass road near the loop to keep the forward end of the sampler on the bottom. The total weight of the sampler is about 13 pounds. As Twenhofel and Tyler (47, p. 25) have pointed out, this type of sampler has the disadvantages that selective washing of the material occurs on the trip to the surface and that the dredge digs to varying depths below the surface of the bottom.

Sampling was done from a small boat rented near the sampling area. Once the site to be sample was reached, the sampler was heaved overboard and allowed to sink to the bottom. Before any dragging was attempted, all the line was run out so as to secure as small an angle as possible between the sampler and the boat. The power of the boat was used to drag the sampler along the bottom when the drift of the boat did not provide the necessary drag.

Once the sampler was thought to have dredged sufficient sediment, it was slowly pulled aboard and emptied into a bucket. After several minutes, the excess water was poured off and the remaining sediment loaded into a half-gallon cardboard ice cream container. If the sample as collected was too large, it was thoroughly mixed and a representative portion taken.

United States Coast and Geodetic Survey Charts were used to plot these sampling locations of bottom samples. Sites were plotted at 1/2 mile, 1 mile, or 1-1/2 mile intervals along a given course, depending on the nature of the bottom and depth of water. Courses and sampling stations were plotted so as to utilize all possible navigational aids (buoys, beacons, lights, bells, and horns). This was desirable because small boats were used and such aids facilitated location of sample sites. When navigational aids were absent, distances were determined on the basis of a previous time-distance check.

Information on location and description of each offshore sample is summarized in Table 1.

TABLE: 1 Location and Description of Sea Bottom Samples

Sample	Depth (Ft.)	Latitude (N)	Longitude (W)	Description
B-11	23	38° 29.3'	74° 01.0'	Dark yellow brown quartz sand with varying amounts of shell glauconite, and rock fragments; grains oil stained.
B-13	12	38° 30.8'	74° 00.8'	Same as above.
B-21	20	38° 28.5'	73° 58.9'	Yellowish gray quartz sand with varying amounts of shell and glauconite; grains oil stained.
B-23	45	38° 29.0'	73° 55.8'	Dark yellow brown quartz sand with abundant glauconite; grains oil stained.
B-31	40	38° 11.4'	74° 00.0'	Yellowish gray quartz sand with varying amounts of shell and glauconite.
B-32	52	38° 11.3'	73° 59.3'	Light olive gray quartz sand with small amounts of shell and glauconite.
B-41	49	38° 10.8'	74° 00.1'	Same as above.
B-42	40	38 10.7'	73 59.4'	Yellowish gray quartz sand containing abundant pebbles and varying amounts of shell and glauconite.

TABLE: 1 Location and Description of Sea Bottom Samples

Sample	Depth (Ft.)	Latitude (N)	Longitude (W)	Description
B-51	17	38° 29.7'	75° 18.3'	Yellowish gray quartz sand with small amount of shell.
B-53	20	38° 31.4'	75° 17.5'	Light olive gray quartz sand with small amount of shell.
B-61	9	38° 28.2'	75° 18.0'	Greenish gray quartz sand with over 5% dark mineral grains; shell present.
B-64	10	38° 30.6'	75° 16.5'	Light olive gray quartz sand with some shall.
B-71	20	38° 28.3'	75° 16.7'	Greenish gray quartz sand with over 5% dark mineral grains; shell present.
B-72	26	38° 29.1'	75° 16.2'	Same as above.
B-73	19	38° 29.9'	75° 15.7'	Light olive gray quartz sand with some shell.
B-81	36	38° 55.8'	74° 51.4'	Light olive gray quartz sand with small amounts of shell and pebble.

TABLE: 1 Location and Description of Sea Bottom Samples

Sample	Depth (Ft.)	Latitude (N)	Longitude (W)	Description
B-82	40	38° 55.4'	74° 51.0'	Light olive gray quartz sand with small amounts of shell and pebble.
B-83	40	38° 54.5'	74° 50.3'	Same as above.
B-91	23	38° 59.0'	74° 58.4'	Light olive gray quartz sand with small amounts of shell, pebble and mud.
B-93	10	38° 59.0'	75° 00.3'	Light olive gray quartz sand with about 30% mud and a few shell fragments.
C-1	4	39° 46.7'	74° 09.2'	Olive gray quartz sand with over 10% mud and a few shell fragments.
C-6	4	39° 58.4'	740 05.6'	Same as above.
C-7	6	39° 58.5'	74° 06.3'	Same as above.

LABORATORY INVESTIGATION

Grain Size Determination

Laboratory Methods

For convenience, a flow sheet of the general procedure used in the preparation of all sediment samples for analysis is presented in Figure 2.

U. S. Standard Sieve Series, utilizing a square-root-of-two scale, was employed in all grain size analyses. The U. S. Series numbers and the sieve openings in millimeters and phi units for this series are listed in Table 2.

After preliminary preparations, each sample was placed in the nest of sieves and shaken for 15 minutes in a Ro-Tap machine. The relative amount of sand in the different size grades was determined by weighing the amount retained on each sieve.

The terms used in this report for sedimentary particles of various sizes are those of the Udden grade scale as modified by Wentworth (48, p. 381) and are shown in Table 3.

Statistical Interpretation

In describing and comparing sediments, quartile measures are perhaps as widely used as any other statistical device. Three quartile values are sufficient for

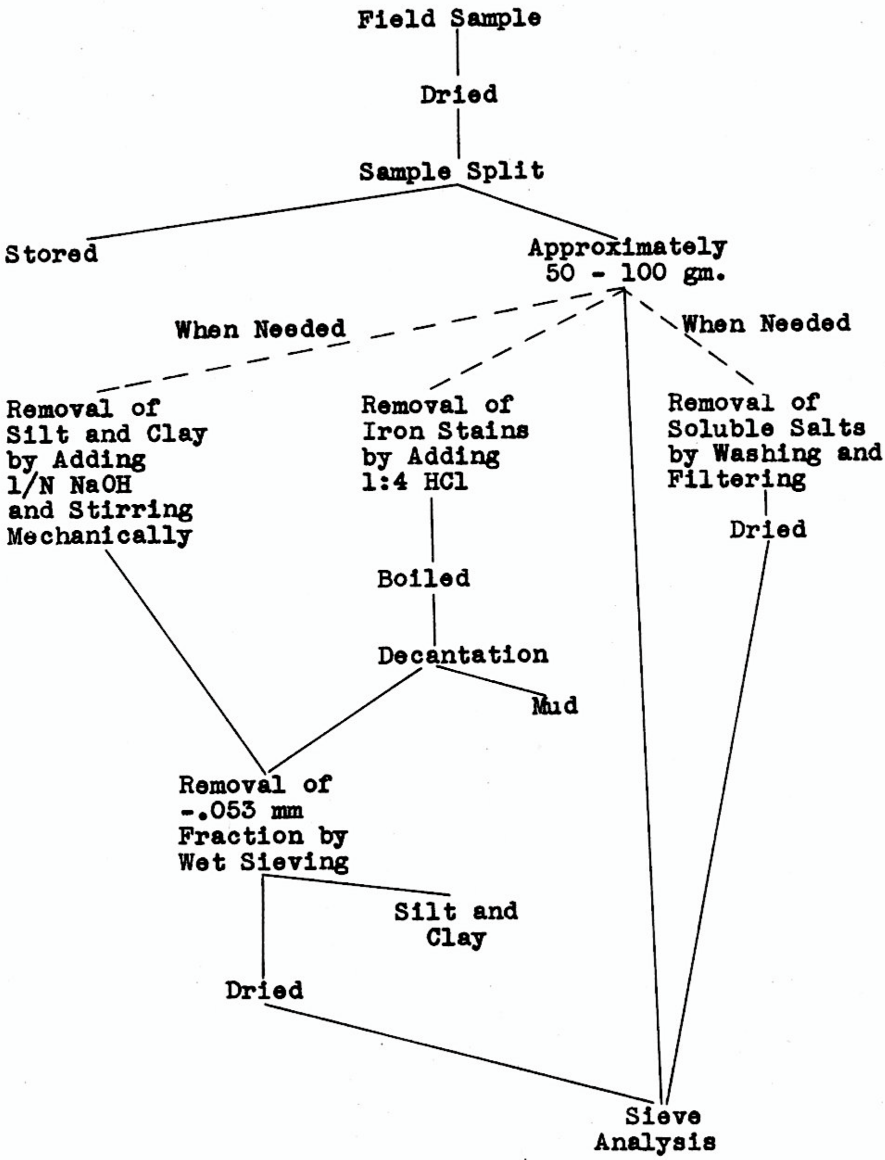


Figure 2. General Preparation of Field Samples

TABLE 2

Grade Scale and Corresponding U. S. Series Numbers and Phi Units

U. S. Series Numbers	Sieve Opening (Mm.)	Phi Units
3	6.680	- 2.75
4	4.760	- 2.25
6	3.360	- 1.75
8	2.380	- 1.25
12	1.680	- .75
16	1.190	- .25
20	.840	+ .25
30	.590	+ .75
40	.420	+ 1.25
50	.297	+ 1.75
70	.210	+ 2.25
100	.149	+ 2.75
140	.105	+ 3.25
200	.074	+ 3.75
270	.053	+ 4.25

TABLE 3

Laboratory Class Limits and Terms

Grade Limits (Mm.)	Class Terms
64 - 4	Pebble
4 - 2	Granules
2 - 1	Very Coarse Sand
1 - 1/2	Coarse Sand
1/2 - 1/4	Medium Sand
1/4 - 1/8	Fine Sand
1/8 - 1/16	Very Fine Sand
1/16 - 1/256	Silt
Below 1/256	Clay

Adopted from Wentworth (48, p. 381)

computation of these measures. These are:

(1) Q_1, the first quartile, refers to the diameter value which has 75 percent by weight of the sample larger than itself in size distribution.

(2) Md, the median diameter is the mid-point in the size distribution of a sediment.

(3) Q_3, the third quartile diameter indicates 25 percent by weight of the sample larger than itself in distribution.

A measure of the dimensional spread of a sediment is known as sorting. Trask (46, p. 71) introduced a coefficient of sorting (So) which expressed the measure of the average spread of size distribution between the first and third quartiles. His formula is:

$$So \sqrt{\frac{Q_3}{Q_1}}$$

where Q_1 and Q_3 are expressed in millimeters.

Trask states that if the coefficient of sorting is greater than 4.5, the sediment is poorly sorted; if it is about 3.0, the sediment has normal sorting; and if it is less than 2.5, the sample is well sorted.

A measure of the tendency of data to spread on one side or the other of the median diameter of the size distribution is known as skewness. As introduced by

Trask (46, p. 72), the measure of skewness is derived from the two quartile diameters and the median diameter by the following formula:

$$Sk = \frac{Q_1 Q_3}{Md^2}$$

where Q_1, Q_3 and Md are expressed in millimeters. If the coefficient of skewness (Sk) is unity, the modal grain diameter[1] coincides with the median diameter; if it is greater than unity, the maximum sorting of the sediment lies on the coarse side of the median diameter; and if the skewness is less than unity, on the fine side.

The phi scale of Krumbein (23, p. 84) is of considerable value in plotting cumulative curves from data of grain size analyses. Krumbein introduced an equation which transforms a geometric grade scale to a logarithmic scale (phi scale). The formula is:

$$\phi = -\log_2 D$$

where D equals the grain size diameter in millimeters. The square-root-of-two grade scale expressed in phi units will be found on Table 2.

After sieving, weight percentages for each size fraction of all samples were calculated. From these values cumulative weight percentages were determined. For each

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[1]The modal grain diameter represents the most abundant particle in a sediment.

sample these data were plotted against the grade sizes (phi scale) on ordinary cross section paper and the various points connected with a French curve. As the quartile measures are based on millimeter values, it was necessary to convert the derived phi quartile value (Q_1, Q_3 and Md) to millimeters. A conversion chart, based on Krumbein's (20, p. 41) original presentation, was used. Determination of So and Sk were made on the basis of formulae cited in the preceding paragraph.

Mineralogical Analysis

Laboratory Methods

A flow sheet for the general preparation of material for mineralogical analyses is presented as Figure 3.

Small amounts of magnetite were detected and separated from each heavy mineral fraction by means of a horseshoe magnet. Each fraction was thinly spread out in a "U"-shaped aluminum tray. Then the magnet, guided by the vertical sides, was slowly passed over the tray so that the distance between the magnet and the dispersed grains remained constant.

The nonmagnetic minerals were identified under the petrographic microscope by optical properties and descriptions of their appearance.

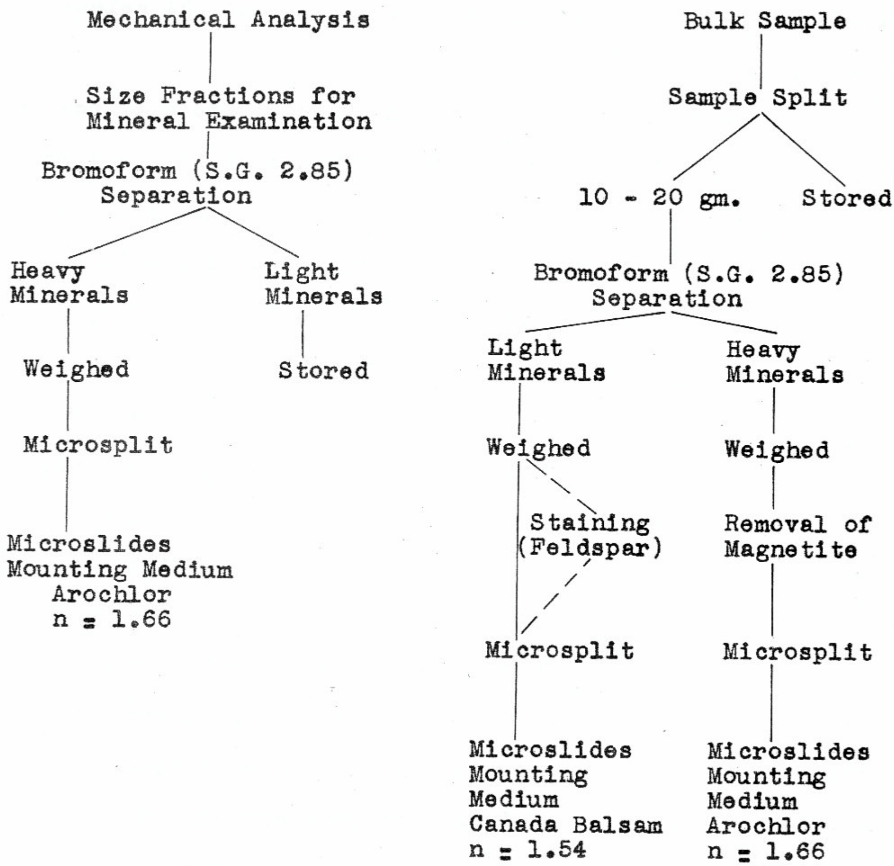

Figure 3. General Preparation of Material for Mineral Analysis

Quartz and feldspar were distinguished by (1) refractive index, (2) cleavage and twinning, and (3) selective stains.

The identification procedure using index of refraction is based on the refractive indices of both quartz and feldspar as compared with that of Canada balsam (1.54). The index of refraction of quartz varies from 1.544 to 1.553; that of potash feldspar between 1.518 and 1.526; and soda feldspar (albite) from 1.525 to 1.536.

A selective staining technique was utilized to separate quartz, potash feldspar, and plagioclase feldspar. This procedure was based in part on the method developed by Keller and Chuen Pu Ting (19, p. 124). Each light mineral fraction was split down to approximately two grams by means of an Otto microsplitter. This fraction was placed in a lead dish and bathed in warm concentrated hydrofluoric acid for one minute. After thorough washing, the material was immersed in a 1 percent aqueous solution of malachite green for 5 minutes, rinsed, immersed in a saturated solution of sodium cobaltinitrite for 5 minutes, rinsed, and dried. The material was again split and mounted in Canada balsam. Quartz remains unchanged, potash feldspar stains yellowish, and plagioclase, green.

Material containing significant quantities of potash bearing minerals, such as glauconite, produces erroneous results as these minerals will also absorb the yellow stain.

The relative proportions of the different detrital minerals were determined by counting carefully spaced fields of grains, arranged systematically over the area of the slide. A minimum of 300 grains were tabulated for each count and in most samples 400 grains were counted.

All mineral frequencies are subject to a progression of errors beginning with field sampling and ending with the various laboratory operations. Krumbein and Rasmussen (24, p. 18) believe that among the various Laboratory errors, the counting error[1] is of prime importance and their investigations support Dryden's earlier findings of the effect of the number of grains counted on the accuracy of heavy mineral analysis. Dryden (13, p. 236) shows that the probable error in counting is greatest for the rarer constituents and lowest for the abundant components. He also suggests that, perhaps, a 300-grain count will suffice for most ordinary work.

[1] The counting error refers to sample size and does not consider the additional error of incorrect identification of grains.

TEXTURE OF BEACH AND SEA BOTTOM SEDIMENT

Regional Variations of Texture of Beach Sands

Presentation of Data on Grain Size Analyses

The results of grain size analyses have been tabulated in two tables. Appendix II lists the grain size distribution and Appendix III presents the derived values for the various beach sands. A graphic plot of the derived values and distance along the beach is presented in Figure 4. Detailed information concerning sample locations may be found in Appendix I and on Map I.

Variations in Median Diameters

The median size of the various ocean and bay-beach samples (Figure 4) shows a wide range of values along the 145 miles of shoreline.

Coarse sand is found in two general areas, namely, from Spring Lake to Bay Head, and along the Delaware Bay shore. Medium sand is abundant between Spring Lake and Sandy Hook Point, Bay Head and Tucker Island, and Cape May and Town Bank. All the fine sand occurs between Tucker Island and Cape May.

On the plot of median diameters (Figure 4), the sands to the north and south of the Point Pleasant area show a gradual decrease in size; in the vicinity of Sandy Hook, this tendency is reversed and the sands grow coarser

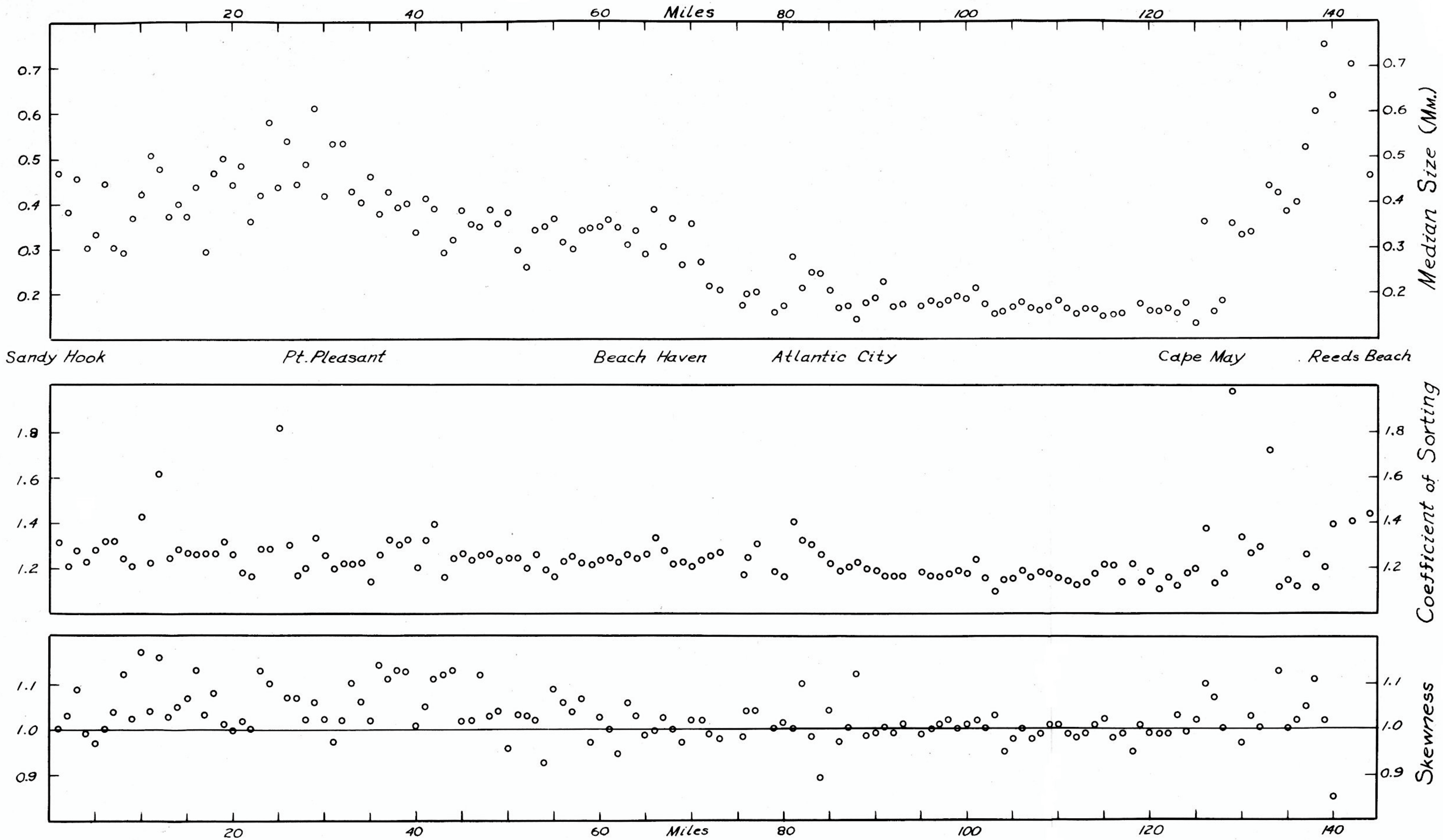

Figure 4 Quartile Measures

toward the distal end of the spit; near Stone Harbor (115 miles) the sands reach their finest size, but in the direction of Cape May Point the sand grows coarser. Along the Delaware Bay beaches the sands are much coarser than the adjacent ocean beach sands.

As has been pointed out previously, the beaches north of Point Pleasant are artificially controlled for the most part by sea walls and groins. This fact may account for some of the extreme variations noted in the median sizes in this area. However, the overall irregular pattern exhibited by the median sizes in most beach areas reflects the significance of variations due to differences in local conditions from one sampling site to the next, or the errors resulting from sampling and analyzing the beach sands. The variations in local conditions are caused by (1) irregularities in beach structure and shoreline, (2) depth of water and the configuration of the bottom in front of the beach, and (3) differences in wave and current strength.

Median Size and Distance of Transportation

The predominant direction of littoral drift along the New Jersey coast has been well known for some time. As Johnson (17, p. 355), MacCarthhy (28, p.42), the Beach Erosion Board (8, 2/11) and Wicker (49, p.8) have pointed out, the directions of prevailing drift diverge in the area between Bay Head and Barnegat Inlet. From this area toward Sandy Hook the drift is to the north; toward Cape May the shore drift is to the south. This fact has been clearly established by the results of current observations, by the trends of submarine bars, and by study of shoreline changes.

In general, there is a trend of decreasing size in the direction of sand movement (Figure 4). MacCarthy (28, p. 49) concludes that the increase in fineness is a linear function of the distance traveled. This view implies that the most vigorous shore current activity is restricted to the Bay Head - Barnegat Inlet area. There is no oceanographic or erosional evidence to support this inference.

In the vicinity of Sandy Hook and Cape May the median size grows coarser. MacCarthy {28, p. 38) states:

> "The increase in fineness of sand in the direction of the shore drift holds only so long as the velocity of the transporting currents does not increase greatly. If the shore currents just north of Cape May increase in velocity as the Cape is approached, the sands shifted by them should grow progressively coarser with such increase in velocity since the finer fractions would be washed out and hurried southward, leaving a distinctly coarser residue behind."

As it is known that shore currents converge toward Delaware Bay and the Hudson Esturary, the velocity of the currents should increase considerably as these large openings in the coast are approached. In addition, the tidal sweep in and out of these estuaries should augment the action of the shore currents.

Local erosional conditions may alter the effectiveness of this explanation. In the vicinity of Cape May the establishment of adequate beach preservation measures in one place and not in the other is an important factor in determining the texture of its beaches. When wave action is unopposed, erosion proceeds at a rapid rate and the great bulk of material reaching the shore comes directly from the receding coast.

The evolution of Sandy Hook itself may indirectly bring another force into operation which tends to remove the finer sediment. As this spit grows toward the north, the area of free flow is slowly reduced so that the velocity of the currents passing the Sandy Hook area are gradually increased and the finer sizes of sand are effectively removed.

Relation of Sorting to Grain Size

Figure 4 shows that nearly all the coefficients of sorting for the beach sands lie between 1.10 and 1.40. According to the Trask standard (46, p. 71) these sands are well sorted. The irregularities in sorting between samples may be explained by the same factors which effect variations in median size.

Comparing this graphic plot of coefficient of sorting (Figure 4) with that of the median diameters, it appears that a general relationship exists between size and sorting for these beach sands. The sands having the smallest sorting values are those with median sizes between 0.2 mm. -0.15 mm. (fine sand); while the medium and coarse sands have larger sorting values.

These findings seem to corroborate the observations of a number of workers. Schalk (41, p. 46) noted a similar trend for beach sands in Massachusetts. Recently Inman (16) and Griffiths (15) made more detailed studies of the relationship between size and sorting of water-deposited material. Inman (16, p. 67) concluded that sediments with median diameter near the grade of fine sands are the best sorted and sediments coarser and finer are more poorly sorted. Griffiths' (15, p. 237) results indicate that the best sorted sediments lie around 0.177 mm. in median diameter. Therefore, the conclusion is justified that a definite relationship between size and sorting exists.

Relation of Skewness to Grain Size

The plot of skewness values (Figure 4) indicates no general trend, but the area between Atlantic City and Cape May shows the most regular pattern. When comparing the skewness values with those of sorting and size, a certain inference might be suggested.

The beach sands in the Atlantic City-Cape May area are fine sands and are the best sorted littoral sediments. As might be expected, the skewness values of these sands are clustered around unity (Figure 4). It appears that skewness too has a general relationship with median size. However, Inman (16, p. 67) believes that the relationship of skewness to median size is more complex than the relationship of sorting and average size. As indicated by Mississippi River samples, skewness goes through several cycles; coarse sands are skewed toward the coarse sizes; fine sands have little or no skewness; and very fine sands are skewed toward the finer sizes. In part, the data of the beach sands seem to support these findings.

Regional Variations of Texture of Offshore Sediment

Presentation of Data on Grain Size Analyses

The results of grain size analyses have been listed in two tables. Appendix IV lists the grain size distribution and Appendix V presents the derived values of the offshore samples. Detailed information concerning sample location and description may be found in Table I and on Map I.

Interpretation of Quartile Measures

A study of these bottom samples has shown no definite trend in gradation of grain size on the continental shelf in the vicinity of the beaches. However, decreasing median diameters seaward from the shore were found in lower New York Bay and Delaware Bay (Appendix V, B-11, B-13, B-91 and B-93) and it is believed that this general pattern of sedimentation is controlled by local conditions. Variations in size, as indicated by the alternation of decreasing and increasing of median diameters, are unrelated to depth of water or distance offshore.

It is evident from an examination of these median diameters from area to area that there must be quite a patchy arrangement of coarse and fine material adjacent to the beaches. According to Shepard and Cohee (42, p.444) this characteristic is typical of New Jersey shelf sediments.

Generally, the coefficient of sorting and skewness (Appendix V) shows no definite trend for these samples. Each value seems to be influenced by the nature of the sediment and local current and wave conditions.

Comparison of Bottom Sediments with Beach Sands

The derived values of the grain size analyses of the offshore samples and adjacent beach sands have been listed in Table 4.

In the Sandy Hook area (Samples 5, B-11 and B-13) there is a gradual decrease in median size seaward toward the north. It is believed that this reduction in size is caused by the selective removal of the finer material from

TABLE: 4 Comparison of Texture of Offshore and Beach Samples

Locality	Sample	Depth (Ft.)	Distance Offshore (Miles*)	Md.	So.	Sk.
Sandy Hook	5**			.469	1.31	1.00
	B-11	23	0.5	.378	1.37	1.18
	B-13	12	2.0	.317	1.42	1.27
	6**			.381	1.21	1.03
	B-21	20	1.0	.347	1.23	1.10
	B-23	45	3.5	.389	1.17	1.01
Shark River	26**			.360	1.16	1.00
	B-31	40	0.5	.908	1.38	.94
	B-32	52	1.0	.269	1.33	.98
	27**			.414	1.28	1.18
	B-41	49	0.5	.120	1.17	1.02
	B-42	40	1.0	.936	2.86	2.77
Little Egg Inlet	B-53	20	Inlet	.198	1.21	1.04
	75**			.271	1.23	1.02
	76**			.219	1.26	.98
	77**			.257	1.19	1.01
	78**			.211	1.25	.99
	B-64	10	0.5	.287	1.26	.99
	B-73	19	1.25	.345	1.22	.98

*Nautical miles.
**Adjacent beach sample.

TABLE: 4 Comparison of Texture of Offshore and Beach Samples

Locality	Sample	Depth (Ft.)	Distance Offshore (Miles*)	Md.	So.	Sk.
Little Egg Inlet (Cont'd.)	B-51	17	Inlet	.287	1.30	1.00
	78*			.211	1.25	.99
	79*			.178	1.16	.98
	B-72	26	1.5	.114	1.14	1.01
	79			.178	1.16	.98
	80			.199	1.24	1.04
	B-61	9	0.75	.184	1.21	1.03
	B-71	20	1.75	.139	1.20	1.01
Cold Springs Harbor	126**			.177	1.17	.99
	127**			.130	1.19	1.02
	B-81	36	1.0	.640	1.42	1.01
	B-82	40	1.5	.278	1.67	1.16
	B-83	40	2.5	.287	1.33	1.01
North Cape May	136**			.415	1.11	1.12
	B-91	23	0.5	.224	1.97	1.39
	B-93	10	2.0	.095	1.52	.57

*Nautical miles.
**Adjacent beach sample.

the littoral zone with subsequent deposition in finer sizes to the north of Sandy Hook. The sorting and skewness values increase seaward. From the beach seward the line of samples (6, B-21 and B-23) shows no general trend in size, sorting or skewness.

In the Shark River and Little Egg Inlet areas no consistent trend in size, sorting or skewness is apparent, while at Cold Springs Harbor the offshore samples (B-81, 82 and 83) are coarser than the beach samples (126 and 127). Here the sorting values of the beach sands are lower than the bottom sands. The North Cape May line of samples (136, B-91 and B-93) shows a decrease in size from the beach seaward into Delaware Bay.

MINERALOGY OF BEACH SANDS AND SEA BOTTOM SAMPLES

Value of Mineral Studies

Detailed studies of mineral composition of clastic sediments are exceedingly useful in helping to decipher geologic history. In this connection, the heavy mineral assemblage in sediments is most important, as these minerals afford valuable information on correlating sands, outlining petrographic provinces, and indicating sources and past history of the source material. Other minerals, like quartz and feldspar are more nearly ubiquitous and their value as diagnostic indicators is therefore less.

The importance or value of mineral composition is not solely limited to correlation and source investigations. The distribution of each mineral offers significant information concerning the mechanics of transportation and deposition of sediments. Unfortunately, few workers have devoted any time or patience to this knotty problem. However, until the basic principles of sediment transportation and deposition in each environment are clearly understood, source and correlation studies by mineral composition can never realize their potential wide-spread application.

Regional Differences in Mineral Composition of Beach Sands

Presentation of Data of Mineral Analyses

The results of heavy mineral analyses have been recorded for a number of selected size grades. These data are presented in two parts: Part 1 summarizes weights and percentages of heavy minerals for the various sizes and Part 2 tabulates the grain counts by number for these same sizes. Individual counts are listed in tenths of a percent because of the necessity of getting a good summation in calculation of weight percent for hydraulic ratios. Heavy mineral analyses of beach sands are presented in Table 5 and Figure 9.

In compiling these grain frequencies, certain mineral varieties were grouped to simplify the tables. These varieties are listed under the fo11owing headings:

Diopside	Diopside, augite and other monoclinic pyroxenes.
Epidote	A11 varieties of epidote, zoisite, and clinozoisite.
Garnet	A11 varieties of garnet.
Hornblende	A11 varieties of amphiboles, except tremolite.
Hypersthene	Hypersthene and enstatite.
Tourmaline	A11 varieties.

TABLE 5

Heavy Minerals in Beach Sands - Part 1 - Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
5	.210	8.14	7.82	.315	--	3.9
	.149	.63	.57	.064	--	1.0
9	.210	19.62	18.30	1.325	.004	6.7
	.149	7.37	6.18	1.190	.022	16.2
	.105	1.00	.66	.340	.019	34.0
14	.210	14.53	14.33	.199	.001	1.4
	.149	2.19	1.93	.260	.002	11.9
	.105	.20	.12	.085	.003	42.5
19	.420	15.42	15.17	.218	x*	1.4

*Denotes trace

TABLE: 5 Heavy Minerals in Beach Sands - Part 2
Frequency by Number

Sample	5		9			14			19
Size (Mm.)	.210	.149	.210	.149	.105	.210	.149	.105	.420
Minerals	Per Cent								
Andalusite	x*	.6	1.2	.8	.8	2.9	x	1.1	.9
Apatite									
Chlorite						x			
Diopside	.6	x	.6	.5	1.0	.9	x		
Epidote		1.4	.9	.8	1.6	2.1	3.9	x	
Garnet	.9	2.9	16.3	7.8	5.6	2.7	7.0	3.1	
Glauconite	85.3	56.0	10.8	4.8	1.6	37.9	7.3	3.6	91.4
Hornblende	.6	2.9	4.0	2.4	2.4	6.2	2.7	x	
Hypersthene		1.4	1.2	.5	1.3			.6	
Kyanite	1.2	2.3	2.2	1.6	1.0	.9	1.2	.6	
Muscovite									
Rutile		.6	.9	1.3	1.6		1.2	1.1	.9
Sillimanite	.6	.6	x	x	x	.6	x	.6	
Staurolite	3.2	10.9	29.5	11.8	4.0	12.8	17.0	2.5	1.7
Titanite			x	.5	1.0				
Tourmaline	2.1	2.3	2.5	1.3	.8	8.3	2.7	1.1	
Tremolite									
Zircon		x	x	6.5	7.2		3.9	6.4	
Augite		x							
Chloritoid		1.1	x	x	.5	.9	.6		
Collophane				x	x	.9	x		
Monazite					x				
Blk. Opaques	2.1	12.9	22.5	54.8	65.6	11.3	45.7	74.8	2.9
Leucoxene	1.8	1.7	2.5	1.6	1.9	3.9	2.2	1.1	.6
Miscellaneous**	1.5	2.0	3.7	1.9	2.0	7.2	3.6	2.8	1.4

Remarks:
* denotes trace
** includes shell, composite, altered, and unknown grains.

TABLE 5

Heavy Minerals in Beach Sands - Part 1 - Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
19	.297	30.13	29.74	.387	.002	1.3
	.210	17.64	17.43	.208	.002	1.2
	.149	2.25	2.11	.138	.002	6.1
	.105	.06	.05	.015	x	25.1
24	.210	8.17	7.97	.201	.002	2.5
	.149	.80	.70	.100	.002	12.5
	.105	.03	.02	.012	.002	40.0
26	.210	15.60	15.20	.399	.002	2.6
27	.210	9.76	9.66	.101	x	1.0

TABLE: 5 Heavy Minerals in Beach Sands - Part 2
Frequency by Number

Sample	19				24			26	27
Size (Mm.)	.297	.210	.149	.105	.210	.149	.105	.210	.210
Minerals	Per Cent								
Andalusite	1.1	3.9	2.1	.8	.9	1.8	1.2	1.9	1.2
Apatite									
Chlorite		1.3	x			x			
Diopside				x	.6	1.8	1.2	2.5	1.8
Epidote		1.9	4.9	1.4		2.0	1.8	x	x
Garnet	x	3.9	7.0	4.2	3.1	6.4	6.2	2.5	3.3
Glauconite	81.5	46.0	18.8	1.4	47.1	8.7	2.1	43.8	46.6
Hornblende	1.1	1.9	1.2	2.5	5.2	5.8	5.9	3.3	2.4
Hypersthene		x		1.6	x	.6	1.2	.5	x
Kyanite	x	1.9	3.9	2.5	2.1	2.6	1.5	2.5	1.8
Muscovite						x		x	x
Rutile			.9	1.7		1.4	1.5		
Sillimanite			.9	.6	1.6	1.2		.8	2.4
Staurolite	5.5	17.2	17.6	5.9	10.7	13.8	3.3	5.5	5.6
Titanite				.6			1.2		
Tourmaline	2.4	5.2	3.9	.6	4.7	x	1.8	6.1	5.9
Tremolite									
Zircon		x	1.5	4.0		1.2	7.7		x
Chloritoid			2.1	x					
Collophane				x	x	x	.6	.8	x
Monazite							x		
Zoisite							x		
Blk. Opaques	4.7	9.7	28.6	65.6	17.5	46.6	57.0	15.0	15.7
Leucoxene	1.3	3.6	4.2	2.3	1.8	2.6	1.8	4.2	4.7
Miscellaneous	1.6	2.6	1.8	4.2	3.7	2.5	4.0	10.0	7.7

Remarks:

TABLE 5

Heavy Minerals in Beach Sands - Part 1 - Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
29	.210	12.21	12.17	.040	.001	0.3
	.149	3.25	2.15	.098	x	3.0
	.105	.24	.20	.042	.001	17.5
34	.210	10.69	10.65	.045	x	0.4
	.149	1.53	1.47	.057	.001	3.7
39	.210	11.52	11.48	.042	x	0.4
	.149	.40	.34	.062	x	15.5
44	.210	28.81	28.74	.070	x	0.2
	.149	1.87	1.62	.250	.001	13.3

TABLE: 5 Heavy Minerals in Beach Sands - Part 2
Frequency by Number

Sample	29			34		39		44	
Size (Mm.)	.210	.149	.105	.210	.149	.210	.149	.210	.149
Minerals	Per Cent								
Andalusite	3.7	2.1	.8	.6	x	2.6	.5	2.2	.6
Apatite		x	.8			x			
Chlorite	x	x	x			.6		x	
Diopside	2.6	3.6	1.5	2.5	3.1	4.5	3.0	2.2	2.0
Epidote		1.2	1.8	x	.6		1.8	x	1.1
Garnet	2.3	6.3	5.7	2.2	6.7	2.2	11.5	1.3	4.8
Glauconite	39.7	11.0	2.1	25.0	7.3	22.4	4.4	14.3	8.0
Hornblende	6.0	11.0	9.8	6.5	10.0	6.7	4.1	6.8	6.6
Hypersthene	1.4	1.2	3.6	.6	1.2	.6	2.2	.8	2.3
Kyanite	.9	1.5	.8	1.9	1.8	1.0	1.4	1.6	2.0
Muscovite					x				
Rutile			.5		.6		1.4	x	.6
Sillimanite	2.6	3.3	.8	1.9	3.7	1.0	1.4	2.4	1.1
Staurolite	7.5	6.0	2.6	9.0	8.2	7.4	10.1	5.9	6.9
Titanite			x		x		x		x
Tourmaline	3.4	1.2	1.0	5.9	2.1	3.5	3.0	5.7	1.4
Tremolite					.6				
Zircon		1.5	1.8	.9	.6		1.9	1.8	1.1
Chloritoid	x		.5	x			x		1.4
Collophane	.6	.9		x		1.6	x		x
Blk. Opaques	16.4	42.4	57.3	25.0	41.2	31.7	47.6	37.9	50.4
Leucoxene	4.6	3.0	2.3	7.7	5.2	7.4	2.2	8.7	6.3
Miscellaneous	7.5	3.0	5.6	9.3	6.1	6.8	3.0	8.4	2.6

Remarks:

TABLE 5

Heavy Minerals in Beach Sands - Part 1 - Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
44	.105	.08	.01	.067	.002	83.7
49	.210	17.45	17.41	.045	x	0.3
	.149	.95	.86	.095	.001	10.0
54	.210	14.47	14.26	.215	x	1.5
	.149	1.80	1.44	.362	x	20.1
	.105	.09	.02	.070	x	77.7
59	.210	16.94	16.81	.132	--	0.8
	.149	1.81	1.51	.304	--	16.8
	.105	.10	.03	.067	x	67.0

TABLE: 5 Heavy Minerals in Beach Sands - Part 2
Frequency by Number

Sample	44	49		54			59		
Size (Mm.)	.105	.210	.149	.210	.149	.105	.210	.149	.105
Minerals	Per Cent								
Andalusite	x	2.0	x	1.9	2.1	x	2.8	1.0	x
Apatite									
Chlorite		x				x	x		x
Diopside	1.2	3.5	3.8	3.1	.9	x	3.7	2.3	
Epidote	.9	x	1.3	x		x	.6	x	1.2
Garnet	10.7	6.8	6.7	7.1	7.5	5.4	5.9	9.3	10.4
Glauconite	1.5	7.0	4.8	2.2	1.5	x	1.1		
Hornblende	2.4	10.3	10.5	9.0	6.9	1.2	6.5	9.9	8.4
Hypersthene	.6	.6	1.3	1.2	2.7	1.4	1.7	1.0	1.4
Kyanite	.9	1.8	1.6	2.8	1.2	1.2	2.3	1.0	x
Muscovite						x			
Rutile	.9		x		x	1.0			.9
Sillimanite	.6	2.7	1.6	1.2	x	x	1.7	1.8	.9
Staurolite	2.4	8.5	5.7	12.4	8.7	2.4	7.7	7.4	1.7
Titanite	x		x			.7		.8	x
Tourmaline		7.6	3.8	5.3	2.1	x	11.0	1.3	.6
Tremolite									
Zircon	9.4	x	2.4	1.2	.6	12.9	1.4	1.0	9.6
Chloritoid	x		x	x	x		.6	x	
Monazite	x				x				
Blk. Opaques	65.5	37.7	49.3	44.2	62.2	71.4	40.8	56.4	62.4
Leucoxene	1.8	4.1	2.9	3.4	.9	1.2	5.1	2.3	x
Miscellaneous	2.0	7.4	3.4	4.3	1.8	--	6.8	2.8	2.4

Remarks:

TABLE 5

Heavy Minerals in Beach Sands - Part 1 - Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
64	.297	38.81	38.67	.049	--	0.1
	.210	21.60	21.49	.106	--	0.5
	.149	3.94	3.56	.383	x	9.7
	.105	.27	.13	.143	x	53.0
	.074	.27	.26	.015	--	5.6
69	.210	38.01	37.57	.441	--	1.2
	.149	13.00	12.26	.736	x	5.7
	.105	.99	.47	.519	--	52.5
74	.210	13.05	11.25	1.803	x	13.8

TABLE: 5 Heavy Minerals in Beach Sands - Part 2
Frequency by Number

Sample	64					69			74
Size (Mm.)	.297	.210	.149	.105	.074	.210	.149	.105	.210
Minerals	Per Cent								
Andalusite	3.9	1.2	.6		x	1.2	1.2		x
Apatite					x		x	x	
Chlorite	.7	1.2	.6			1.6	x	x	
Diopside	2.1	2.5	1.8	.7	x	2.2	2.1	.8	1.4
Epidote		.9	2.3	1.4	4.8	x	.6	2.2	
Garnet	1.8	3.4	6.2	7.2	7.7	5.7	5.0	5.3	9.9
Glauconite	.7	.9	.6	x		x	.6	x	
Hornblende	7.8	6.2	11.1	5.7	13.4	7.0	10.4	15.6	3.2
Hypersthene		.9	1.2	x	.8	x	1.5	2.2	
Kyanite	3.2	1.8	2.1	x		2.2	3.0	x	1.4
Muscovite	1.4	.6							
Rutile		x		1.0	1.6			1.4	
Sillimanite	1.8	2.7	2.9	x	x	1.9	4.2	1.4	1.7
Staurolite	10.2	10.8	5.3	1.4	X	7.0	4.7	3.4	12.8
Titanite			.6		1.6		x		
Tourmaline	13.7	9.9	2.9	x	x	5.7	3.0	x	2.6
Tremolite					x				
Zircon			.9	9.9	20.9		x	2.2	2.6
Chloritoid			.6	x	x		x	x	
Monazite				x	x				
Zoisite				x	x			x	
Blk. Opaques	32.0	43.2	55.5	65.8	43.0	52.4	55.3	59.5	56.9
Leucoxene	9.5	8.3	3.5	2.5	1.6	6.4	3.3	2.2	3.5
Miscellaneous	10.9	4.9	1.2	2.0	2.0	6.3	3.9	2.5	3.0

Remarks:

TABLE 5

Heavy Minerals in Beach Sands - Part 1 - Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
74	.149	3.91	1.47	2.445	x	62.5
	.105	.45	.08	.375	x	83.3
77	.210	32.33	31.19	1.136	--	3.5
	.149	11.70	9.73	1.970	--	16.8
	.105	1.37	.38	.986	x	72.0
79	.149	53.52	51.57	1.952	--	3.6
	.105	16.34	11.67	5.170	x	30.8
	.074	3.91	.22	3.690	x	94.4
83	.210	7.47	7.44	.029	--	9.4

TABLE: 5 Heavy Minerals in Beach Sands - Part 2
Frequency by Number

Sample	74		77			79			83
Size (Mm.)	.149	.105	.210	.149	.105	.149	.105	.074	.210
Minerals	Per Cent								
Andalusite			x	x	x	x	.6		1.2
Apatite					x		2.7	1.1	x
Chlorite						x			4.0
Diopside	x	.5	2.9	1.1	x	3.8	2.8	1.1	2.7
Epidote	x	x	.6	.5	1.9	3.5	7.1	5.4	3.4
Garnet	8.3	6.0	6.9	6.2	10.0	2.9	6.5	17.4	7.7
Glauconite			x				x		
Hornblende	2.1	3.7	2.7	12.4	14.7	46.8	48.2	28.4	30.3
Hypersthene	.9	1.3	.9	1.1	1.9	2.3	4.7	6.8	3.4
Kyanite	.6	.5	1.5	.8	x	.6	.6	.5	x
Muscovite									3.1
Rutile	x	1.6	x	.5		x			
Sillimanite	.6		3.4	1.9	1.2	2.9	2.7	.8	2.2
Staurolite	3.6	1.0	17.3	6.2	1.2	3.2	1.2	1.1	3.4
Titanite	x	1.3	x	x	x		.6	1.3	
Tourmaline	.6	x	6.6	3.2		3.5	.9	.5	4.6
Tremolite						1.5	.6		.6
Zircon	5.7	17.7	.9	1.6	8.4	x	x	3.8	.6
Chloritoid	x				x	.6	x	.5	
Monazite				x					
Biotite									.9
Blk. Opaques	73.5	64.1	49.3	58.8	56.4	16.9	12.4	29.2	24.4
Leucoxene	2.4	1.3	.9	2.4	1.2	2.6	1.2	.8	2.2
Miscellaneous	.6	.5	5.0	3.0	1.9	8.2	6.2	2.0	4.2

Remarks:

TABLE 5

Heavy Minerals in Beach Sands - Part 1 - Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
83	.149	34.64	34.20	.438	x	1.3
	.105	14.15	12.49	1.660	x	11.8
	.074	1.73	.32	1.415	x	81.8
88	.210	12.91	12.90	.010	--	0.1
	.149	17.10	17.03	.071	--	0.4
	.105	2.48	2.28	.202	--	8.1
93	.149	31.52	31.27	.255	--	0.8
	.105	8.69	7.73	.959	x	11.0
97	.149	14.60	14.56	.045	--	0.3

TABLE: 5 Heavy Minerals in Beach Sands - Part 2
Frequency by Number

Sample	83			88			93		97
Size (Mm.)	.149	.105	.074	.210	.149	.105	.149	.105	.149
Minerals	Per Cent								
Andalusite	.5	x		2.5	1.1		.8		
Apatite	x	.5	2.0		x	1.6	x	2.1	
Chlorite	1.9	x	.5	12.7	3.5	x	2.0	x	10.9
Diopside	3.0	4.0	2.4	1.9	2.9	3.8	5.9	3.9	3.3
Epidote	2.7	5.0	6.1		3.3	8.1	2.4	5.5	.9
Garnet	3.5	9.2	15.9	1.9	2.7	2.7	2.2	2.8	4.7
Glauconite	x			2.2	.5				.9
Hornblende	36.3	52.6	39.5	15.8	36.1	56.7	49.2	60.4	23.7
Hypersthene	2.7	5.4	4.4	1.5	4.6	4.9	4.4	4.1	2.7
Kyanite		x	x			x	.6	.5	
Muscovite	3.5	x		8.1	.8	.5	x		2.7
Rutile			x			x	x		
Sillimanite	1.9	2.4	2.7	4.0	1.6	1.9	4.4	2.1	4.4
Staurolite	1.4	.5	1.5	x	.5	x	x	.5	.6
Titanite		1.0	1.0		.8	1.1	x	.5	
Tourmaline	1.4	.7		3.4	3.5	1.1	.8	x	1.5
Tremolite	1.4	1.4	.7	.6	2.3	1.4	2.5	1.7	1.2
Zircon	.8	1.2	1.7			.8		x	
Augite	.5	.5							
Chloritoid	x	.5	x	x	.5	.5	x	1.1	x
Blk. Opaques	17.5	7.1	17.4	7.4	3.3	4.9	1.7	2.1	6.8
Leucoxene	2.5	1.7	x	5.0	4.9	1.6	2.0	1.7	3.0
Miscellaneous	18.0	6.1	3.4	33.0	27.2	8.4	20.4	10.2	32.6

Remarks:

TABLE 5

Heavy Minerals in Beach Sands - Part 1 - Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
97	.105	7.47	7.23	.241	--	3.2
102	.210	10.33	10.30	.032	--	0.3
	.149	22.22	21.97	.251	--	1.1
	.105	5.45	4.55	.896	--	16.5
	.074	.66	.15	.512	x	77.5
107	.149	15.61	15.37	.239	--	1.5
	.105	6.96	6.26	.696	x	10.0
112	.149	24.56	24.41	.149	--	0.6
	.105	4.92	4.28	.645	x	13.1

TABLE: 5 Heavy Minerals in Beach Sands - Part 2
Frequency by Number

Sample	97	102				107		112	
Size (Mm.)	.105	.210	.149	.105	.074	.149	.105	.149	.105
Minerals	Per Cent								
Andalusite		1.2	.5	x		.5		.5	
Apatite	1.2		.7	2.7	1.3	.5	1.7	1.0	.5
Chlorite	x	1.6	1.2			1.0	.6	1.3	x
Diopside	3.4	6.9	6.8	4.0	2.8	6.4	3.8	5.8	3.6
Epidote	5.6	1.9	1.7	6.4	4.6	2.4	5.8	3.4	5.5
Garnet	2.2	2.2	1.5	5.1	19.2	6.7	11.0	3.5	3.9
Glauconite	x	2.2	x				.6	x	
Hornblende	57.9	36.3	54.3	55.4	34.9	43.6	39.1	49.4	60.0
Hypersthene	3.2	1.6	4.1	5.6	4.6	2.9	5.2	2.5	5.2
Kyanite	.7					.7	x	x	.5
Muscovite	.7	.5	.5			x		x	
Rutile				x	x				x
Sillimanite	2.7	4.4	3.1	2.4	.8	3.0	2.6	3.4	1.9
Staurolite	x	.9	.5	x	x	2.0	.9	x	.5
Titanite	x		x	1.9	3.1	.5	.9	x	.8
Tourmaline	.5	5.3	1.7	.5	.5	.5		1.5	.8
Tremolite	1.9	x	1.7	.5	.5	1.7	1.7	1.5	1.4
Zircon	.5		x	x	2.6		1.4		
Chloritoid	x				.8	.5	.9	x	x
Augite		x					x		
Monazite						x			
Blk. Opaques	3.7	7.2	5.1	6.1	21.4	12.0	10.4	2.3	2.5
Leucoxene	1.0	4.1	.7	1.1	.8	2.6	1.2	2.3	1.4
Miscellaneous	13.9	23.4	15.2	7.2	1.8	12.4	11.9	20.9	10.5
Remarks:									

TABLE 5

Heavy Minerals in Beach Sands - Part 1 - Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
117	.149	12.69	12.65	.042	--	0.3
	.105	10.58	10.29	.294	--	2.8
122	.210	2.45	2.44	.006	x	0.2
	.149	23.88	23.75	.133	x	0.6
	.105	16.25	15.38	.873	x	5.4
	.074	1.78	.75	1.034	x	57.8
127	.210	.53	.53	.003	--	0.6
	.149	12.61	12.57	.045	--	0.4
	.105	21.39	20.98	.412	--	1.9

TABLE: 5 Heavy Minerals in Beach Sands - Part 2
Frequency by Number

Sample	117		122				127		
Size (Mm.)	.149	.105	.210	.149	.105	.074	.210	.149	.105
Minerals	Per Cent								
Andalusite		x	.9	.5				x	
Apatite	x	2.9	.9		1.4	1.7		.8	2.0
Chlorite	11.3	x	7.5	5.1	1.0		46.5	21.6	2.0
Diopside	2.2	2.6	5.3	4.4	3.6	1.4	1.3	1.4	3.3
Epidote	1.6	6.0	2.8	2.6	6.1	7.7		x	4.3
Garnet	1.6	3.1	10.0	3.5	5.6	17.2	.7	1.4	3.3
Glauconite	1.3		x	1.0	.5			.8	
Hornblende	24.7	56.4	31.2	38.0	57.2	45.6	2.9	20.2	57.8
Hypersthene	1.3	4.3	5.9	3.0	4.4	6.4	1.4	2.6	4.3
Kyanite			.9						.5
Muscovite	10.5	.5	6.9	5.9	x	x	27.4	19.5	1.2
Rutile									
Sillimanite	1.6	.7	2.8	1.8	.8	1.9		1.8	2.0
Staurolite	.6	x	.6	.5	.8	x			x
Titanite		1.4	.9	.5	.5	1.4		x	.5
Tourmaline	1.6	.7	1.2	.5	x	.7	x	1.3	.5
Tremolite		1.7	.6	1.5	1.7	.5		.8	.8
Zircon			1.9		.5	2.4	.7	x	x
Chloritoid	.8	.2	x	.5	x			x	
Monazite			x						
Augite				1.3	.5	x			
Biotite							3.6	x	
Blk. Opaques	1.3	1.4	12.7	7.2	5.0	9.9	5.6	3.9	1.2
Leucoxene	2.4	1.7	4.0	2.0	1.0	x	1.0	2.3	1.2
Miscellaneous	36.5	15.8	3.0	20.1	9.2	2.4	8.2	20.8	14.6
Remarks:									

TABLE 5

Heavy Minerals in Beach Sands - Part 1 - Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
127	.074	7.54	6.14	1.400	--	18.6
130	.210	21.32	21.24	.084	x	0.4
	.149	46.72	46.08	.643	.001	1.4
	.105	13.27	11.24	2.028	.001	15.3
132	.210	15.13	14.67	.461	.001	3.0
	.149	7.98	7.06	.917	.001	11.5
	.105	1.96	1.25	.715	.001	36.5
137	.210	2.01	1.98	.032	--	1.6
	.149	.49	.48	.012	--	2.5

TABLE: 5 Heavy Minerals in Beach Sands - Part 2
Frequency by Number

Sample	127	130			132			137	
Size (Mm.)	.074	.210	.149	.105	.210	.149	.105	.210	.149
Minerals	Per Cent								
Andalusite		1.0	.5	x	1.3			1.8	.9
Apatite	3.1		x	1.5		x			
Chlorite		1.5	.5				x	.8	.6
Diopside	2.5	x	3.1	3.7	.8	2.2	1.8	.8	1.7
Epidote	5.8	1.3	4.1	6.7	.8	1.7	3.4	.5	1.1
Garnet	6.0	4.0	7.5	10.6	5.9	7.8	20.4	3.9	5.7
Glauconite			x						
Hornblende	53.2	12.8	36.2	46.0	5.2	12.4	12.4	3.1	8.9
Hypersthene	7.0	1.0	3.9	3.7	1.1	2.9	.8	1.8	1.1
Kyanite	x	.7	x		3.9	.7		2.1	1.4
Muscovite	x	.5							x
Rutile						x	.5	x	x
Sillimanite	2.5	4.5	4.6	2.0	2.6	2.4	1.6	1.3	.9
Staurolite	x	9.8	2.1	x	16.3	7.8	.8	10.4	4.3
Titanite	1.5		x	.6			.5	x	
Tourmaline	.7	10.5	2.8	1.3	4.9	1.2	x	3.4	1.4
Tremolite	1.0	x	2.3	.6					
Zircon	1.7	.7	1.8	1.1	1.8	3.9	5.8	1.8	6.6
Augite	x					x			
Zoisite	x								x
Chloritoid			x	1.1		1.0	x		
Biotite						x			
Blk. Opaques	6.0	32.9	15.9	16.4	48.3	49.5	48.4	62.4	58.3
Leucoxene	.7	7.5	4.6	1.2	2.6	3.4	1.1	2.9	2.9
Miscellaneous	8.3	10.6	9.2	3.3	4.1	2.4	1.6	2.3	3.4

Remarks:

TABLE 5

Heavy Minerals in Beach Sands - Part 1 - Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
137	.105	.09	.08	.006	--	6.7
142	.210	5.60	5.53	.070	--	1.2
	.149	1.96	1.87	.092	--	4.7
	.105	.21	.16	.047	--	22.4

TABLE: 5 Heavy Minerals in Beach Sands - Part 2
Frequency by Number

Sample	137	142							
Size (Mm.)	.105	.210	.149	.105					
Minerals	Per Cent								
Andalusite	1.2	.8	x						
Apatite	x								
Chlorite	x	x	x	x					
Diopside	1.8								
Epidote	9.2		x	.8					
Garnet	9.5	2.5	x	1.0					
Glauconite									
Hornblende	24.2	x	1.6	1.0					
Hypersthene	3.7	x	x	x					
Kyanite	.6	1.5	1.9	.8					
Muscovite									
Rutile	x	1.3	1.3	1.3					
Sillimanite	1.2	2.8	1.6	.5					
Staurolite	2.4	9.3	6.8	1.9					
Titanite	1.5			x					
Tourmaline	1.8	4.8	.8	.8					
Tremolite		x							
Zircon	4.3	6.6	5.4	18.2					
Chloritoid	.6			x					
Zoisite	x								
Blk. Opaques	29.4	63.7	75.4	69.1					
Leucoxene	2.4	2.0	2.4	1.6					
Miscellaneous	5.5	3.8	1.9	2.8					

Remarks:

Black Opaque .... All black opaque minerals.

Leucoxene .... All grains which are white or yellowish-white in reflected light.

However, occasionally one of these varieties was recorded separately due to its greater frequency.

Grain counts on the light mineral fraction have been recorded for a number of bulk samples. Because of the difficulty in mounting grains larger than 0.42 mm., the coarser sand samples have been screened so that only the minus 0.42 mm. size was examined for these sands.

The varieties of feldspar have been grouped when light mineral frequencies have been recorded. When staining was used, all potash feldspar and soda-lime feldspar were grouped separately, otherwise all feldspar was tabulated together.

Light mineral grain counts for each of the bulk five-mile beach samples are presented graphically in Figure 5.

Minerals Present

As shown in Table 6 many minerals are found in the New Jersey beach sands. This list may be incomplete as all possible sizes of each sample were not examined. However, it agrees essentially with the findings of

Colony (11, p. 156), Martens[1] and Light (26, p. 175) although Colony reports the presence of cordierite but no kyanite.

TABLE 6

MINERALS IN THE BEACH SANDS

Actinolite	Epidote	Monazite
Anatase	Potash Feldspar	Muscovite
Andalusite	Soda-Lime Feldspar	Quartz
Apatite	Garnet	Rutile
Augite	Glauconite	Sillimanite
Biotite	Graphite	Staurolite
Chlorite	Hornblende	Titanite
Chloritoid	Hypersthene	Tourmaline
Collophane	Kyanite	Tremolite
Corundum	Leucoxene	Zoisite
Diopside	Magnetite	Zircon

Quantitative data on the heavy mineral assemblage are presented in Table 5. Although the nature of this assemblage is generally the same along the entire coast, the proportions by number of several of the species are much different from one area to another for those size fractions studied. For example, hornblende makes up over 30 percent of the count in those sands of southern New Jersey (Samples

[1]Unpublished notes.

79-130) and only 5 to 10 percent in the same size to the north (Samples 5-74) and along Delaware Bay (Samples 132-142). Tourmaline, kyanite, staurolite and zircon are more common in the grade sizes of northern New Jersey and Delaware Bay beaches than in those sands of southern New Jersey. Hypersthene and epidote occur in the greatest abundance in those sands between Pullen Island and Cape May. Those minerals collectively referred to as black opaques make up a greater percentage by number in the sands between Point Pleasant and Pullen Island and along Delaware Bay than in the beach areas between Sandy Hook and Point Pleasant and from Pullen Island and Cape May. The glauconite of the heavy fraction is restricted mainly to those sands of northern New Jersey (Sandy Hook-Barnegat Inlet).

The small amount of magnetite detected in the beach sands is restricted to those areas of Sandy Hook to Point Pleasant and in the vicinity of Cape May. In all other areas, only a trace of this mineral was found. According to Colony (11, p. 156), the presence of magnetite is closely related to the composition of the protective groins. The areas north of Point Pleasant and in the vicinity of Cape May contain large numbers of these groins. In view of this condition, Colony's finding seems justified.

Several heavy mineral species occur in a number of varieties. Hornblende is found as brown, green, and blue-green varieties; garnet occurs as pink and colorless varieties; tourmaline is present as blue, pleochroic green-pink, and light brown-brown varieties; diopside is found in colorless and pale green varieties; and epidote occurs as colorless and pleochroic yellow varieties.

An unsized fraction of each 5-mile sample was examined for heavy mineral species. The relative abundance by number of several of these minerals is presented graphically in Figure 9.

A bulk fraction from these same samples was examined for light minerals and several species were recorded. These minerals are quartz, potash and soda-lime feldspar, glauconite, and mica.

The relative abundance by number of several of these minerals is presented graphically in Figure 5. These frequencies are comparable to those shown by Martens[1] for feldspar and glauconite in the New Jersey beach sands. In all beach areas except southern New Jersey, the total feldspar content by number is less than 5 percent (Figure 5). From Little Egg Inlet to Cape May the total feldspar ranges between 15 and 22 percent. Of this total percentage by number approximately one-third to one-sixth is soda-lime feldspar. The glauconite in the light

[1]Unpublished graph of light mineral frequencies in New Jersey beach sands.

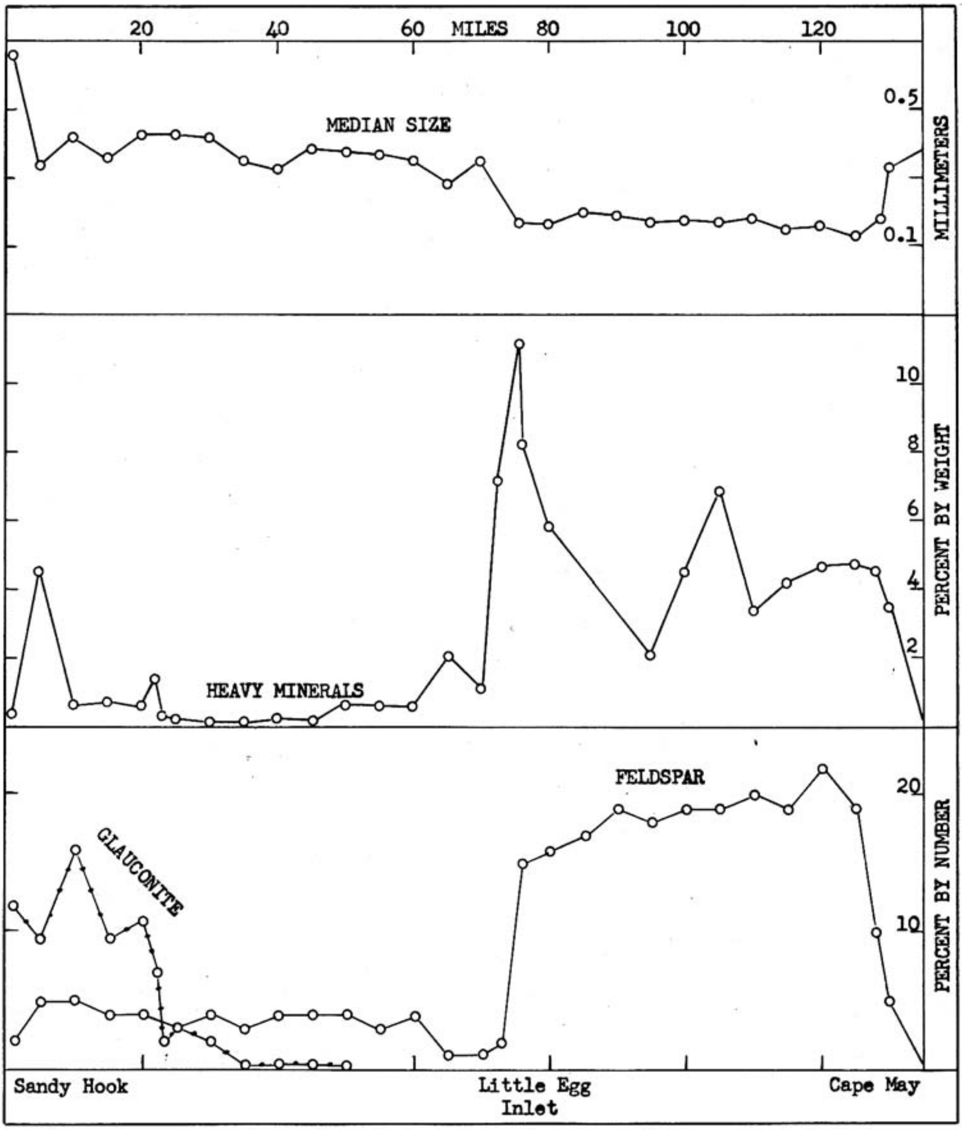

Figure 5 The Distribution of Heavy and Light Minerals in Beach Sands

TABLE 7

Percentage of Light Fraction Finer than 0.42 Mm.

Sample	Percent Minus 0.42 Mm.
9	72.0
14	47.0
19	58.0
24	38.0
26	68.0
27	44.0
29	48.0
34	51.0
39	75.0
44	79.0
49	52.0
54	58.0
59	64.0
64	65.0
69	93.0
74	64.0
132	69.0
137	67.0
142	24.0

fraction is restricted mainly to the area north of Point Pleasant (Figure 5) and the greatest percentage by number occurs between Shark River Inlet (22 mile post) and Sandy Hook. Toward the south there is a steady decrease in percentage. Colony (11, p. 156) and MacCarthy (28, p. 48) noted similar findings. A trace of mica was noted in several of these samples, but at no time does the amount approach one percent.

For the sand samples between Sandy Hook and Little Egg Inlet and along Delaware Bay, the light-fraction counts were based on the minus 0.42 mm. size material. This means that the frequencies which were recorded for these minerals are not a true indication of the abundance of the light mineral constituents in these samples. The percentage of minus 0.42 mm. material in each of these samples is listed in Table 7.

These light minerals are also characterized by the following features. Most quartz grains contain unoriented inclusions, and rounded quartz grains with secondary growths were frequently found along the entire beach area. Glauconite occurs as well-rounded and often lobate grains with polished surfaces which are sometimes cracked.

Variations in Total Heavy Mineral Content

The percentage by weight of the total heavy mineral content is shown graphically in Figure 5. In general, from Sandy Hook to Little Egg Inlet, the amount of heavy minerals in the beach sands is less than one percent and no great variations occur between adjacent samples along this stretch of the beach. Between Little Egg Inlet and Cape May there is a considerably greater amount of heavy minerals which show some variation from sample to sample. Along the Delaware Bay shore the weight percentage of heavy minerals again falls below one percent.

Several reasons have been advanced to account for the variations noted in amounts of heavy minerals along the beach. According to the District Engineer, U. S. Army[1], the sands around Absecon Light in Atlantic City (Figure 5, 85-mile post) were pumped from the adjacent inlet channel to form the present beach. This may account for the small weight of heavy minerals at this point.

In addition, it will be noted that in the vicinity of several of the inlets (Figure 5), namely Little Egg and Shark River (22-mile post), there is an increase in heavy mineral content. Colony (11, p. 155) found similar concentrations near inlets and believed that the activity of the tidal currents was responsible for this condition.

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[1] Personal communication

Areas of active wave erosion along the beach also show a local concentration of heavy minerals. This is especially true if sand dune material is being reworked as at the 5-mile post on Sandy Hook (Figure 5).

Variation in local conditions which affect the mechanics of transportation and deposition of sediment are of prime importance in determining heavy mineral concentrations. These variations are caused by (1) irregularities in beach structure and shoreline, (2) depth of water and the configuration of the bottom in front of the beach, and (3) differences in wave and current strength.

Relation of Texture to Mineral Composition

The relative amount by weight of heavy minerals is closely related to the texture of the beach sands. Figure 5 shows that the finest sands contain the greatest percentage of heavy minerals by weight and the medium and coarse sands have the smallest amounts of these minerals. Two factors are involved, (1) lack of availability of heavy minerals of sufficiently large size to be associated with the coarser sands and (2) a greater tendency toward formation of heavy concentrates on the upper part of the beach where the sand is finer.

A relationship of the median diameters of the light and heavy mineral fractions for beach sands of different texture is shown in Table 8. The median size is

TABLE 8

Relation of Grain Size to Composition

Grade Size (Mm)	Percent by weight .420	.297	.210	.149	.105	.074	.053	Median Size (Mm)
Tourmaline	3	23	35	35	4			
Hornblende		6	11	66	13	4		
Epidote			9	69	17	5		
Staurolite	3	14	27	51	5			
Garnet		2	10	60	25	2		
Zircon				17	68	15		
Light Minerals	22	42	23	4	x	x		.351
Heavy Minerals	2	7	15	53	20	2		.183
Hornblende			2	5	48	43	2	
Epidote				3	40	57	x	
Staurolite				11	89			
Garnet				2	21	73	4	
Zircon			2		13	72	15	
Light Minerals			5	54	36	2	x	.159
Heavy Minerals			x	6	42	49	3	.105

larger for the light than for heavy minerals. In addition, there is less spread between these two values in the fine sand than in the medium sand, and the diameters of the heavy minerals in each sample show less deviation than the size of the light minerals in these two samples.

The effect of texture on the weight percentages of several heavy mineral species over a range of grade sizes is presented in Table 8. In each textural type (medium and fine sand), heavy minerals have their maximum concentrations in different grade sizes. In the medium sand, hornblende, epidote, staurolite, and garnet have their greatest concentrations in 0.210 mm.-0.149 mm. grade size. Tourmaline is concentrated in several sizes, namely, 0.297 mm.-0.210 mm. and 0.210 mm.-0.149 mm. grades, while zircon is restricted to the 0.149 mm.-0.105 mm. size. Incidentally, it can be seen that the greatest abundance of hornblende, epidote, staurolite and garnet is closely related to the maximum concentration of total heavy minerals, whereas tourmaline is displaced toward the coarser sizes and zircon toward the finer sizes.

In the fine sand, hornblende and staurolite have their greatest abundance in the 0.149 mm.-0.105 mm. size; epidote, garnet and zircon occur with maximum concentrations in the 0.105 mm.-0.074 mm. size and all these minerals are closely clustered around the median size of the heavy fraction.

Table 8 shows clearly the effect of different textural types on the concentrations of each heavy mineral species. For example, hornblende has its greatest concentration in the 0.210 mm.-0.149 mm. size for the medium sand and in the 0.149 mm.-0.105 mm. grade size for the fine sand.

Table 5, Part 2, shows that the fine sands of southern New Jersey (Samples 79-127) have a different proportion by number of certain heavy mineral species than the adjacent medium sands along Long Beach Island (Samples 59-74) in those sizes studied. For example, hornblende, hypersthene, and epidote occur in greater abundance in the fine sands than in the medium sands; while torumaline, kyanite, staurolite and zircon are relatively more common in the medium sands.

The relation between texture and mineral composition is not restricted to heavy minerals alone. Figure 5 shows that the abundance of feldspar is also closely related to texture. The fine sands of southern New Jersey have a much greater abundance of feldspar by number than the adjacent medium and coarse sands. In fact, as the median diameters decrease along the beach, there is a relative increase in the percentage of feldspar. Thus the finest sands contain the greatest concentration of feldspar. In studying beach sands of the south Atlantic states, Martens (31, p. 529) also found relatively more feldspar in the fine sand than in the medium to coarse sand.

Comparison of Heavy Mineral Suites,

Sedimentary petrologists have commonly adopted several methods for comparing the heavy mineral composition of geological formations. In these methods the similarity or dissimilarity of heavy mineral assemblages is established on the basis of (1) the presence or absence of diagnostic mineral species, (2) the relative abundance by number of each heavy mineral, or (3) ratios between the number frequencies of selected heavy minerals. These descriptive values are determined for the entire sample or for one or more selected size grades.

Because these methods utilize some arbitrary or empirical basis, Rittenhouse (39) proposed and developed a new technique of representing mineral composition which is founded on the principles of sediment transportation and deposition.

Rittenhouse (39, p. 1729) found that experimental data indicate that the size distribution by weight of heavy and light minerals varies systematically among samples. These variations are caused by (1) varying hydraulic conditions at the places and times of deposition, (2) the hydraulic equivalent size of each heavy mineral which is closely related to its density (shape appears to be of secondary importance), (3) the relative availability for deposit of each mineral, and (4) some factor or factors now unknown.

As the relative availability of various sizes of each heavy mineral is constant (at least for low density minerals) it may be used as a basis for representing and comparing heavy mineral compositions. As Rittenhouse (39, p. 1742) states:

> "Relative availability may be expressed as a ratio between the amounts of two minerals by number, volume, or weight. The relation by weight, using light minerals throughout as one of the minerals, is easiest to obtain. In consequence, this hydraulic, relative-availability ratio, termed the 'hydraulic ratio' for convenience, is defined in terms of weight. Because the weight of light minerals is great compared to that of most heavies, the ratio is multiplied by 100 to arbitrarily reduce the number of decimal places. Specifically, then, the hydraulic ratio of a mineral is '100 times the weight of that mineral in a known range of sizes, divided by the weight of light minerals of equivalent hydraulic size'."

Rittenhouse (38, p. 156) believes:

> "The hydraulic-ratio basis of comparing mineral compositions appears to satisfy the three objections to methods in common use, namely: it uses both frequency and absolute amounts of heavy minerals, it eliminates apparent differences in mineral composition that are associated with differences in texture..., and it effectively transposes the data from bed samples into usable data on mineral composition in the stream load."

Because the mechanical composition of New Jersey beach sands reveals significant areal differences in sand texture, hydraulic ratios were used in an attempt to establish the similarity or dissimilarity of samples.

Hydraulic ratios.

The method for determining hydraulic ratios or relative availabilities is quite complex, so that a step-by-step explanation following Rittenhouse (39, p. 1745 and 38, p. 160), will be given.

Along a longitudinal traverse on a beach, the relative availability for deposit of each size of each mineral should not vary greatly from place to place. In addition, the hydraulic equivalent size[1] of the sediment particles as determined by specific gravity, shape and roundness should also be essentially constant along different parts of the traverse. If neither the relative availability nor the hydraulic equivalent value vary greatly from place to place, then these two factors can be determined simultaneously by comparing the mineral composition of several samples from different parts of the traverse.

Accordingly, a series of samples were collected along a longitudinal traverse on the foreshore at Monmouth Beach and Brigantine (Map I). At the foot of Valentine Street, Monmouth Beach, three samples, 0-1, 0-2 and 0-3, were taken 25 feet apart along the high tide line on a

[1]The size of light minerals that on the average will be transported and deposited with heavy minerals of known size.

10 degree slope. Three additional samples, 0-6, 0-7 and 0-8 were collected at 25 foot intervals along the high tide line on a 2 degree slope at Roosevelt Avenue, Brigantine. Each sample was composed of two individual cores.

The reasons for choosing two sampling areas were twofold. First, more different mineral species would be available for determination of hydraulic equivalent sizes and, second, the wide range in textural types would provide additional information on hydraulic equivalent sizes.

These samples were prepared in the manner outlined in the previous section. After mechanical analysis (Table 9), mineral separations were made and grain counts were determined for several size fractions (Table 10).

Next, the actual weight of each heavy mineral species in each size fraction was calculated as shown below:

Grade Size 0.149mm.-0.105mm. Heavy Mineral Weight 0.175gm.

	Number Frequency (Percent)	S. G.	F x SG	Weight Frequency	Weight
Hornblende	35.0	3.2	112.0	27.7%	.0485
Garnet	15.0	3.8	57.0	14.1	.0247
Zircon	50.0	4.7	235.0	58.2	.1018
			404.0	100.0%	.1750

The specific gravities used in the calculation of the weight of each heavy mineral were based on those

TABLE: 9 Mechanical Analyses of Samples for Hydraulic Equivalent Size - Part 1

Sample	Distribution by grade sizes (Mm.) in percent											
	3.360	2.380	1.680	1.190	.840	.590	.420	.297	.210	.149	.105	.074
0-1	.	.2	1.2	4.8	12.5	20.1	27.9	27.8	5.1	.4		
0-2	.1	1.3	2.7	9.0	17.3	21.1	22.2	21.5	4.4	.4		
0-3	.3	.8	1.6	5.0	11.3	22.2	28.6	25.2	4.5	.4		
0-6							.1	5.7	26.4	53.4	13.5	.8
0-7						.2	1.7	15.8	31.2	41.1	9.4	.6
0-8						.1	1.6	13.6	30.4	43.1	10.4	.6

TABLE 9

Mechanical Analyses of Samples for Hydraulic Equivalent Size - Part 2

Derived Values

Sample	Q_3	Median	Q_1	So	Sk
0-1	.754	.518	.378	1.41	.72
0-2	.930	.615	.410	1.51	1.01
0-3	.760	.615	.412	1.36	.83
0-6	.221	.189	.160	1.17	
0-7	.274	.209	.171	1.27	
0-8	.267	.203	.167	1.26	

TABLE 10

Heavy Minerals of Samples for Hydraulic Equivalent Size - Part 1 - Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
0-1	.297	22.83	20.98	1.850	--	8.1
	.210	4.15	3.60	.550	--	13.3
	.149	.31	.15	.162	--	52.3
0-2	.297	17.86	16.26	1.597	--	8.9
	.210	3.69	3.13	.563	--	15.2
	.149	.30	.12	.177	--	59.0
0-3	.297	22.12	20.36	1.755	--	8.0
	.210	3.96	3.40	.560	--	14.1
	.149	.31	.13	.182	--	58.7

TABLE: 10 Heavy Minerals of Samples for Hydraulic Eqivalent Size- Part 2 - Frequency by No.

Sample	0-1			0-2			0-3		
Size (Mm.)	.297	.210	.149	.297	.210	.149	.297	.210	.149
Minerals	Per Cent								
Andalusite	1.0	1.2	.5	.3	1.1	.2	.5	.9	
Apatite									
Chlorite									
Diopside		.3					.5		
Epidote	.2	1.6	2.0		1.7	1.5		.9	1.6
Garnet	.5	6.9	9.9	1.8	8.1	9.9	.3	7.7	9.0
Glauconite	86.8	42.7	4.7	85.1	35.3	2.7	86.4	31.0	3.2
Hornblende	1.0	1.2	1.8		1.9	.2	1.8	2.2	1.6
Hypersthene				.3	.3			1.1	.8
Kyanite		2.2	1.4	.3	1.9	2.9	.3	1.4	1.6
Muscovite									
Rutile			1.4		1.1	1.5		1.4	2.1
Sillimanite				.3	.3		x		.3
Staurolite	3.4	15.9	14.7	4.3	19.7	12.8	5.4	19.2	14.1
Titanite		.3							
Tourmaline	1.9	4.4	2.0	3.0	4.2	.7		6.0	.8
Tremolite									
Zircon			2.7		.6	1.9		.6	3.2
Chloritoid		.9	.2		1.4	.5	.5	.6	.8
Biotite		.3							
Blk. Opaques	2.9	14.0	54.5	2.7	15.3	60.4	2.0	15.2	56.2
Leucoxene	1.0	3.4	1.4	.3	1.4	1.7	.3	4.2	1.1
Miscellaneous*	1.3	4.7	2.8	1.6	5.7	3.1	2.2	7.6	3.6

Remarks:
*includes shell, altered, composite, and unknown grains.

TABLE 10

Heavy Minerals of Samples for Hydraulic Equivalent Size - Part 1 - Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
0-6	.149	23.04	22.75	.295	--	1.3
	.105	5.83	5.29	.545	--	9.4
	.074	.33	.08	.255	--	77.3
0-7	.149	17.80	17.39	.410	--	2.3
	.105	4.06	3.64	.425	--	10.5
	.074	.25	.05	.200	--	80.0
0-8	.149	15.36	15.03	.335	--	2.2
	.105	3.72	3.30	.425	--	11.4
	.074	.21	.05	.160	--	76.1

TABLE: 10 Heavy Minerals of Samples for Hydraulic Eqivalent Size- Part 2 - Frequency by No.

Sample	0-6			0-7			0-8		
Size (Mm.)	.149	.105	.074	.149	.105	.074	.149	.105	.074
Minerals	Per Cent								
Andalusite	x	.5	x	.4	.4		x	.6	
Apatite	x	.5	1.0	2.2	.9	.9		1.7	2.0
Chlorite	1.3	.8							
Diopside	4.8	3.0	2.3	4.6	2.2	1.6	5.4	4.1	.5
Epidote	1.7	3.0	5.6	.4	4.2	6.0	.9	3.0	6.3
Garnet	10.0	7.9	14.3	11.5	9.7	13.4	13.9	10.0	12.6
Glauconite	x								
Hornblende	32.0	49.9	40.7	18.6	42.5	35.2	22.2	41.2	33.2
Hypersthene	2.4	3.0	6.1	2.7	3.1	4.6	2.7	4.5	6.3
Kyanite	.4	.8	.8		.7	.5	.7	.9	.5
Muscovite	2.2	x		1.3			.4		
Rutile		x	.8	.4	.7	x	.9		.5
Sillimanite	1.5	1.4	1.5	2.0	.7	.5	.9	1.9	.8
Staurolite	1.7	.5	.5	3.1	.7	.7	2.0	.9	.8
Titanite		.5	1.5		.9	.9	.7	1.3	1.3
Tourmaline	3.9	1.1	.5	3.1	1.3	x	4.0	1.7	
Tremolite	.7	.5	x	.9	.4	.5	x	1.7	.5
Zircon	.9	1.1	2.8	1.3	2.0	3.5	1.3	2.3	4.3
Chloritoid	.9		1.0	.7	.4	.5	.4	.9	.5
Corundum				x					
Monazite						x			
Augite						.5			x
Blk. Opaques	20.5	9.0	15.4	35.9	19.1	26.2	34.4	15.6	25.9
Leucoxene	2.6	1.4	.5	2.2	1.1	.9	1.8	.4	x
Miscellaneous	12.3	15.1	4.7	8.7	9.0	3.6	6.5	7.3	4.0

Remarks:

presented by Winchell and Winchell (51). However, it was necessary to actually determine the specific gravities of two minerals. Glauconite, which occurs in significant amounts in the heavy mineral fraction in the Monmouth Beach samples was one of these. The specific gravity of this mineral was found to be 2.90 by the pycnometer method.

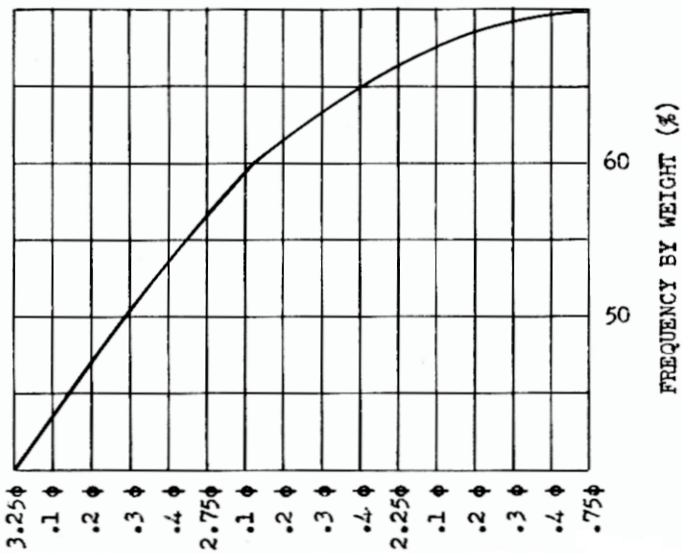
An attempt was made to determine the specific gravity of those grains counted as black opaques by using the same technique. The results were not satisfactory as black opaques from different localities along the beach showed a wide range in values. An average specific gravity of 4.1 was chosen for all calculations although it is recognized that a significant error will probably be introduced for those grade sizes containing large amounts of these minerals. The variations in specific gravity of these so-called black opaques suggest that this group of minerals is in actuality a mixture of various titanium minerals. Some of these grains are undoubtedly ilmenite but others are probably a form of leucoxene containing varying amounts of rutile as has been recently proposed by Creitz and McVay (12, p. 6).

An arbitrary value of 3.8 was assigned as the specific gravity of leucoxene.

All material tabulated as miscellaneous was assigned a specific gravity of 2.90. This group included shell, altered grains, composite grains, unknown minerals and micaceous minerals. Because of the extreme flatness of micas and chlorite, it was felt that no useful purpose would be gained by determining their equivalent sizes so these minerals were also grouped under miscellaneous for weight calculation.

Next, the size distribution of the light minerals of each sample was plotted as a large-scale cumulative curve. Each curve was drawn on 300 millimeter cross section paper in a manner as shown in Figure 6. The percentage of the sample in size grades 0ø, 0.1ø, 0.2ø, etc. larger than the size grade was determined graphically (Figure 6). These percentages were multiplied by the total sample weight of light minerals (Figure 6) to give the weight of sand that is equivalent in hydraulic size to the heavy minerals of the particular grade size. This procedure is repeated for each square-root-of-two grade size.

Relative availabilities for each heavy mineral were computed for a wide range of possible hydraulic equivalent sizes. For each size grade,100 times the weight of each heavy mineral was divided by the weight of light minerals of the same size, the weight of light minerals 0.1ø larger, then by the weight of light minerals 0.2ø larger, etc. For example:



GRADE SIZE IN PHI UNITS

Hydraulic Equivalent weights for Grade Size 0.149 mm.-0.105 mm.

Sample Weight 80 gm.

φ	Cumulative Upper	Percentage Lower	Percentage in Size Grade	Weight in Size Grade*
.0	56.2	40.0	16.2	13.0 gm.
.1	59.2	43.5	15.7	12.6 "
.2	61.6	46.7	14.9	11.9 "
.3	63.5	50.0	13.5	10.8 "
.4	65.1	53.4	11.7	9.4 "
.5	66.3	56.2	10.1	8.1 "
.6	67.2	59.2	8.0	6.4 "
.7	68.0	61.6	6.4	5.1 "
.8	68.7	63.5	5.2	4.2 "
.9	69.3	65.1	4.2	3.4 "
1.0	70.0	66.3	3.7	3.0 "

*Weight = Percentage X Total Weight of Sample Light Minerals

13.0 gm. = 16.2 X 80.0 gm. for .0 φ

Figure 6 Computation of Hydraulic Equivalent Weights

Epidote, (0.105 mm. -0.074 mm. grade size)

$$0\phi = \frac{100 \times .009 \text{ gm.}}{3.7 \text{ gm.}} = .242$$

$$0.1\phi = \frac{100 \times .009 \text{ gm.}}{6.7 \text{ gm.}} = .134$$

$$0.2\phi = \frac{100 \times .009 \text{ gm.}}{9.4 \text{ gm.}} = .096$$

A range of availabilities or hydraulic ratios for epidote in samples 0-6, 0-7, and 0-8 is presented in Table 11.

It is obvious that the availability of epidote is not the same at the spots where 0-6, 0-7, and 0-8 were deposited for this particular size of material. It is necessary therefore to employ a statistical measure called the coefficient of variation in order to establish the similarity between the hydraulic ratios for a range of hydraulic equivalent sizes. According to Richardson (37, p. 91) the coefficient of variation is defined in the formula:

$$\text{Coefficient of variation} = \frac{\text{standard deviation}}{\text{arithmetic mean}}$$

where the standard deviation = $\dfrac{(X-M)^2}{N}$

X = Individual variate

M = Arithmetic mean

N = Number of variates

TABLE: 11

Hydraulic Ratios for Epidote in the 0.015 Mm-0.074 Mm. Grade Size

Sample or Derived Factor	Hydraulic Equivalent Size										
	0φ	.1φ	.2φ	.3φ	.4φ	.5φ	.6φ	.7φ	.8φ	.9φ	1.0φ
0-6	.24	.14	.101	.079	.067	.061	.061	.066	.076	.092	.123
0-7	.27	.15	.104	.081	.068	.062	.064	.068	.072	.076	.081
0-8	.24	.13	.096	.078	.066	.058	.062	.065	.070	.074	.082
Mean	.25	.14	.10	.079	.067	.060	.062	.066	.073	.081	.095
Standard Deviation	.014	.007	.03	.0014	.0007	.0017	.0014	.0014	.0024	.0025	.02
Coef. of Variation	.057	.055	.30	.018	.012	.029	.023	.021	.035	.031	.21

The coefficient of variation for each hydraulic equivalent size of epidote is presented in Table 11. The lowest value is .012 and it occurs at the 0.4ϕ size. In other words, epidote apparently is transported and deposited with light minerals almost one square-root-of-two grade size larger.

Similar computations were made for several size grades and a number of heavy minerals using the data from those samples collected at Brigantine and Monmouth Beach. The best values are presented in Table 31.

For comparative purposes, beach samples spaced at 5-mile intervals were chosen for hydraulic ratio determinations. However, additional samples were selected in those areas showing visible changes in texture or mineral composition, or both texture and mineral composition. The locations of these samples are presented in Table 12 and Map I.

It was also necessary to select several size grades that would be represented in all samples chosen for comparison. Originally the 0.297 mm.-0.210 mm., 0.210 mm. -0.149 mm., and the 0.149 mm.-0.105 mm. grades had been set up for hydraulic ratios. However, it was soon learned that hydraulic equivalent weights could not be determined for the 0.297 mm.-0.210 mm. grade size for these fine sands of southern New Jersey. Therefore, hydraulic ratios

TABLE 12

Locations of Samples Used for Hydraulic Ratios

Sample	
5	Sandy Hook Point, Sandy Hook
9	Sandy Hook
14	Seabright
19	Long Branch
24	Asbury Park
26	Avon
27	Belmar
29	Spring Lake
34	Point Pleasant
39	Camp Osborne
44	Seaside Park
49	Island Beach
54	Island Beach
59	Long Beach Park
64	Surf City
69	Beach Haven Park
74	Holgate
77	Tucker Island
79	Pullen Island
83	Brigantine
88	Atlantic City
93	Margate City
97	Ocean City
102	Ocean City
107	Sea Isle City
112	Avalon
117	Stone Harbor
122	Wildwood
126	Cape May
130	Cape May
132	Cape May Point
137	Town Bank

were calculated for the 0.210 mm.-0.149 mm. and 0.149 mm.-0.105 mm. sizes.

Hydraulic ratios were computed for all samples in the following manner:

(1) Determination of actual weight of each heavy mineral present in each size.

(2) Graphic determination from large scale cumulative curves of the percentages of each sample in size grades 0φ, 0.1φ, 0.2φ, etc. larger than each square-root-of-two sieve size (Figure 6).

(3) Calculation of the weight of sand that is 0φ, 0.1φ, 0.2φ, etc. hydraulic equivalent sizes larger than each square-root-of-two grade size (Figure 6).

(4) Computation of hydraulic ratio by formula.

$$\text{Hydraulic ratio} = \frac{100 \times \text{weight of each heavy mineral}}{\text{weight of light minerals of equivalent hydraulic size}}$$

Example:

Hornblende - weight 0.0485 gm. (p. 99)
equivalent size 0.2φ (Table 31)
equivalent weight 11.9 gm. (Figure 6)

$$\text{ratio} = \frac{100 \times 0.485 \text{ gm.}}{11.9 \text{ gm.}}$$

$$= 0.475$$

Hydraulic ratios are summarized in graphic form for a number of heavy minerals in the 0.210 mm.-0.149 mm. and 0.149 mm.-0.105 mm. grade sizes (Figure 7).

Geological Interpretation.

Before examining the data on hydraulic ratios, the objectives for using the hydraulic ratio basis of comparing heavy mineral compositions should be briefly reviewed. The reasons for using this method were (1) to provide information concerning the similarity or dissimilarity of adjacent beach samples for the purpose of geologic correlation and (2) to locate possible sources for the beach sands.

The results of hydraulic ratio computations for each heavy mineral species are presented graphically for several grade sizes in Figure 7. Certain inferences are apparent from these graphs. First, the ratios of the mineral glauconite indicate that the area to the north of Shark River Inlet (22-mile post) is dissimilar to the areas toward the south. However, this indication is not borne out by the other minerals. Second, the ratios of most of the other minerals show a marked change in the vicinity of Little Egg Inlet (75-mile post). This trend is generally continuous down the beach. At Cape May (125-mile post) there is a sharp dip in the ratios of most of the minerals and the values return to the small numbers

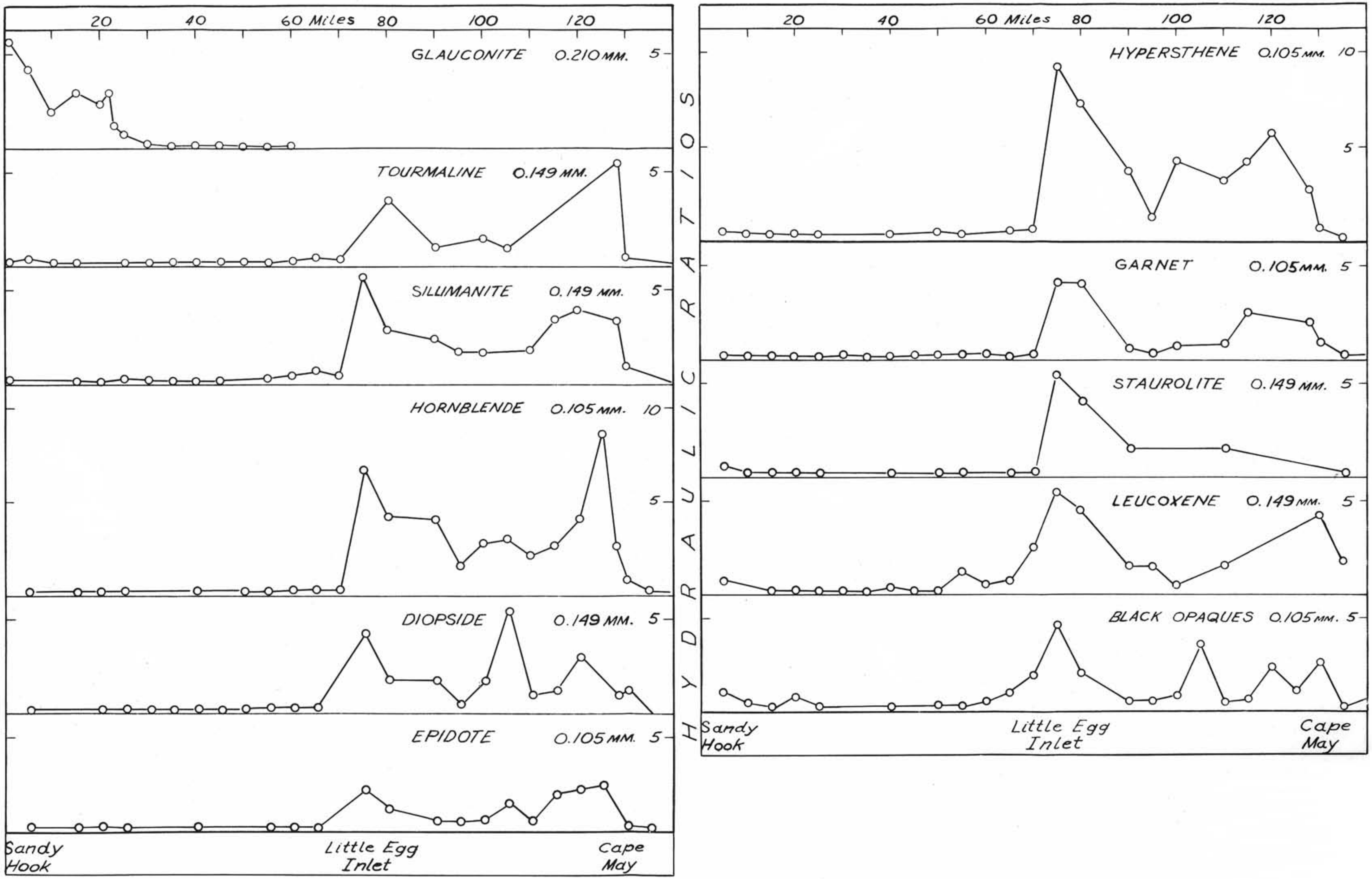


Figure 7 Hydraulic Ratios of Selected Heavy Minerals

which characterize the other beach areas to the north. This marked deviation in ratios along southern New Jersey beaches suggests that these sands are not correlative with those in the areas toward the north and along Delaware Bay. As the quantitative evidence supporting this last supposition is based on minerals which occur in significant amounts in these sands, the validity of this inference must be carefully considered.

Along the coastal areas in the vicinity of Barnegat Inlet, the beach sands have a medium texture and a small amount of heavy minerals. As is shown in Table 5 (Samples 44-74), the heavy mineral assemblage is dominated by black opaques, with much smaller amounts of hornblende, garnet, tourmaline, staurolite and zircon. A close examination of the heavy mineral data of these medium sands (Table 5) shows conclusively that abrasion of the present beach minerals could not alone produce a sufficient quantity of fine sand particles of heavy mineral species to account for the large amount of heavy minerals that occur in the fine sands of southern New Jersey. If these sands have a common source with those sands along the southern New Jersey beaches, then a fine sand fraction must be available at some place in the area. A most likely spot should be Barnegat Bay.

According to Johnson (17, p. 374) debris brought by beach drifting or other longshore currents is seized by the inflowing current at the tidal inlet and transported into the lagoon. Lucke (27, p. 25) examined the Barnegat Inlet delta sediments and found positive proof that Johnson's assumption was correct.

If it can be demonstrated that pine sands are prevalent in Barnegat Bay, and that these sands have comparable amounts and frequencies of heavy mineral species with those fine sands of the southern New Jersey beaches, then it is probable that a complex source area is supplying these beaches between Point Pleasant and Cape May and the mineral composition of the beach sands within this region are not correlative as indicated by the hydraulic ratios.

Bay bottom samples (C-1, C-6, and C-7) were collected near Waretown and Lavellette (Map I). Grain-size and mineral data are presented in Appendix IV and V and Table 13.

The mechanical analyses and derived values of these bay samples should be compared with certain selected beach sands of southern New Jersey and offshore samples (Table 13). The Barnegat Bay samples show finer median sizes and poorer sorting than the beach sands, but indicate more consistent values with those presented for the offshore samples.

TABLE 13

Comparison of Texture of Barnegat Bay Samples with Beach and Offshore Samples

Locality	Sample	Md.	So.	Sk.
Barnegat Bay	C-1	.104	1.26	.92
	C-6	.130	1.55	1.29
	C-7	.087	1.42	.72
Beach at Pullen Island	79	.178	1.16	.98
Beach at Sea Isle City	107	.168	1.15	.98
Beach at Cape May	127	.130	1.19	1.02
Little Egg Inlet	B-72	.114	1.14	1.01
Delaware Bay	B-93	.095	1.52	.57

Because differences exist in the size distribution of the Barnegat Bay samples and beach sands, mineralogical correlation of these sands cannot be easily visualized. However, heavy mineral frequencies of several grade sizes and data on weights and percentages of heavy minerals of the bay samples are presented in Table 18, and similar data on the beach sands (Samples 79, 107 and 127) and offshore samples (Samples B-72 and B-93) are available for comparison in Table 5 and Table 18. These various sediment samples are derived from different environments and are therefore subject to different factors which directly influence the transportation and deposition of sediment. Thus any conclusions on correlation must be weighed in view of environmental influence.

Light and heavy mineral data of an unsized fraction of several Barnegat Bay, selected beach, and offshore samples are presented in Tables 14 - 16. It is believed that the frequencies show enough similarity to justify the supposition that sands of comparable mineral distribution are located at various points and in various environments in the coastal region of southern New Jersey.

TABLE 14

Comparison of Amounts of Heavy Minerals of Barnegat Bay with Beach and Offshore Samples

Sample	Location	Percent by Weight of Heavy Minerals
C-1	Barnegat Bay	7
C-6	Barnegat Bay	3
79	Pullen Island	11
107	Sea Isle City	7
127	Cape May	5
B-72	Little Egg Inlet	12
B-93	Delaware Bay	4

TABLE: 15 Comparison of Heavy Mineral Frequencies of Barnegat Bay with Beach and Offshore Samples

Sample	C-1	C-6	79	107	127	B-72	B-93		
Size (Mm.)									
Minerals	Per Cent								
Andalusite		x				1	1		
Apatite	2	1	1	1	4	1	1		
Chlorite	1	1	x	x		1	1		
Diopside	x*	2	2	2	3	x	x		
Epidote	7	8	4	2	5	5	3		
Garnet	11	9	14	16	10	11	9		
Glauconite		1							
Hornblende	32	30	30	38	42	39	47		
Hypersthene	2	4	6	5	6	5	10		
Kyanite	1	1	1	x	1	1	x		
Muscovite	1	1	1	1	1	3	5		
Rutile			1		x				
Sillimanite	2	x	2	2	1	2	x		
Staurolite	2	1	2	2	1	2	1		
Titanite	2	2	1	2	1	1			
Tourmaline	1	3	1	1	x	x			
Tremolite	1	1					x		
Zircon	5	4	4	4	2	4	3		
Chloritoid	1	2	1	1		1	x		
Blk. Opaques	28	20	24	16	13	16	12		
Leucoxene	1	1	1	2	4	3	1		
Miscellaneous**	3	5	4	3	4	2	6		

Remarks:
* denotes trace
**includes shell, composite, altered, and unknown grains

TABLE 16

Comparison of Light Minerals of Barnegat Bay with Beach and Offshore Samples

	Percent by Number		
Sample	Quartz	Total Feldspar	Others
C-1*	84	15	1
C-6*	88	12	--
79	85	15	--
107	81	19	--
127	80	20	--
B-72	78	22	--
B-93*	78	13	9

*Unstained

Regional Differences in Mineral Composition of Offshore Sediment

Presentation of Data on Mineral Content

The results of heavy mineral analyses have been recorded for a number of selected size grades. These data are presented in Table 18.

Grain counts on the light mineral fraction have been listed for a number of bulk samples in Table 19.

Minerals Present

Most mineral species found in the beach sands were noted in the offshore sands. These minerals are listed below:

TABLE 17

Minerals in the Sea Bottom Samples

Actinolite	Potash Feldspar	Muscovite
Andalusite	Soda-Lime Feldspar	Quartz
Apatite	Garnet	Rutile
Augite	Glauconite	Sillimanite
Biotite	Hornblende	Staurolite
Chlorite	Hypersthene	Titanite
Chloritoid	Kyanite	Tourmaline
Collophane	Leucoxene	Tremolite
Corundum	Magnetite	Zoisite
Diopside	Monazite	Zircon
Epidote		

TABLE 18

Heavy Minerals in Sea Bottom Samples - Part 1
Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
B-13	.210	25.02	24.85	.172	.002	0.7
	.149	4.62	4.45	.172	.002	3.7
	.105	.18	.16	.025	--	13.9
B-21	.210	19.55	19.04	.507	.004	2.6
	.149	2.24	2.04	.205	.004	9.2
B-23	.210	5.64	5.34	.305	.003	5.4
	.149	.98	.98	.042	.001	4.3
B-32	.210	27.13	26.05	1.085	--	4.0
	.149	18.12	17.37	.755	--	4.2

TABLE: 18 Heavy Minerals in Sea Bottom Samples - Part 2
Frequency by Number

Sample	B-13			B-21		B-23		B-32	
Size (Mm.)	.210	.149	.105	.210	.149	.210	.149	.210	.149
Minerals	Per Cent								
Andalusite	1	1		x	1	1	1		
Apatite		x*	1		x				x
Chlorite	1							x	1
Diopside	2	2	1	2	3	x	2	x	1
Epidote	x	1	3		1		x	x	3
Garnet	18	9	14	5	10	43	21	1	7
Glauconite	3		x	57	6	34	14	85	22
Hornblende	23	34	33	8	19	3	13	5	19
Hypersthene	3	7	3	3	3	1	2		3
Kyanite	2	4	5	x	3	x	3		1
Muscovite	1	x							
Rutile					x				
Sillimanite	x	x	2	1	2		2		1
Staurolite	5	8	6	4	10	5	10	x	8
Titanite		1	1	x			1		
Tourmaline	1	2	x	2	2	3	1	1	3
Tremolite	1		x		x	x	x	x	1
Zircon		x	2		1		x		
Augite	x	x	1	1	3	1			1
Biotite	1								
Monazite	x				x				
Chloritoid					1				x
Collophane								1	2
Corundum									x
Blk. Opaques	16	17	20	4	26	6	17	2	23
Leucoxene	2	2	1	4	2	1	2	x	1
Miscellaneous**	20	11	6	9	6	2	10	4	4

Remarks:
* denotes trace
**includes shell, composite, altered, and unknown grains

TABLE 18

Heavy Minerals in Sea Bottom Samples - Part 1
Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
B-32	.105	3.41	2.98	.435	--	12.8
B-41	.105	12.79	12.60	.190	--	1.5
	.074	5.89	5.34	.550	--	9.3
B-51	.210	23.54	23.45	.093	--	0.4
	.149	10.13	9.74	.390	--	3.8
	.105	3.41	3.04	.370	--	10.9
B-61	.149	42.52	42.06	.464	--	1.1
	.105	17.70	16.02	1.680	--	9.5
B-64	.210	31.80	31.63	.167	--	0.5

TABLE: 18 Heavy Minerals in Sea Bottom Samples - Part 2
Frequency by Number

Sample	B-32	B-41		B-51			B-61		B-64
Size (Mm.)	.105	.105	.074	.210	.149	.105	.149	.105	.210
Minerals	Per Cent								
Andalusite	1	1	1	1	x		1	x	3
Apatite	x		1		1	2		2	
Chlorite		8	1	1	x	x	3	1	x
Diopside		2	1	4	2	2	3	2	4
Epidote	3	3	8	x	2	3	2	5	1
Garnet	8	2	5	7	10	6	7	6	7
Glauconite	5	9	1					x	
Hornblende	11	13	28	6	11	29	25	39	2
Hypersthene	2	2	4	1	2	3	2	4	1
Kyanite	1	1	2	1	x	x	1	1	1
Muscovite		6	1	1	1		5	1	2
Rutile	x	1			x	1		x	
Sillimanite	x	x	1	2	2	2	2	1	1
Staurolite	6	3	3	7	2	x	3	2	8
Titanite		x	x		x	1	x	1	x
Tourmaline	3	4	4	10	2	1	2	1	9
Tremolite	x	x	x	x	x	x	x	1	
Zircon	2	x	1	1	1	5		1	1
Augite	x	x		1	x	x	x	1	1
Chloritoid	x	1	1		1	1		1	x
Collophane	1	1							
Biotite		1							x
Monazite				x					
Blk. Opaques	46	18	16	44	54	35	30	21	45
Leucoxene	1	4	1	4	2	x	2	1	6
Miscellaneous	9	18	18	8	6	8	11	7	7
Remarks:									

TABLE 18

Heavy Minerals in Sea Bottom Samples - Part 1
Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
B-64	.149	41.90	14.47	.427	--	2.9
	.105	1.89	1.62	.267	--	14.1
B-71	.105	44.27	40.03	4.340	--	9.8
	.074	10.28	4.26	6.020	--	58.5
B-72	.105	52.96	51.52	1.444	--	0.3
	.074	31.52	24.85	6.670	--	21.2
B-73	.210	19.19	17.76	1.430	--	7.5
	.149	4.70	3.04	1.660	--	35.3
	.105	3.08	2.81	.272	--	8.8

TABLE: 18 Heavy Minerals in Sea Bottom Samples - Part 2
Frequency by Number

Sample	B-64		B-71		B-72		B-73		
Size (Mm.)	.149	.105	.105	.074	.105	.074	.210	.149	.105
Minerals	Per Cent								
Andalusite	x	1	x		1		x		1
Apatite		1	2	2	2	2		x	1
Chlorite	1		1		3	x		x	1
Diopside	2	1	2	1	x	1	2	1	2
Epidote	1	3	4	6	5	8			5
Garnet	9	11	8	17	5	9	10	7	15
Glauconite	x								
Hornblende	9	27	44	36	51	48	2	3	33
Hypersthene	1	4	2	4	5	4	x	x	3
Kyanite	x	x	1	x	1	x	1	1	x
Muscovite			x		1				
Rutile				x			x	1	
Sillimanite	2	2	2	1	2	2	x	1	1
Staurolite	4	1	1	1	x	1	8	3	x
Titanite	x	1	1	1	x	1	x	x	1
Tourmaline	4	1	x		1	1	4	1	1
Tremolite		x	x	x	1	2			x
Zircon	3	5	1	5	1	1	x	5	4
Monazite	x	x		x				1	
Collophane	x								
Augite			x		x		x	1	1
Chloritoid			1	1	1	1			
Biotite					x	x			x
Blk. Opaques	53	36	18	18	3	9	62	71	22
Leucoxene	2	1	2	1	1	1	5	2	1
Miscellaneous	8	5	9	5	15	8	4	3	7

Remarks:

TABLE 18

Heavy Minerals in Sea Bottom Samples - Part 1
Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
B-83	.149	12.93	12.66	.267	--	2.1
	.105	3.93	3.32	.315	--	8.0
B-93	.105	17.47	17.23	.245	--	1.4
	.074	15.00	13.94	1.060	--	7.1
C-1	.105	13.25	12.98	.274	--	2.1
	.074	9.42	8.64	.780	--	8.3
C-6	.105	11.75	11.50	.250	--	2.1
	.074	7.40	6.99	.410	--	5.5

TABLE: 18 Heavy Minerals in Sea Bottom Samples - Part 2
Frequency by Number

Sample	B-83		B-93		C-1		C-6		
Size (Mm.)	.149	.105	.105	.074	.105	.074	.105	.074	
Minerals	Per Cent								
Andalusite	1	x				x		x	
Apatite		1	x	2	1	2	x	3	
Chlorite	3	1	13	3	4	3	6	3	
Diopside	1	1	1		3	1	1	2	
Epidote	3	4	4	7	3	7	1	3	
Garnet	6	4	5	7	4	7	8	6	
Glauconite		x					x		
Hornblende	18	14	40	55	37	33	18	33	
Hypersthene	1	2	3	5	4	4	3	5	
Kyanite	1	1	1		x	x	1	1	
Muscovite		x	6	1	8	3	4	2	
Rutile							x	1	
Sillimanite	2	2	x	x	3	1	2	1	
Staurolite	3	2		x	x	1	4	4	
Titanite	x			1		1		1	
Tourmaline	2	1	x		1	2	1	2	
Tremolite	1	1	2	1	1			1	
Zircon	2	5	x	1	1	2	4	2	
Augite	x								
Chloritoid	x		1	1	1	1	1	1	
Monazite	1								
Biotite			3	1	1				
Blk. Opaques	43	52	4	3	10	21	41	25	
Leucoxene	3	3	1	1	3	3	2	1	
Miscellaneous	8	5	16	12	15	8	2	3	

Remarks:

This assemblage of minerals is very similar to the suites of minerals found by Alexander (1, p. 13), and Shepard and Cohee (42, p. 449) in their investigations of the mineralogy of the continental shelf sediments.

Varietal features of several species were recorded. For example, hornblende occurred in green, brown and blue-green varieties; garnet was observed in pink and colorless grains. Certain of the garnet grains were characterized by the presence of crystal faces and a distinctive nucleus of inclusions. Several varieties of tourmaline were noted, including pleochroic green-pink and light brown-brown grains. Colorless and pale green diopside and colorless and pleochroic yellow varieties of epidote were also recorded.

A study of the light minerals was restricted to a bulk unsized fraction for several of the samples. This suite of minerals included quartz, potash and soda-lime feldspar, glauconite, and muscovite. The relative amounts of each of these minerals for a number of samples is presented in Table 19. It will be noted that glauconite and small amounts of feldspar characterize the area north of Shark River Inlet, whereas the other areas show a generally large amount of feldspar and no glauconite. Shepard and Cohee (42, p. 449) found the sands off New Jersey contained from 10 to 20 percent feldspar.

TABLE 19

Light Minerals in Sea Bottom Samples

Percent by Number

Sample	Location	Quartz	Total Feldspar	Glauconite	Muscovite
B-13*	Sandy Hook	88	3		
B-21*	"	86	5	5	
B-23*	"	96	1	2	
B-32*	Shark River	69	4	26	
B-41	"	81	12	6	
B-51	Little Egg Inlet	90	10		
B-53	"	88	12		
B-61	"	87	12		
B-64	"	93	7		
B-71	"	80	20		
B-72	"	78	22		
B-73	"	94	5	x	
B-83	Cape May	86	12		
B-93	North Cape May	78	13		2

*Includes the minus 0.420 mm. size material only.

Several species were found to occur in restricted areas and therefore have diagnostic value. These minerals are glauconite, magnetite, and garnet with the nucleus of inclusions. Glauconite was noted in varying quantities in both light and heavy fractions but this mineral was limited to the shelf area north of Shark River Inlet. Magnetite and garnet with the nucleus of inclusions was found exclusively in the area around Sandy Hook.

Relation of Texture to Composition

The total percentage of heavy minerals by weight for a number of samples is presented in Table 20. In general, it will be observed that the coarser sands have a smaller weight of heavy minerals than the finer sands.

The effect of texture on the relative proportions of each mineral species can be noted in Table 18. In general, there is a less striking change in relative amounts by number of the mineral species in the same size from sample to sample.

The distribution of feldspar also shows the effect of texture (Table 19). There is a relative increase in the abundance of feldspar in the ocean bottom sands as the median size of the sand decreases. However, this trend is not as drastic as observed for the beach sands (Figure 5).

TABLE 20

Percentage by Weight of Heavy Minerals in Sea Bottom Samples

Sample	Location	Median Size (Mm.)	Weight Percentage of Heavy Minerals
B-13	Sandy Hook	.317	0.8
B-21	"	.347	0.9
B-23	"	.389	0.6
B-32	Shark River	.269	4.0
B-41	"	.120	5.0
B-42	"	.936	0.9
B-51	Little Egg Inlet	.287	1.4
B-53	"	.198	2.7
B-61	"	.184	4.2
B-64	"	.287	1.1
B-71	"	.139	13.6
B-72	"	.114	12.3
B-73	"	.345	4.5
B-81	Cape May	.640	0.5
B-83	"	.287	1.6
B-93*	North Cape May	.095	3.0

*Plus 0.074 mm. grade size.

ORIGIN OF BEACH SANDS

Sediment Petrographic Zones

General Statement

For descriptive purposes it is possible to delineate several mineral zones along the beach from Sandy Hook to Reeds Beach on Delaware Bay. A mineral zone embodies characteristics which are repeated laterally in a number of samples and thus set it apart from the adjacent littoral areas. Each zone is characterized by a generally constant proportion of light and heavy minerals and by a particular relationship between the various mineral species.

On this basis of mineralogy (hydraulic ratios, Figure 7; light mineral analyses, Figure 5; and amounts of heavy minerals, Figure 5), it is possible to establish three zones along the beach which are composed of dissimilar sand. These zones may be called the glauconite zone (Sandy Hook to Shark River); the black opaque zones (Shark River to Pullen Island and Cape May Point to Reeds Beach); and the hornblende zone (Pullen Island to Cape May) (Figures 8 and 9).

It should be emphasized that the boundaries between adjacent mineral zones are not sharp and distinct, but show considerable lateral transition from one mineral

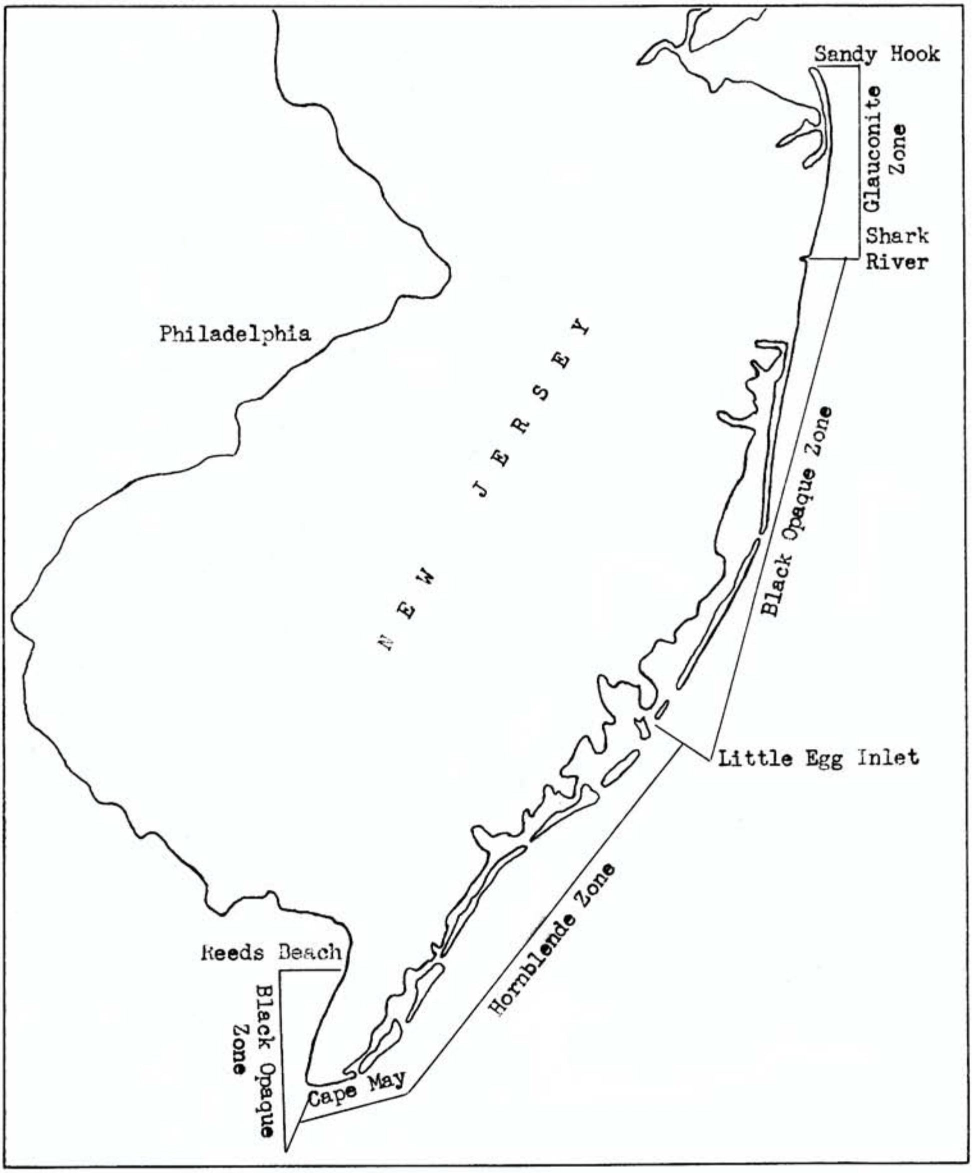


Figure 8 Sediment Petrographic Zones

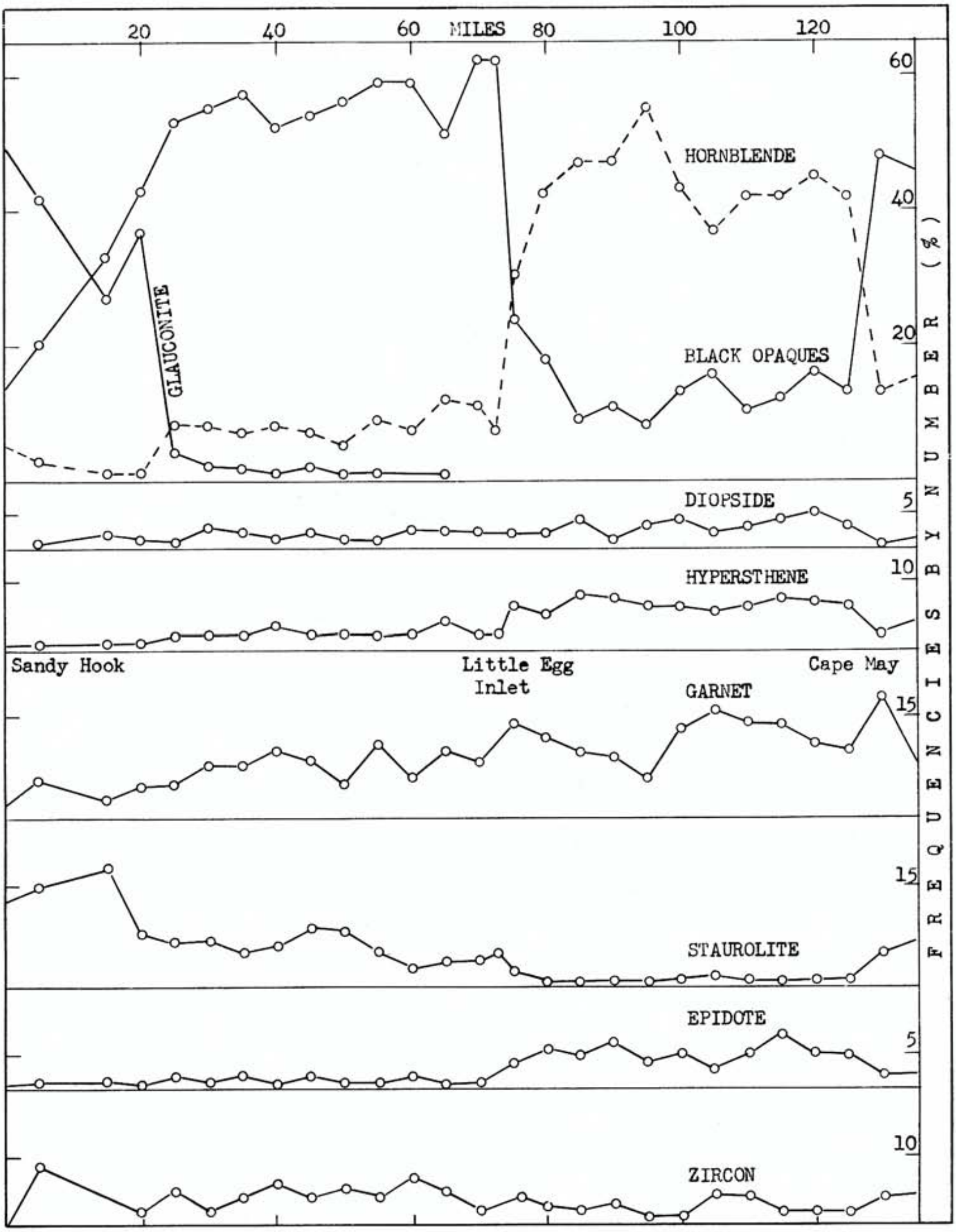


Figure 9 Heavy Minerals in the New Jersey Beach Sands

zone to the next. Therefore it is impossible to define the exact limits of each mineral zone. However for descriptive purposes, an arbitrary boundary will be established based on the location where the character of one mineral zone predominates in relation to the other zone.

The Glauconite Zone

The beach sands of the extreme northern part of the coastal area of New Jersey, namely from Shark River to Sandy Hook, are characterized by the presence of significant amounts of glauconite in both the heavy and light mineral fractions (Figures 8 and 9). In the light fractions glauconite makes up from 7 to 16 percent by number and in the heavy fractions it is from 2 to 37 percent by number.

The areal extent of this particular zone is greatly increased if the offshore samples are considered (Table 19). In the vicinity of Sandy Hook (Samples B-1l-B-23) there is a general decrease in abundance of glauconite toward Romer Shoal (north) and Ambrose Channel (east), while off Shark River Inlet, glauconite shows an increase in abundance (Table 19). Since no bottom samples were collected toward the south of Shark River Inlet in this general area, it is impossible to delineate any offshore southern boundary for this zone.

Evidence of contamination of the glauconite zone was noted along the beaches of Sandy Hook. A peculiar grain of garnet was found which featured a nucleus of inclusions. This garnet was not observed in the beach sands toward the south. However, the bottom samples in this area showed additional grains with this feature. A small amount of magnetite (Table 18) was detected in these same bottom samples. Although magnetite was also found on the beaches as dubious traces, it was attributed to contamination from the numerous groins. However, the presence of magnetite in the beach sands of Sandy Hook may actually be closely related to the presence of the garnet, as both these minerals could represent a reworked product from the glacial terminal moraine which crosses Staten Island and the Narrows immediately north of Sandy Hook.

The Black Opaque Zone

Two large beach areas show a very similar arrangement of heavy mineral constituents. One of these areas stretches from Shark River to Pullen Island and the other from Cape May Point to Reeds Beach on Delaware Bay (Figure 8). In these beach sands, the unsized heavy mineral fraction is monopolized by the abundant occurrence of the so-called black opaque minerals. These minerals make up over 50 percent of the heavy minerals present. In addition, the greater relative abundance of staurolite and zircon (Figure 9) is characteristic of this zone. Another distinguishing feature is found in the light fraction where the total feldspar constitutes less than 4 percent of the unsized light minerals (Figure 5). Each of these areas is entirely composed of medium and coarse sand which contains a total of less than 1 percent of heavy minerals (Figure 5).

Although offshore samples were collected in several localities, their value is strictly limited as indicators of mineral zone boundaries as there is no true representation of continental shelf sediment types for the greater part of the coastal area.

The glauconite zone overlaps the black opaques zone for some distance south of Shark River. In fact, greater than 1 percent of glauconite in the heavy fraction is noted as far south as Island Beach, some 30 miles in distance.

The Hornblende Zone

The fine sand from Pullen Island to Cape May represents the hornblende zone (Figure 8). These beach sands contain over 2 percent heavy minerals and are characterized by the predominance of hornblende in the heavy mineral fractions (Figures 5 and 9). In addition, significant amounts of epidote and hypersthene (Figure 9) occur in the heavy mineral assemblage. This zone is also distinguished by the feldspar content in the light fraction. The relative amount of total feldspar in these sands varies between 13 and 22 percent by number (Figure 5).

At each extreme limit of this zone, namely in the vicinity of Little Egg Inlet and near Cape May Point, there is an intermingling of mineral associations with the adjacent black opaque zone.

Ultimate Source

Previous Investigations

Several workers have published their views on possible original source areas for the beach sands. Colony (11, p. 158) states:

> ".....The heavy minerals in the sands of the New Jersey beaches represent reworked heavy detrital matter from the Coastal Plain sediments, derived initially from the Appalachian region......."

According to Lucke (27, p. 26), the Barnegat Bay sediments are at least thrice removed from their original source, the Appalachian region, from which they were deposited in the Coastal Plain sediment, then along the beaches, and finally in the bay.

Wicker (49, p. 5) believes that the Coastal Plain formations are a result of erosion of the upland now included in the Appalachian Mountain terrain and the material composing the New Jersey beaches is derived from the

TABLE 21

Detrital Mineral Suites Characteristic of Source Rock Types

Reworked Sediments

Barite	*Quartzite fragments
*Glauconite	*Leucoxene
*Quartz (esp. with worn overgrowths)	*Rutile
	*Tourmaline, rounded
*Chert	*Zircon, rounded

Low-Rank Metamorphic

Slate and phyllite fragments	*Tourmaline, (Small pale brown euhedra)
*Biotite and muscovite	
*Chlorite	*Leucoxene
*Quartz and Quartzite fragments	

High-Rank Metamorphic

*Garnet	*Quartz
*Hornblende (blue-green variety)	*Muscovite and biotite
*Kyanite	*Feldspar(acid plagioclase)
*Sillimanite	*Epidote
*Andalusite	*Zoisite
*Staurolite	*Magnetite

Acid Igneous

*Apatite	*Sphene
*Biotite	*Zircon, euhedra
*Hornblende	*Quartz
*Monazite	*Microcline
*Muscovite	*Magnetite
	*Tourmaline, pink euhedra

Basic Igneous

*Anatase	*Leucoxene
*Augite	Olivine
Brookite	*Rutile
*Hypersthene	*Plagioclase, intermediate
*Ilmenite and magnetite	Serpentine
Chromite	

Pegmatite

Fluorite	*Monazite
*Tourmaline, typically blue (indicolite)	*Muscovite
	Topaz
*Garnet	*Albite
	*Microcline

*Denotes those minerals or varietal mineral species found in the beach sands.

Adapted from Pettijohn (34, p. 98)

deposits found in the portions of the Coastal Plain adjacent to the beaches.

Beach Mineral Assemblage and Source Rock Types

Pettijohn (34, p. 98), has compiled a table of common mineral suites which are indicative of source rock types. The data from this table are presented in Table 17 and the mineral assemblage of the beach sands is appropriately designated.

An examination of this table reveals that the mineral association of the beach sands is represented in each of the source rock types listed. The assemblage is not only well diversified but it also has sufficient representation in each rock type so as to leave little doubt that all of these rock types must contribute in some way toward the composition of the beach sediment.

Reworked sediments, metamorphic rocks, acid and basic igneous rocks and pegmatites are all found within 50 miles of the present New Jersey beaches.

Areal Geology in Eastern Pennsylvania, New Jersey and Southeastern New York

A general description of the character of numerous geologic formations and rock types in the various physiographic provinces of New Jersey and surrounding states is presented (Table 22 and Figure 10) so that the original source materials can be more conveniently localized.

TABLE 22

Areal Geology in Eastern Pennsylvania, New Jersey and Southeastern New York

Physiographic Province & Location	Formation, Age & Rock Types	Mineral Constituents
Appalachian Plateaus; N.Y., Central Pa. into W. Va.	C; ss., sh. & ls.	
Appalachian Valley, N.Y., N.J., & Pa.	Є to C; cg., ss., sh. & ls.	
Appalachian Mts. N.Y., N.J., to Reading, Pa.	Franklin; pЄ; crystalline ls. qtzite	
	pЄ; schist	Graphite, quartz, mica, & garnet.
	Pockunk; pC; gn.	Oligoclase, orthoclase, diopside, hornblende, hypersthene, biotite, magnetite & quartz.
	Losee; pЄ; gr. gn.	Oligoclase, & quartz: Minor; diopside, hornblende, hypersthene, biotite, apatite, sphene, zircon, & magnetite.
	Byram; pЄ; gr. gn.	Quartz, microcline, orthoclase, hornblende, & biotite Minor; apatite, sphene, & magnetite; diopside & hypersthene are not common.

TABLE 22

Areal Geology in Eastern Pennsylvania, New Jersey and Southeastern New York

Physiographic Province & Location	Formation, Age & Rock Types	Mineral Constituents
Westchester Co., & N.Y.C., N.Y.	Fordham; p€; ?; gn.	Quartz, feldspar, & biotite; Minor; hornblende, zircon, apatite, sphene, garnet & magnetite.
	Hudson; p€; schist	Quartz, feldspar, & biotite: Minor; garnet, kyanite, staurolite.
Piedmont; Central N.J. & SE Pa.	TR; sh., ss., argil, cg. & ign. rks.	
SEPa. to Md.	Baltimore; p€; gr. gn.	Quartz, orthoclase, microcline, acidic plagioclase, garnet, hornblende, biotite, augite, epidote, sphene, staurolite.
	Wissahicken, p€; gn.	Quartz, orthoclase & plagioclase, feldspar, & mica: Minor; apatite, zircon, tourmaline, garnet, andalusite, sillimanite & zoisite.
	€ to O; schist, qtzite, dol. ls.	

TABLE 22

Areal Geology in Eastern Pennsylvania, New Jersey and Southeastern New York

Physiographic Province & Location	Formation, Age & Rock Types	Mineral Constituents
	pC; gr. gn.	Quartz, feldspar, biotite, & hornblende: Minor; sphene, epidote, apatite, actinolite.
	pC; gabbro	Hypersthene, augite & plagioclase feldspar: Minor; garnet ilmenite, zircon, aphene & hornblende.
	pyroxenites & peridotites	Serpentine, steatite, tremolite, hornblende, actinolite, epidote, chlorite.
Coastal Plain; N.J.	K; s. & cl., lign. s. & cl. glauc. s. & ml. T; glauc, ml., glauc. qtz s. & lime s. T; mic. s., qtz. s., & g. & cl. Q; g. & s.	

Adapted from:

Bascom et al	(2, p. 1)	Bayley et al	(6)
Butts	(10, p. 1)	Merrill et al	(33, pp. 3 & 4)
Stose	(43, pp. 1 & 3)	Bascom and Stose	(5, p. 1)
Kummel	(25, pp. 42, 43, 45)	Bascom at al	(3)
Willard and Fraser	(50, pp. 7-12)	Bascom and Miller	(4)

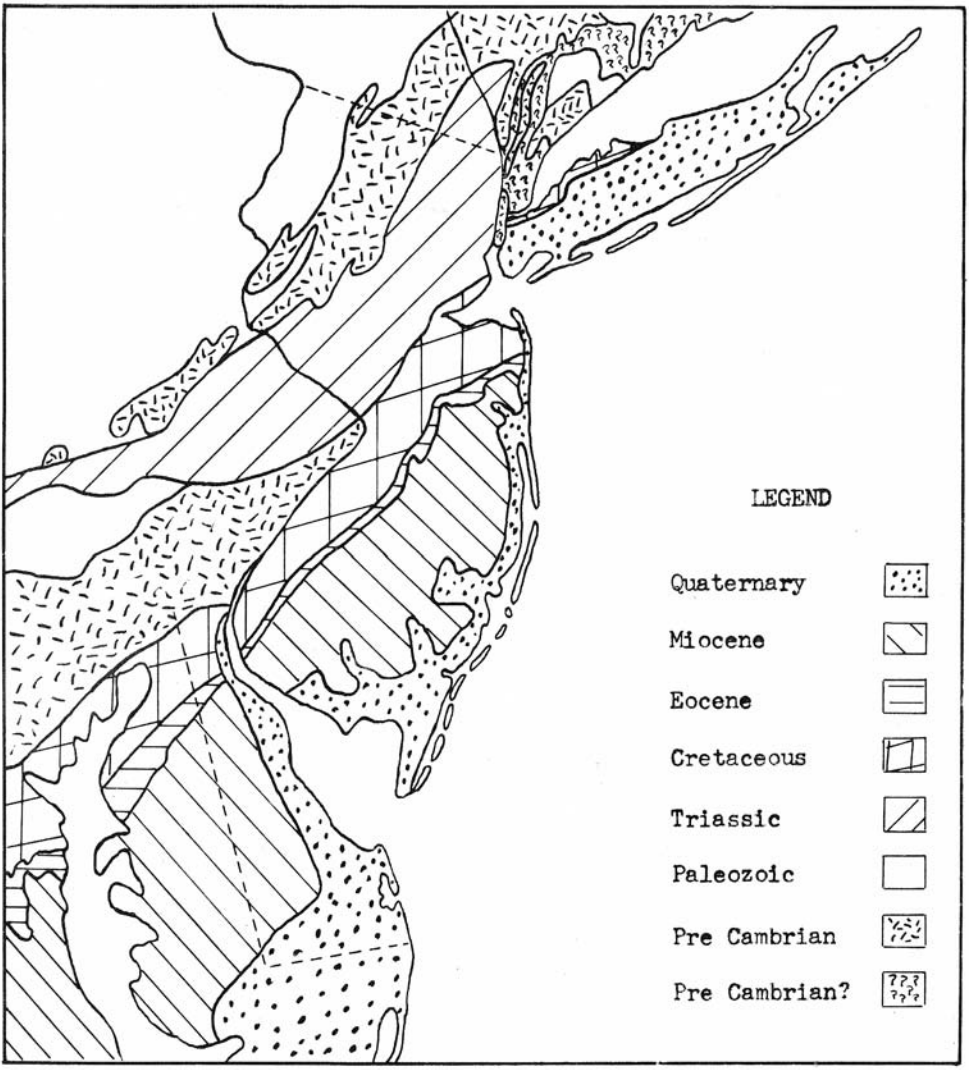


Figure 10 Geologic Map of New Jersey and Surrounding Region

After Stose (44)

Original Sources

By comparing the heavy mineral suite of the New Jersey littoral sediments (Table 17) with the character of the geologic formations and rock types in the various physiographic provinces (Table 22), it is concluded that the primary original source material was derived from the Appalachian Province, particularly the sedimentary, metamorphic, and igneous rock complex of the Piedmont and Highlands, which extend as discontinuous belts across part of New York, New Jersey and eastern Pennsylvania (Figure 10). In addition, many of the Coastal Plain formations are represented directly or indirectly in these beach sands. Although Dryden and Dryden (14, p. 1993) show that the Coastal Plain sediments were derived essentially from these same crystalline rocks of the Piedmont and Highlands, the mineral glauconite, which is an important constituent in some of the beach sands, has been contributed from the sedimentary environment of certain of the Coastal Plain deposits. It should be strongly emphasized that the 150 miles of littoral sediment is not an end product of many erosion cycles recorded in the Coastal Plain formations.

Immediate Source

Previous Investigations

Several workers have expressed opinions concerning immediate source areas for the New Jersey beach sands. According to MacCarthy (28, p. 49), offshore erosion supplies materials to the beaches of the New Jersey coast. Colony (11, p. 159) states:

> "The significant minerals in them (beach sands of New Jersey) are common to the coastal plain sediments of New Jersey; hence the Cretaceous and Tertiary sediments comprising the coastal plain represent the immediate source of these sands."

Colony (11, p. 159) based this conclusion on the assumption that the littoral movement of sands along the coast from Monmouth Beach to Cape May was generally toward the south. Light (26, p. 92) concluded that the source of the sands of the Barnegat Bar is the submerged part of the Coastal Plain in its immediate vicinity, whereas the beach sands of the adjacent headland areas were derived from the mainland itself.

Distributive Areas

For these source studies it was decided to delineate three general distributive areas along the New Jersey coast. A northern area from Bay Head to Monmouth Beach or, in other words, the area in which the headlands are subject to wave attack; a southern area between Bay Head and Cape May in which the beach is removed a distance of several miles from the mainland; and a bay area from Cape May to Reeds Beach providing another distributive headland area (Map I).

Sampling of Source Sediments

Samples were collected from geological formations in these provinces. Some of the samples were spot samples representing individual beds. Others were channel samples taken so as to contain equal amounts of material from each 1-foot section of a cleaned vertical outcrop surface.

Sample S-1 is located 125 feet south of Joline Avenue, on the beach at North Long Branch (Map I). Headlands are exposed toward the north and south in this area. A composite sample, below the soil, was collected from this exposure (Plate 12).

The following section was recorded:

3 ft.	Dune sand
1 ft.	Soil
2 ft.	Yellow sandy clay
1.5 ft.	Yellow pebbly clayey sand
1 ft.	Brown pebbly sand
1.2 ft.	Brown silty sand
1 ft.	Gray clay
1.2 ft.	Light yellow sand

A. Headlands at North Long Branch
Notice overlying dune.

B. Wave-cut scarp at West End.
Notice the weathered and unweathered part of this section.

PLATE 12

Johnson (18) maps this exposure as the Vincentown formation.

Sample S-5 is located 150 feet south of Brighton Avenue on the beach at West End (Map I). A 13-foot wave scarp is exposed at this locality (Plate 12). The vertical section of the outcrop may be described as follows:

1 ft.	Soil
6 ft.	Yellow pebbly sand
2 ft.	Yellow sand which grades into white sand at the bottom of the bed
3 ft.	White pebbly sand
3 ft.	White sand
2 ft.	Cross bedded white sand

According to Johnson (18), this exposure is part of the Cape May formation. A composite sample of this section was taken.

Sample S-6 was taken on the beach at the terminus of Brighton Avenue in Deal (Map I). A 16-foot scarp is exposed in this area (Plate 3). The following section was noted:

1.5 ft.	soil

14.5 ft.	Yellow-gray sand and clay (thin layers of gray clay separate yellow layer of sand)
.75 ft.	Brown pebbly sand

Johnson (18) maps this exposure as a part of the Shark River formation. A composite sample of this section was taken.

Sample S-8 is located on the beach at Essex Avenue in Spring Lake (Map I). A sewer trench uncovered this section, 5 feet below the surface.

2 ft.	Yellow pebbly sand

According to Johnson (18) this section is a part of the Cape May formation. A composite sample was collected.

Professor James H. C. Martens provided Samples S-10 and S-15 and the location and description of each sample was taken from his personal file.

Sample S-10 was taken from the mill of the New Jersey Pulverizing Company at Pinewald (Map I). The sand was pumped from a suction dredge, the coarser material (plus 1/2 inch) removed, and the undersize material was washed and dried. Professor Martens believes this deposit to be a part of the Cape May formation.

Sample S-15 was collected at Absecon, New Jersey on the southeast side of the railroad near the bay (Map I). The following bank section was exposed:

6 ft.	Yellow medium to fine sand, somewhat weathered subsoil zone
3.5 ft.	White to light yellow medium to coarse sand
3.5 ft.	Light gray fine to medium sand
1.7 ft.	White sand
0.2 ft.	Gray coarse sand
0.5 ft.	White fine sand
1.5 ft.	Nearly white very coarse pebbly sand
1 ft.	Light gray medium sand

A composite sample of the lower 12 feet of this section was saved. According to Johnson (18) this exposure is a part of the Cape May formation.

Sample S-19 is located on the beach at Higbee Beach (Map I). Outcrop is a 2.5 foot wave-cut scarp (Plate 10) and may be described as follows:

2.5 ft.	Dark yellow pebbly, clayey sand

Johnson maps this outcrop as a part of the Cape May formation. A composite sample of the vertical section was collected.

Sample S-20 was taken on the Cape May Canal, 380 feet west of the Bay Shore Road bridge near West Cape May (Map 1). A 13-foot section may be described as follows:

3 ft.	Yellow sand
7.5 ft.	Light gray sand interstratified with lenses of pebbles
2.5 ft.	Gray fine sand with thin streaks of black opaque minerals. Lenses of clay present. Cross bedding extremely complex

Johnson (18) maps this section as Cape May material. The bottom 2.5 feet were sampled.

Sample S-21 is located on the beach at Adelphia Avenue, Town Bank (Map I). Outcrop is 12-foot wave-cut cliff (Plate 10). The section may be described as follows:

6 ft.	Yellow pebbles and sand. Cross bedded in part. Lenses of pebbles pinch out irregularly.

2 ft.	Yellow sand with a few pebbles
4 ft.	Yellow pebbles and sand

This outcrop is a part of the Cape May formation according to Johnson (18). A sample of the 2 feet of yellow sand was collected.

Preparation of Samples for Laboratory Study

Source samples were prepared for mechanical and mineralogical analyses according to the methods described in a previous section.

Source for the Glauconite Mineral Zone

Along the northern part of the New Jersey coastal area, a series of overlapping geologic formations outcrop in the vicinity of the ocean beaches. These formations range from Cretaceous to Quaternary in age (Figure 10).

From Sandy Hook to Monmouth Beach the mainland is protected from direct wave action by a narrow bar and spit. Behind this barrier, Johnson (18) recognizes a number of unconsolidated Cretaceous formations containing variable sands and clays, glauconitic marls, and lignitic sands and clays; Tertiary formations (restricted to the Atlantic Highlands) of sand and glauconitic marl; and a Quaternary deposit of gravel and sand.

South of Monmouth Beach a series of formations are exposed directly to ocean wave attack. According to Johnson (18) these formations are the Hornerstown Marl (Eocene), outcropping adjacent to the beach from Monmouth Beach to North Long Branch and consisting of glauconitic marl; the Vincentown Sand (Eocene) occurring near the beach from North Long Branch to West End and containing glauconitic quartz sand; the Shark River-Manasquan Marl (Eocene) outcropping from West End to Asbury Park and composed of a mixture of glauconite and quartz sand, and fine clay. Between Asbury Park and Bay Head, the Kirkwood formation (Miocene) containing fine micaceous sand occurs in the immediate vicinity of the beach.

These older formations are overlapped along the coastline by a narrow belt of Quaternary and Recent deposits (Figure 10). Johnson (18) finds the Cape May formation (Quaternary), a deposit of gravel and sand, outcropping in a discontinuous pattern along the entire stretch of beach from Bay Head to Monmouth Beach. Between Shark River and Asbury Park, and West End and Monmouth Beach, Johnson shows (18) Recent beach deposits overlapping the older formations a distance of half a mile to a mile inland.

Composite samples were collected from several of these geologic formations which outcrop on the beach. These samples are S-1 from the Vincentown formation at

TABLE: 23 Mechanical Analyses of Source Samples - Part 1

Distribution by grade sizes (Mm.) in percent

Sample	6.680	4.780	3.360	2.380	1.680	1.190	.840	.590	.420	.297	.210	.149	.105	.074	.053	Pan
S-1	.7		.1	.2	.5	.8	2.1	3.8	6.8	14.3	13.9	8.0	3.1	1.7	1.3	42.8
S-5		2.3	1.6	1.9	1.4	1.9	3.1	6.2	14.3	40.6	23.4	3.2	.1			
S-6				.1	.4	2.1	5.2	7.0	12.0	23.9	18.6	8.4	4.5	3.3	1.2	13.3
S-8	.9	.3	.6	.8	1.5	2.8	7.4	14.5	21.6	26.5	13.1	4.5	1.0	.3		4.2
S-10							.5	6.8	18.7	24.1	18.3	23.6	7.1	.7		
S-15	.8	1.7	1.3	3.3	2.9	4.1	6.3	8.1	11.6	19.6	16.9	15.2	7.4	1.0		
S-19		.7	.7	1.8	1.9	2.2	3.0	7.1	17.1	17.0	10.8	14.1	6.9	1.6	.5	14.3
S-20			.2		.4	.1	.5	1.1	3.0	5.0	9.7	44.9	29.6	3.6	.3	1.8
S-21			.2	.6	1.0	2.2	5.0	8.7	12.8	17.4	21.8	28.4	1.4	.2	.1	

TABLE 23

Mechanical Analyses of Source Samples - Part 2

Derived Values

Sample	Q_3	Median Size	Q_1	So
S-1	--	.160	--	--
S-5	.484	.366	.287	1.30
S-6	.435	.297	.172	1.59
S-8	.638	.420	.308	1.44
S-10*				
S-15	.685	.351	.217	1.78
S-19	.500	.308	.160	1.77
S-20	.203	.168	.135	1.22
S-21	.500	.287	.197	1.59

*Derived values incomplete due to nature of sampling. (See p. 154)

TABLE 24

Heavy Minerals of Source Samples - Part 1 - Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
S-1	.210	10.84	10.71	.133	--	1.2
	.149	6.25	6.07	.177	--	2.8
	.105	2.39	2.27	.124	--	5.2
S-5	.210	17.29	17.28	.012	--	0.7
	.149	2.36	2.34	.025	--	1.1
	.105	.10	.09	.007	--	7.0
S-6	.210	9.76	9.70	.057	--	0.6
	.149	4.41	4.31	.102	--	2.3
	.105	2.39	2.32	.074	--	3.1

TABLE: 24 Heavy Minerals of Source Samples - Part 2
Frequency by Number

Sample	S-1			S-5			S-6		
Size (Mm.)	.210	.149	.105	.210	.149	.105	.210	.149	.105
Minerals	Per Cent								
Andalusite	2	1		4	2	x	4	1	1
Apatite						x	x		x
Chlorite				3			x		x
Diopside		x		x	x	1	2	1	x
Epidote	1	2	3	1		2	x	3	3
Garnet	1	2	2	1	2	13	14	9	6
Glauconite	46	35	3	11	1	3	2	1	
Hornblende		3	4	2	12	20		1	5
Hypersthene		1		x	1	4		1	1
Kyanite	3	2	1	3	6	4	2	1	1
Muscovite	x*	1	x	3	1	x	1	2	
Rutile	1	1	1		2	x	x	1	1
Sillimanite	1	2	1	4	2	1	1	2	1
Staurolite	18	12	5	11	21	8	22	14	4
Titanite						x		x	
Tourmaline	6	5	2	22	10	1	12	8	3
Tremolite						x			
Zircon	x	2	2		1	6	2	1	4
Chloritoid	1	1	1	1		1		1	x
Collaphane			x						
Monazite				x		x			
Biotite							x		
Blk. Opaques	8	23	50	7	20	27	27	42	61
Leucoxene	4	3	4	13	10	2	3	6	5
Miscellaneous**	8	5	20	13	8	4	7	5	3

Remarks:
*denotes trace
**Includes shell, composite, altered, and unknown grains.

TABLE 24

Heavy Minerals of Source Samples - Part 1 - Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
S-8	.210	7.22	7.17	.053	--	0.7
	.149	2.44	2.36	.084	--	3.4
	.105	.56	.50	.059	--	10.5
S-10	.210	7.94	7.89	.050	--	0.6
	.149	10.24	10.13	.110	--	1.1
	.105	3.07	2.94	.134	--	4.4
S-15	.149	8.37	8.27	.100	--	1.3
	.105	4.09	3.98	.110	--	2.7
S-19	.210	4.94	4.90	.042	--	0.8

TABLE: 24 Heavy Minerals of Source Samples - Part 2
Frequency by Number

Sample	S-8			S-10			S-15		S-19
Size (Mm.)	.210	.149	.105	.210	.149	.105	.149	.105	.210
Minerals	Per Cent								
Andalusite	x	1	1	x	1				1
Apatite							2	1	1
Chlorite									
Diopside	7	6	6						1
Epidote	1	1	3						x
Garnet	7	8	8	x	1			2	11
Glauconite	x								
Hornblende	2	2	6				x	1	1
Hypersthene	5	4	6					x	1
Kyanite	1	x	3	1	1	x		2	2
Muscovite			x	1			3	x	1
Rutile		x	1	1	1	1	1	1	x
Sillimanite	2	2	1	3	4	5	1	3	3
Staurolite	10	6	4	4	2	2	2	3	13
Titanite		x	x	x					
Tourmaline	7	5	3	6	3	2	3	1	11
Tremolite	1	x							
Zircon	1	2	2	2	2	3	2	5	1
Augite	1	x							
Chloritoid		1	1						x
Biotite								x	
Monazite									x
Blk. Opaques	38	50	49	64	68	77	76	71	46
Leucoxene	6	4	2	13	12	6	6	7	3
Miscellaneous	9	7	4	5	5	3	3	2	5

Remarks:

TABLE 24

Heavy Minerals of Source Samples - Part 1 - Weight and Percentage of Heavy Minerals

Sample	Size (Mm)	Weight (Gm)	Weight of Light Minerals (Gm)	Weight of Heavy Minerals (Gm)	Weight of Magnetite (Gm)	Heavy Minerals In Size Grade (Percent)
S-19	.149	6.46	5.39	.067	--	1.0
	.105	3.16	3.04	.117	--	3.7
S-20	.149	20.59	20.48	.110	--	0.5
	.105	13.53	12.90	.635	--	4.7
S-21	.149	13.94	13.85	.090	--	0.6
	.105	.71	.57	.140	--	20.0

TABLE: 24 Heavy Minerals of Source Samples - Part 2
Frequency by Number

Sample	S-19		S-20		S-21				
Size (Mm.)	.149	.105	.149	.105	.149	.105			
Minerals	Per Cent								
Andalusite	2	x	x	x	1	x			
Apatite									
Chlorite	2	4	11	4	1				
Diopside	x		2	5	x	x			
Epidote	1	5	1	3	1	2			
Garnet	3	3	8	9	2	5			
Glauconite									
Hornblende	2	5	15	23	2	7			
Hypersthene	1	1	5	10	1	2			
Kyanite		x	1	1	1	2			
Muscovite	1	2	4	2	1	1			
Rutile	1	1		x	1	2			
Sillimanite	4	3	3	2	5	3			
Staurolite	6	4	5	4	9	4			
Titanite									
Tourmaline	5	3	4	2	7	3			
Tremolite	x		1	1					
Zircon	5	4	1	2	1	3			
Monazite	x								
Chloritoid		1	1	1	1	1			
Biotite					x				
Blk. Opaques	60	56	24	23	51	61			
Leucoxene	4	3	5	2	8	3			
Miscellaneous	2	4	9	7	6	1			

Remarks:

North Long Branch; S-4 and S-5 from the Cape May formation at West End; S-6 from the Manasquan-Shark River formation at Deal; and S-8 from the Cape May formation at Spring Lake. Data on the textural and mineral analyses of these samples are presented in Tables 23 and 24.

A comparison of the grain size analyses of these source samples with those adjacent beach sands (Appendix II, Samples 5-29), reveals several interesting observations. First, the distribution of size grades in the sand fraction of each of these source samples is sufficient to adequately produce the textural components of the modern beach sands of the area. Second, most of these samples contain pebbles, granules, clay and silt in varying amounts. The presence of these sediment types accounts for the poorer sorting values of these samples. Although the coarser particles probably remain on the beach, the finer sediment is selectively removed by wave and current action (Table 23, Part 1).

In comparing the mineral composition of these source samples with those of the beach sands, it is well to remember that similar grade sizes of heavy minerals are used and therefore the composition of these sizes is subject to variations due to differences in texture and sorting.

The heavy mineral data for several grade sizes of source Samples S-1, S-5, S-6, and S-8 and beach Samples 14, 19, 24, and 29 are presented for comparison in Table 25. It will be noted that these samples, generally, have a smaller weight percentage of heavy minerals per grade size than the adjacent beach sands.

The distribution of heavy mineral frequencies in these source samples and beach sands is compared in Table 26. Sample S-1 has a relative distribution of heavy minerals which is similar, in a general way, to beach Samples 14 and 19; Sample S-5 has an abundance of leucoxene, tourmaline and hornblende but lacks the glauconite of the beach sands (Sample 19); Sample S-6 contains relatively more tourmaline but considerably less glauconite than the beach sands (Samples 19 and 24) and; Sample S-8 has only a trace of glauconite, while the beach sands (Sample 29) show a relatively large amount of this mineral.

The relative distribution of the light minerals (unsized fraction) from each of these source samples is presented for comparison with the beach sands in Table 27. Certain facts are apparent: (1) The total feldspar content of the source samples is similar to that of the adjacent beach sands (except Sample S-8), and (2) the glauconite content of Sample S-6 (Deal) has a similar distribution to that of the beach sands.

TABLE 25

Comparison of Percentages of Heavy Minerals of Source and Beach Samples in Glauconite Mineral Zone

Sample	Location	Percent Heavy Minerals Grade Size (Mm) .210	.149
14	Seabright	1.4	11.9
S-1	Long Branch	1.2	2.8
19	Long Branch	1.2	6.1
S-5	West End	0.7	1.1
S-6	Deal	9.6	2.3
24	Asbury Park	2.5	12.5
29	Spring Lake	0.3	3.0
S-8	Spring Lake	0.7	3.4

TABLE: 26 Number Frequencies of Heavy Minerals in Source and Beach Sands in Glauconite Zone

Sample	14		S-1		19		S-5		
Size (Mm.)	.210	.149	.210	.149	.210	.149	.210	.149	
Minerals	Per Cent								
Andalusite	3	x	2	1	4	2	4	2	
Apatite								x	
Chlorite	x*				1	x	3		
Diopside	1	x		x			x	x	
Epidote	2	4	1	2	2	5	1		
Garnet	3	7	1	2	4	7	1	2	
Glauconite	38	7	46	35	46	19	11	1	
Hornblende	6	3		3	2	1	2	12	
Hypersthene				1	x		x	1	
Kyanite	1	1	3	2	2	4	3	6	
Muscovite			x	1			3	1	
Rutile		1	1	1		1		2	
Sillimanite	1	x	1	2		1	4	2	
Staurolite	13	17	18	12	17	18	11	21	
Titanite									
Tourmaline	8	3	6	5	5	4	22	10	
Tremolite									
Zircon		4	x	2	x	1		1	
Chloritoid	1	1	1	1		2	1		
Collaphane	1	x							
Monazite							x		
Blk. Opaques	11	46	8	23	10	29	7	20	
Leucoxene	4	2	4	3	4	4	13	10	
Miscellaneous**	7	4	8	5	3	2	13	8	

Remarks:
*Denotes trace
**Includes shell, composite, altered, and unknown grains.

TABLE: 26 Number Frequencies of Heavy Minerals in Source and Beach Sands in Glauconite Zone

Sample	S-6		24		29		S-8		
Size (Mm.)	.210	.149	.210	.149	.210	.149	.210	.149	
Minerals	Per Cent								
Andalusite	4	1	1	2	4	2	1	1	
Apatite						x			
Chlorite	x			x	x	x			
Diopside	2	1	1	2	3	4	7	6	
Epidote	2	3		2		1	1	1	
Garnet	14	9	3	6	2	6	7	8	
Glauconite	2	1	47	9	40	11	x		
Hornblende		1	5	6	6	11	2	2	
Hypersthene		1	x	1	1	1	5	4	
Kyanite	2	1	2	3	1	1	1	x	
Muscovite	1	2		x					
Rutile	x	1		1				x	
Sillimanite	1	2	2	1	3	3	2	2	
Staurolite	22	14	11	14	7	6	10	6	
Titanite		x						x	
Tourmaline	12	8	5	x	3	1	7	5	
Tremolite							1	x	
Zircon	2	1		1		1	1	2	
Augite							1	x	
Chloritoid		1			x			1	
Biotite	x								
Collaphane			x		1	1			
Blk. Opaques	27	42	17	47	16	42	38	50	
Leucoxene	3	6	2	3	5	3	6	4	
Miscellaneous	7	5	4	2	7	3	9	7	

Remarks:

TABLE 27

Comparison of Light Minerals in Source Samples and Beach Sands in Glauconite Zone

Sample	Location	Percent by Number Quartz	Feldspar	Glauconite
14	Seabright	78	5	16
S-1	Long Branch	92	5	3
19	Long Branch	85	4	9
S-5	West End	95	1	4
S-6	Deal	86	4	10
24	Asbury Park	85	4	11
29	Spring Lake	92	3	5
S-8	Spring Lake	89	10	1

On the basis of the textural and mineral data it is believed that the subareal contributors for the littoral sediment are the Tertiary, Quaternary, and Recent formations which outcrop in the area between Asbury Park and Monmouth Beach. However, at the present time, due to the protective groins and sea walls, unrestricted erosion of this source material is limited to a series of unprotected areas at Deal, West End, and Long Branch (Map I).

Shark River could possibly contribute additional sediment from the interior, but this stream is extremely sluggish and its mouth would be completely closed by debris deposited by longshore currents if protective jetties were not maintained. Several bottom samples from the upper and lower parts of the river course were examined for mineral content in a qualitative manner. These samples showed that beach sand has been carried up the river about half a mile from the inlet, but no sand was found in the upper parts of the stream course which resembled the littoral sediment. Therefore, it must be concluded that Shark River contributes a negligible amount of sediment for the ocean beaches.

The high content of glauconite in the beach sands extends as far south as Shark River although the glauconitic bearing formations do not outcrop south of

Asbury Park (Figure 10). As the prevailing littoral drift is toward the north in this area, it is believed that northeasterly storms have been successful in moving large quantities of sediment southward along the beach. This phenomenon is not restricted to this particular area but is a regular part of the natural regimen of the littoral zone, so that the beach sands in all areas are actually moved up and down the shore, rather than in one definite direction. Thus, the termination of the glauconite mineral zone at Shark River seems to be coincidental rather than directly related to the influences of the river.

Because the actual contribution of the mainland either by direct attack of the waves or by stream transported material appears to be of meager volume, some additional source must be feeding the littoral drift in this area.

According to MacCarthy (28, p. 49), glauconite furnished the best evidence that offshore erosion supplies materials to the beaches. He believed the unworn glauconite grains found at Sandy Hook and other localities north of Monmouth Beach must have had a local derivation and these grains seem to prove that submarine erosion, with accompanying deposition upon the beach, is prevalent along this stretch of coast.

Recently the Beach Erosion Board (9) in cooperation with the U. S. Army, Corps of Engineers, New York District, completed an investigation of the use of dredged material deposited offshore to nourish the beaches in the vicinity of Long Branch. Sediment was placed in a ridge about half a mile from shore in 38 feet of water. The beaches and offshore areas were surveyed before, during, and after the dumping. The results show that the shoreline continued to recede, while the stockpile gained additional sediment. As Wicker (49, p. 18) remarks: "The conclusion is inescapable that the offshore stockpile did not nourish the beach."

In relation to this apparent fact, it should be noted that a large volume of fine sediment is probably transported by the longshore currents. However, as the beaches in this area have moderate slopes, most of the fine sediment carried up these inclinations will be selectively removed by the backwash.

There is some evidence that a very small amount of sediment has worked its way to the Sandy Hook littoral zone from the older underlying sea bottom. A peculiar variety of garnet containing a nucleus of inclusions and some magnetite, was found in all the offshore samples in the Sandy Hook area. These source minerals were also recorded in the Sandy Hook beach sands. It is believed that these minerals represent reworked glacial material which was undoubtedly distributed over the present Lower New York Bay bottom by the swollen Hudson River. As Sandy Hook developed this glacial material became mixed with the sediment transported from the mainland toward the south.

It should be evident from these findings that the only immediate source material for the beach sands of the glauconite mineral zone is the truncated headlands of Tertiary, Quaternary, and Recent formations which outcrop between Shark River and Monmouth. However, as the mineral glauconite is such an important constituent of these beach sands, it is believed that the Tertiary formations supply the greatest bulk of sediment for this zone.

Source for Black Opaque and Hornblende Mineral Zones

Between Bay Head and Cape May, the ocean beaches are separated from the mainland by a narrow marshy lagoon. Immediately adjacent to this lagoon, the geologic formations of the mainland overlap each other toward the northwest (Figure 10). According to Johnson (18), the youngest of these formations is the Cape May deposit (Quaternary) which is generally limited to the region bordering the lagoon south of Bay Head but extends irregularly up the various stream courses in the area, especially the Mullica and the Great Egg Harbor drainage basins. South of Tuckahoe, the Cape May gravel and sands have a much greater areal distribution, covering almost the entire southeastern corner of the state and extending as a belt along the shoreline of Delaware Bay. Older patches of Quaternary gravel and sands are widely scattered over the mainland surface in the vicinity of the coastline. These deposits overlie the quartz sands of the Cohansey formation (Miocene) which have the largest areal distribution of any Coastal Plain formation.

Samples were collected from the Cape May formation at several points along the mainland from Bay Head to the shores of Delaware Bay. These samples are S-10 from Pinewald; S-15 from Absecon; S-19 from Higbee Beach; S-20 from the Cape May Canal, near Cape May; and S-21 from Town Bank. The results of textural and mineral analyses of these samples are presented in Tables 23 and 24.

In comparing the grain size analyses of these source samples with those of adjacent beach sands (Samples 44-142, Appendix II), it should be noted that the source samples are either composite samples covering a number of feet of an outcrop or restricted samples of a sediment unit which are not truly representative of the total section. Therefore, it is believed that these textural data have limited value for comparative purposes. In general, these source samples show the dominance of medium sand in the sections sampled along this part of the coast. This statement does not imply complete absence of fine sand but rather predominance of coarser sand in the surface deposits of Cape May formation which were sampled. These source samples do not show changes in texture from Bay Head to Cape May which characterize the modern beach deposits. However, a sample of fine sand was secured along the Cape May Canal and this sand is comparable in texture to that sand found along the littoral zone of southern New Jersey.

The percentages of heavy minerals in sands of the Cape May formation are listed with those of selected beach samples in Table 28. In general, the beach sands show a greater concentration of heavy minerals in the finer size of each group than the adjacent source samples. Sample S-20, a fine sand, is similar to Sample 122 which is also a fine sand.

Heavy mineral frequencies of the source samples are presented in Table 24. The distribution of the heavy minerals in these source samples and selected beach sands are compared in Table 29. First, it will be noted that the source samples (S-8, S-10, S-15, S-19 and S-21) have high proportions of black opaques; that S-10 and S-15 are particularly barren of variety in other mineral species; and that Sample S-20, a fine sand, contains significant quantities of a greater variety of minerals. Second, the ocean beach sands (Samples 44 and 64) have relatively large amounts of black opaques and show greater variety and persistence of other mineral species than either S-10

TABLE 28

Comparison of Percentages of Heavy Minerals of Source and Beach Samples in Black Opaque and Hornblende Zones

Sample	Location	Percent Heavy Minerals Grade Size (Mm) 0.210	0.149	0.105
S-8	Spring Lake	0.7	3.4	--
44	Sea Side Park	0.2	13.3	--
S-10	Pinewald	0.6	1.1	
64	Surf City	0.5	9.7	--
83	Brigantine	--	1.3	11.8
S-15	Absecon	--	1.3	2.7
122	Wildewood	--	0.6	5.4
S-20	Cape May	--	0.5	4.7
130	Cape May	--	1.4	15.3
S-19	Higbee Beach	0.8	1.0	--
137	Town Bank	1.6	2.5	--
S-21	Town Bank	--	0.6	--
142	Norburys Landing	1.2	4.7	--

TABLE: 29 Number Frequencies of Heavy Minerals in Source and Beach Sands in Black Opaque and Hornblende Zones

Sample	S-8		44		S-10		64		83
Size (Mm.)	.210	.149	.210	.149	.210	.149	.210	.149	.149
Minerals	Per Cent								
Andalusite	1	1	2	1	x	1	1	1	x
Apatite									x
Chlorite			x*				1	1	2
Diopside	7	6	2	2			2	2	3
Epidote	1	1	x	1			1	2	3
Garnet	7	8	1	5	x	1	3	6	3
Glauconite	x		14	8			1	1	
Hornblende	2	2	7	7			6	11	36
Hypersthene	5	4	1	2			1	1	3
Kyanite	1	x	2	2	1	1	2	2	
Muscovite					1		1		3
Rutile		x	x	1	1	1	x		
Sillimanite	2	2	2	1	3	4	3	3	2
Staurolite	10	6	6	7	4	2	11	5	1
Titanite		x		x	x			1	
Tourmaline	7	5	6	1	6	3	10	3	1
Tremolite	1	x							1
Zircon	1	2	2	1	2	2		1	1
Chloritoid	1	1		1				1	x
Blk. Opaques	38	50	38	50	64	68	43	55	17
Leucoxene	6	4	9	6	13	12	8	3	2
Miscellaneous**	9	7	8	3	5	5	5	1	18

Remarks:
*Denotes trace
**Includes shell, composite, altered, and unknown grains.

TABLE: 29 Number Frequencies of Heavy Minerals in Source and Beach Sands in Black Opaque and Hornblende Zones

Sample	83	S-15		122		S-20		130	
Size (Mm.)	.105	.149	.105	.149	.105	.149	.105	.149	.105
Minerals	Per Cent								
Andalusite	x			x		x	x	x	x
Apatite	x				1			x	1
Chlorite	x	2		5	1	11	4	x	
Diopside	4		1	4	4	2	5	3	4
Epidote	5			3	6	1	3	4	7
Garnet	9		2	3	6	8	9	7	11
Glauconite				1	x				
Hornblende	53	x	1	38	57	15	23	36	46
Hypersthene	5		x	3	4	5	10	4	4
Kyanite	x		2			1	1	x	
Muscovite	x	3	x	6	x	4	2		
Rutile		1	1				x		
Sillimanite	2	1	3	2	1	3	2	5	2
Staurolite	x	2	3	x	1	5	4	2	x
Titanite	1			x	x			x	1
Tourmaline	1	3	1	x	x	4	2	3	1
Tremolite	1			1	2	1	1	2	1
Zircon	1	2	5		x	1	2	2	1
Chloritoid	x			x	x	1	1	x	1
Blk. Opaques	7	76	71	7	5	24	23	16	16
Leucoxene	2	6	7	2	1	5	2	5	1
Miscellaneous	6	3	2	20	9	9	7	9	3

Remarks:

TABLE: 29 Number Frequencies of Heavy Minerals in Source and Beach Sands in Black Opaque and Hornblende Zones

Sample	S-19		137		S-21	142			
Size (Mm.)	.210	.149	.210	.149	.149	.210	.149		
Minerals	Per Cent								
Andalusite	1	2	2	1	1	1	x		
Apatite									
Chlorite	1	2	1	1	1	x	x		
Diopside	1	x	1	2	x				
Epidote	x	1	x	1	1		x		
Garnet	11	3	4	6	2	2	x		
Glauconite									
Hornblende	1	2	3	9	2	x	2		
Hypersthene	1	1	2	1	1	x	x		
Kyanite	2		2	1	1	1	2		
Muscovite	1	1		x	1				
Rutile	x	1	x	x	1	1	1		
Sillimanite	3	4	1	1	5	3	2		
Staurolite	13	6	10	4	9	9	7		
Titanite			x						
Tourmaline	11	5	3	1	7	5	1		
Tremolite						x			
Zircon	1	5	2	7	1	7	5		
Chloritoid	x								
Blk. Opaques	46	60	62	58	51	64	75		
Leucoxene	3	4	3	3	8	2	2		
Miscellaneous	5	2	2	3	6	4	2		

Remarks:

or S-15. Third, the ocean beach sands (83, 122, and 130) show no similarity with S-15 but show a degree of similarity with S-20, although this source sample contains less hornblende and slightly larger proportion of black opaques than the adjacent beach sands. Fourth, the Delaware beach sands are similar in composition to S-19 and S-21.

One fact seems apparent from a study of these samples of the Cape May formation: There is a greater variety and number of heavy mineral species present at the extreme ends of this line of samples (S-8 and S-19, S-20 and S-21) than associated with those samples which were collected toward the middle of the traverse. It is believed that this fact is directly related to the character of the source material available for deposition during Cape May time in different parts of the state.

A comparison of the distribution of light minerals in these same beach and source samples is presented in Table 30. The feldspar in S-10 and S-15 is similar to the ocean beach sands (44 and 64); Sample S-20 shows a proportion of feldspar that resembles the beach sands of southern New Jersey; and along Delaware Bay, the source and beach samples have comparable feldspar content.

Any similarities between these possible mainland source areas and the adjacent beach sands should be evident. Samples S-8, and possibly S-10 and S-15, have

TABLE 30

Comparison of Light Minerals in Source and Beach Samples in Black Opaque and Hornblende Zones

Sample	Location	Percent by Number Quartz	Feldspar	Glauconite
S-8	Spring Lake	89	10	1
44*	Sea Side Park	96	3	x
S-10	Pinewald	99	x**	
64*	Surf City	96	4	x
83	Brigantine	83	16	
S-15*	Absecon	98	2	
122	Wildwood	78	22	
S-20	Cape May	85	12	2
130	Cape May	90	10	
S-19	Higbee Beach	95	5	
137*	Town Bank	99	1	
S-21*	Town Bank	98	2	
142*	Norburys Landing	99	x	

*Minus 0.420 mm. size.
**Denotes trace.

heavy and light mineral compositions which could probably produce uncontaminated beach sands comparable to those found from Shark River to Beach Haven (Samples 29-74). In addition, Samples S-19 and S-21 could easily yield the proportion of minerals occurring in the beach sands along Delaware Bay (Samples 137 and 142).

Along the Atlantic seaboard, the possible subareal source contributors are restricted to the mainland areas of Cape May formation between Shark River and Bay Head and in the vicinity of Cape May since a series of barrier bars guard the headlands. In addition, the streams which drain the interior are sluggish and the great majority of these courses do not flow directly into the ocean. It is believed that the Delaware Bay shore littoral sediment is mainly supplied by the Cape May formation which outcrops almost continuously along the bay from Cape May to Reeds Beach.

It is apparent that the major contributor of sediment for the black opaque (except the area between Shark River and Bay Head) and hornblende mineral zones of the ocean beaches cannot be located on the subareal portion of the Coastal Plain. The only alternative must be the continental shelf. Since this portion of the Coastal Plain is receiving only a very small amount of new sediment, the character of the subaqueous deposits should be directly related to the present day beach sands.

Richards (36) studied the subsurface stratigraphy of the Atlantic Coastal Plain from logs and samples of a number of wells. His findings concerning the nature of the underlying formations in southern New Jersey will be briefly summarized.

According to Richards (36, pp. 896-897), the wells at Seaside Park, Beach Haven, Atlantic City, Ocean City, Avalon, Wildwood, and Cape May show that the Cape May formation, a deposit of sand and shell with some gravel and clay, occupies the uppermost 75 to 130 feet of each well section, underlain by varying thicknesses of Quaternary (?) and older Tertiary formations. From these data, it is apparent that the Cape May formation has a considerable thickness along the landward margin of the state south to Point Pleasant.

Evidence concerning the mineral composition of the surface subaqueous material may be found in mineralogical analyses of the offshore samples. (Little Egg Inlet and Cold Springs Harbor, B-51-B-83). Although the ocean bottom samples are too few in number and are too close to shore to reveal the general character of the bottom on the continental shelf, these samples do show a range in texture and composition (Appendix V and Table 18) which is definitely absent in the mainland Cape May samples (Samples S-8 - S-21).

In addition, it will be recalled that the character of sediment dredged at several points in Barnegat Bay was found to be comparable in texture and mineral composition to material sampled at certain beach and offshore localities in southern New Jersey. As the Barnegat Bay sediment was originally derived from the near shore portion of the continental shelf and transported into the bay by wind and currents, it is possible that this shelf area represents a pattern of texture and composition typical of the areas toward the south.

On the basis of the mineralogy of the mainland and subaqueous phases of these possible source areas, it is evident that the mineral composition of the so-called Cape May deposit varies quite noticeably. In view of this apparent fact, it is believed that the surface sediment of the continental shelf adjacent to the southern shore of New Jersey is not a simple repetition of the Cape May material which outcrops on the mainland. If this is a valid assumption, it appears that a more recent influx of sediment was transported to this portion of the continental shelf following the conclusion of typical Cape May sedimentation.

The validity of this supposition has support in the findings of MacClintock and Richards (29, pp.307-309) in their study of the Pleistocene formations of New Jersey.

On the basis of this work Kummel (25, p. 160) states:

> "Sand and gravel terraces along the Delaware River head in the terminal moraine of the Wisconsin glacial stage and can be traced without serious interruption to Trenton, and farther south. Moreover, below Trenton these glacial terraces apparently merge with those which are continuous with the marine terraces along Delaware Bay. The glacially derived material is progressively less below Trenton, but it has been found at intervals as far south as Penns Grove, although the greater bulk of the material of the terraces is gravel and sand characteristic of the Coastal Plain streams, which had no glacial connections and no access to northerly derived material."

It should be noted that MacClintock and Richards (29, p. 308) found notable occurrence of igneous material in the glacial material as far south as Penns Grove.

Kummel (25, p. 161) continues:

> "These facts have led MacClintock and Richards to assume that after deposition in pre-Wisconsin interglacial time, the Cape May formation was partially removed from the Delaware Valley below Trenton before the Wisconsin ice sheet reached its maximum advance. The river was bordered by terraces of typical Cape May gravel, which were more or less cut into by the floods arising from the melting ice. Coastal plain material was thus added to that brought down by the Delaware and the intermingling of material which we now find resulted. According to this hypothesis the terraces now bordering the Delaware below Trenton are composed of Cape May material (interglacial) more or less reworked and redeposited in late Wisconsin time, plus a diminishing amount of glacial material derived from the Wisconsin ice sheet. Post-Wisconsin erosion has removed a large part of the glacial and pre-glacial filling and developed the present terraces."

In conclusion MacClintock and Richards {29, p. 335) believe that the Cape May formation as originally mapped is two-fold, consisting of an interglacial deposit and a deposit of outwash gravels that were carried down the Delaware River and mixed with the older interglacial deposit. It is their belief that the name, Cape May, should be restricted to interglacial sediments.

It seems logical to assume that as a result of the Wisconsin ice sheet and subsequent post-glacial erosion, large quantities of sand and mud reached lower Delaware Bay and the adjacent continental shelf areas. This sediment was either mixed with the older Cape May material or was deposited directly on the surface of the Cape May. As the ocean advanced following the recession of the ice, the surface sediment was subjected to vigorous reworking by wave and current action. It is probable that this action was instrumental in spreading the finer sediment of glacial material over wide areas on the continental shelf. As a result the sediment types in this region on the shelf are either (1) a mixture of glacial and older sediment, (2) essentially glacial material or (3) essentially older Cape May sediment. Further, it is believed that the sediments in this offshore region offer the only source material available for ocean beaches south of Bay Head.

During the evolution of the present shoreline these dissimilar sediments, the older mature material of the Cape May and the more recent immature glacial material, became a part of the shoreline features. The mechanism responsible for this result functioned from the inception of the offshore bar. As waves approached the shoreline and broke, material was thrown into suspension; some of the sediment was carried directly up the beach slope where the coarsest fraction was deposited, with most of the finer material being returned by the backwash; while other sediment was moved directly by the longshore currents. In the sorting action, the finer fraction was selectively reworked by the near shore currents which either carried the sediment down the beach as drift where it was eventually deposited in a lagoon or on the beach, or transported the material seaward to deeper water. As the barrier bar slowly migrated landward, the eroded bottom sediment of the lagoon became available for this same current and wave action.

The wave-breaking zone, or a zone in which large quantities of sand are thrown into suspension, is quite variable along any coastline. According to the Beach Erosion Board (7, p. 11), a 2.5 foot swell will increase in height to about 5 feet by the time it reaches a water depth of 9 feet, at which depth it will break. As Wicker

(49, p. 8) has shown that the waves along the New Jersey coast are similar in their height characteristics, about 90 percent being 4 feet or less in height, it is possible that the wave-breaking zone may extend half a mile or more offshore at some places.

Along the shore between Bay Head and Little Egg Inlet, the coarse Cape May sediment dominates the littoral sediment with the finer glacial material confined, for the most part, to Barnegat Bay. As the barrier bar regresses this finer material becomes subject to current, wave, and wind action once again. It may be carried either as beach drift or it may be transported away from the shore to deep water, or it may be carried back into the lagoon.

The beach sands along the southern shore are composed essentially of the fine glacial sands, with the adjacent lagoon containing finer sediment of this same material. Although some material was added to these beach sands as drift from the north, it is believed that the bulk of this littoral sediment was derived principally from local offshore areas during earlier development.

What principle produced these two mineral zones? Theoretically there is no reason why selective sorting could not account for these zones. However, several factors should be considered which modify the mechanics of this simple process. First, the Bay Head-Beach Haven area is generally more stable than any other area along the coast. Second, the offshore slope of the bottom surface between Little Egg Inlet and Cape May is much more gradual than that toward the north. It is believed that these present conditions are similar to those in the past. This means that only a minimum of sediment has reached, or is reaching, these southern beaches from the north and, therefore, local offshore areas must have served primarily as the source. In addition, it is well known that the texture of a beach is determined in part by the depth of water offshore. This apparent fact suggests that (1) the southern beaches were formed of fine sands because of the configuration of the offshore profile and (2) these fine sands were essentially of more recent origin.

This general explanation may be proposed to account for the development of the black opaque and hornblende mineral zones, previously described, which are obviously dissimilar in composition (results of hydraulic ratios, Figure 7), but which lie adjacent to one another along the beach.

The present day source for the beach sands in this area (Bay Head-Cape May) is local. Therefore, all beach nourishment must be obtained in the vicinity of the beach itself. The beach-building material is derived from a reworking of bottom sediment in the immediate vicinity of protective bars and the sands moved by the drift.

Neither source is sufficient to provide an adequate volume of debris to stabilize this coastal area over long periods of time. Thus the ocean will continue to extend its domain at the expense of the landward margin of the state. The Beach Erosion Board (8, 5/40) and Wicker (49, p. 7) present similar conclusions.

TRANSPORTATION AND DEPOSITION OF HEAVY MINERALS

General Statement

The fundamental principles which govern the transportation and deposition of clastic sediment in a beach environment have not been clearly understood or even recognized, because the comprehensive data needed to provide such an understanding has not been available. It has been tacitly assumed that the factors which control the distribution of sands in a fluvial environment would be applicable with some modification to littoral sediments. Was this assumption justified?

Basically, the correlation of adjacent beach samples was dependent on the validity of the underlying principles which affected the size distribution of light and heavy minerals in the Rio Grande River. These principles were developed by Rittenhouse (39) and were utilized in the determination of modern source sediments in the middle Rio Grande Valley.

Rittenhouse (39, p. 1739) formulated his basic laws of sediment transportation and deposition by noting the relationship in size distribution of various minerals in a single sample and several related samples. To illustrate differences in size distribution by weight of various minerals within a single sample, cumulative curves of a number of minerals were plotted. From these curves several facts were apparent: (1) The size distributions of the heavy minerals form smooth cumulative curves of the same general shape as the cumulative curve of the light minerals; (2) all heavy minerals are finer in texture than the light minerals; (3) in general, increasing specific gravity is accompanied by increasing fineness of the heavy minerals; (4) zircon (sp. gr. = 4.6) is much finer than magnetite (sp. gr. = 5.2); and (5) difference in slope of the curves indicates that heavy minerals in the same sample have different sorting. By using the same method, the size distribution of a number of minerals of several samples was compared. It was noted that differences in average size and degree of sorting of the light minerals were accompanied by consistent differences in the distribution of the heavy mineral assemblage. For example, the sample with the coarsest light minerals contained the coarsest heavy minerals, and the sample which had the finest light fraction also had the finest heavy fraction; or when two samples had the same median size, the sample with the best sorting contained the finest heavy mineral species.

Rittenhouse (39, p. 1778) deduced certain fundamental factors which he believed controlled the differences noted in the size distribution of light and heavy minerals within a single sample and the systematic variations in the distribution of these minerals between samples of differing average site and degree of sorting. These factors were, namely: (1) the hydraulic conditions, which vary with time and position, (2) the hydraulic equivalent size which is closely related to density, (5) the relative availability for deposit of the different sizes of each mineral, and (4) some factor or factors now unknown.

Review of Some Underlying Principles of Hydraulic Ratios

Size Frequency Distributions of Light and Heavy Minerals

Basically, the attributes of size, shape, and density produce variations in the mineral composition of a sediment. Under given hydraulic conditions, these factors determine which particles will be transported and which will be deposited. It is generally agreed that the shape factor is of least importance, although in deposits containing large quantities of micaceous minerals this factor must be recognized. However, the relative importance of size and density in the distribution of various minerals is still a moot question. It is essential, therefore, that the effect of size and density on the sorting of littoral sediments be examined on the basis of quantitative data before any conclusions are drawn as to the relative importance of either factor for this particular environment.

The size distribution by weight of some important heavy minerals and of the light fraction as a whole are presented for three representative beach samples (Figure 11). In most cases, these minerals were selected because they made up a significant percentage by weight of the heavy mineral fraction and therefore are subject to the smallest counting errors.

Same sample.

An inspection of each individual sample reveals certain apparent facts: (1) The size distribution of the heavy minerals form cumulative curves of the same general shape as the cumulative curves of the light minerals; (2) all these heavy minerals are finer in texture than the light minerals; (3) differences in slope of the curves indicate that heavy minerals in the same sample have different sorting; (4) no clear cut relationship exists between density and fineness.

Different samples.

An examination of the influence of average size and degree of sorting on the mineral distribution reveals certain variations (Figure 11). For instance, the sample with the finest light minerals also contains the finest

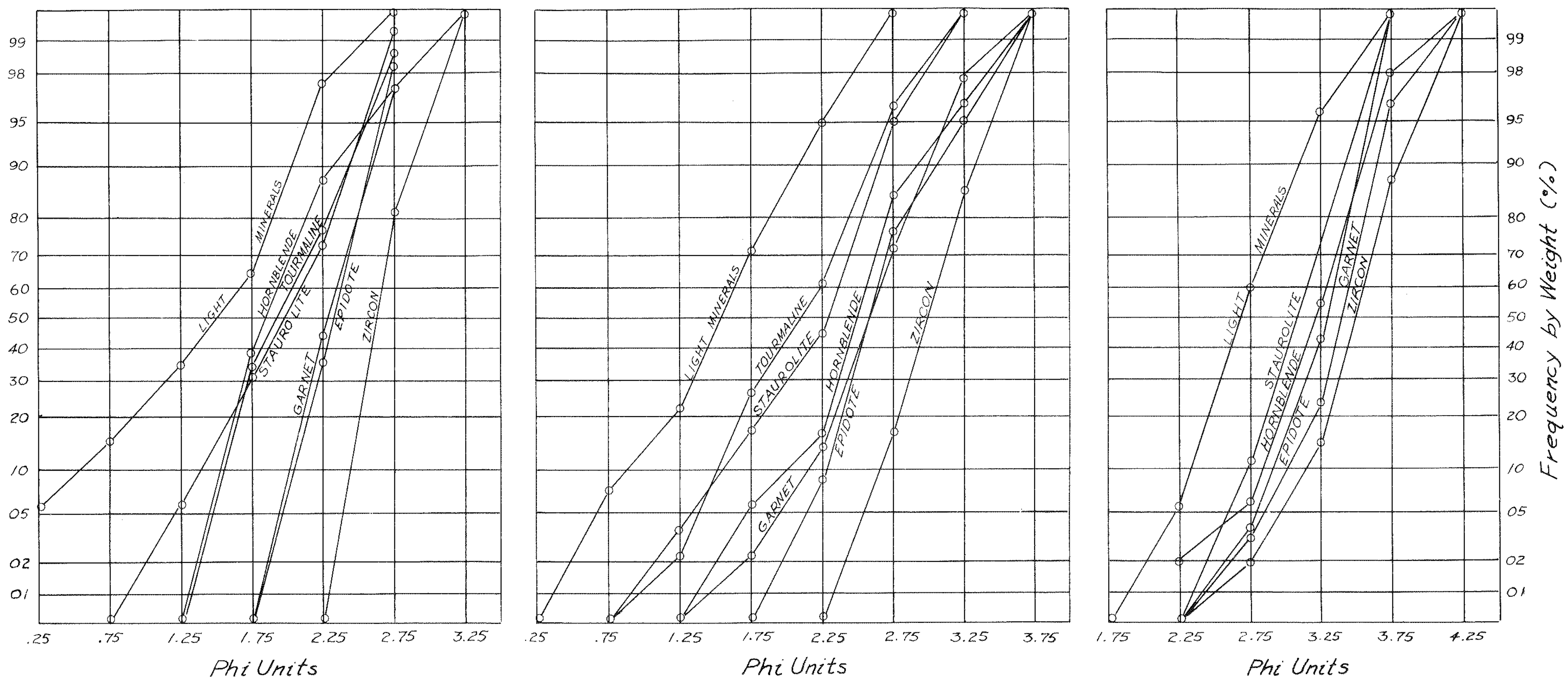


Figure 11

Size Distribution by Weight of Light and Selected Heavy Minerals

heavy fraction. In addition, the relative position of the various heavy minerals is not similar in each of the three samples, but shows considerable difference from place to place along the beach. What factors are responsible for these variations in size distribution?

Possible Factors Controlling Heavy Mineral Distribution

As indicated previously, Rittenhouse (39, p. 1743), on the basis of differences noted in the sorting of various minerals within a single sample and systematic variations observed in the mineral distribution between samples, formulated three principles, namely, hydraulic conditions, hydraulic equivalent size, and relative availability, which he believed affected the size distribution of various heavy and light minerals. These principles are the foundation on which hydraulic ratios are determined. A brief examination of each of these factors is necessary in order to determine their relative influence in the beach environment.

Hydraulic Conditions

There seems little doubt that hydraulic conditions as developed by oceanic processes have a prime effect on the distribution of minerals in a littoral environment. For example, the depth of water offshore and direction and strength of currents and waves will undoubtedly cause variations in texture and in mineral composition. In addition, the configuration and roughness of the beach will contribute to the variations in hydraulic conditions from place to place along the beach.

Turbulent flow is a common feature of wave action along the foreshore of the shore. Therefore, it should be evident that turbulence plays a significant role in the transportation and deposition of material in this zone.

Hydraulic Equivalent Size

Basically, it was assumed that under given hydraulic conditions, light minerals of a certain size will be deposited with heavy minerals of smaller size so that differences in size are compensated by differences in density. Thus, the light and heavy minerals are hydraulically equivalent. If more light minerals are transported as wave action becomes more violent, more heavies of hydraulic equivalent size will be transported; if coarser light minerals are transported, coarser heavy minerals should also be transported. Rittenhouse (39, p. 1759) found no definite evidence concerning a change of hydraulic equivalent size with different sizes.

In Table 31 hydraulic equivalent sizes for various minerals have been computed for several textural types of beach sand. These best values signify the size

TABLE 31

Hydraulic Equivalent Sizes for Various Minerals

Mineral	S.G.	Monmouth Beach Grade Size(Mm) .297 φ	.210 φ	.149 φ	Bigantine Grade Size (Mm) .149 φ	.105 φ	.074 φ	Avg. Best Value
Zircon	4.7	--	1.1	1.0	--	.6	1.0	.9
Opaques	4.1	.4	1.0	.7	.2	.6	1.0	.6
Garnet	3.8	--	1.2	.6	.1	.4	.6	.6
Leucoxene	3.8	--	.6	.1	.0	.1	--	.4
Staurolite	3.7	.4	1.1	.8	.3	--	--	.6
Hypersthene	3.4	--	--	--	.1	.5	.0	.2
Epidote	3.4	--	--	.2	--	.4	.4	.3
Diopside	3.3	--	--	--	.0	.0	.1	.0
Hornblende	3.2	--	--	.5	.0	.1	.0	.1
Sillimanite	3.2	--	--	--	.1	.5	.0	.2
Tourmaline	3.1	--	.8	.2	.0	.5	--	.4
Glauconite	2.9	.0	.0	.4	--	--	--	.1

of larger quartz[1], in $\sqrt{2}$ grades, with which each heavy mineral is deposited. In other words, zircon in the 0.210 mm.-0.149 mm. size is deposited with quartz almost $\sqrt{2}$ grade sizes larger. Although the average best values of each mineral seem to show a general relationship between density and equivalent size, a close inspection of the individual best value for the various sizes in each area indicates a wide range of values for most minerals. Because the exact nature of leucoxene and opaques is in doubt, these minerals were not considered in this analysis. Apparently the variations in hydraulic equivalent sizes are not systematic and are not related to some simple factor.

It is possible that these irregularities in equivalent values are caused by (1) complex variations which result from the interrelationship of natural processes, (2) sampling errors, in that more than one sediment unit is represented, and (3) laboratory errors, especially counting.

It should be noted that basically the processes which affect the shore area may be ascribed to wave, current, and wind action. Waves and currents are instrumental in selectively shifting material along the foreshore

[1]Quartz is used as the reference mineral for the light fraction because of its abundance.

and wind action tends to remove the finer sediment from the exposed portion of the beach. However, these agents do not show the same work efficiency at every point on the foreshore because of their nature and the irregularities in configuration of the coastal area. For example, a large wave may send a great volume of turbulent water rushing up the beach at one point, but at an adjacent station the effective force has been greatly reduced. As a result the mineral distribution may be somewhat different at each point on the foreshore. By visualizing the net effect of each of these agents in shifting and reworking littoral material as the shoreline advances and recedes and the constant changing conditions of effectiveness which accompany each process as climatic and oceanographic conditions vary, it is evident that the proportion of minerals concentrated at any particular spot will show some variation from place to place along the beach. Therefore, it is probable that these processes and their interrelationship may account, in part, for the irregularities in hydraulic equivalent sizes noted in this investigation.

Relative Availability

The concept of relative availability may be illustrated briefly. Under given hydraulic conditions, certain larger light minerals will be deposited with heavy minerals of smaller size. If the current is increased, more light minerals are transported with more heavy minerals of hydraulic equivalent size; if coarser light minerals are transported, coarser heavy minerals will be transported. This, the relative availability for each grade size is constant.

Material available for deposition is directly dependent on (1) the nature and size distribution of minerals within the parent rock, (2) the character of weathering at the source, and (3) the abrasion history during transportation. Certain minerals, Pettijohn states (34, p. 428), "particularly apatite, zircon, and sphene are of much smaller size in the parent rock from which they come than others, such as hypersthene, hornblende, and the like. They may not occur, therefore, in the coarser grades at all--none being available for deposit--and they may 'flood' the finest-size classes". Martens (30, p. 1588) believes that zircon, rutile, and ilmenite usually occur in igneous and metamorphic rocks in grains which are small compared with those of staurolite, garnet, and kyanite. Rittenhouse (39, p. 1761) also recognized that the relative availability of most heavy minerals of the Rio Grande was lower in the coarsest grades than in some fine sizes and he attributed the fact to the absence of the larger sizes in the source rocks. Russell (40, p. 1335) came to similar conclusions on zircon, titanite, rutile and monazite in the finer sands of the lower Mississippi River. It seems only logical as Martens states (30, p. 1586):

> "....that differences in size-distribution of different minerals at the source may be as important as any of the other factors causing sands of different coarseness, derived from the same source, to have different relative amounts of heavy minerals."

The character of weathering at the source is also an important factor. The exact effect of weathering will depend on the nature of the parent rock, the climate, and the relief of the area. Thus, the material at the source may undergo considerable alteration before transportation begins.

The availability is also dependent upon the abrasion history of the sediment during transportation. According to Pettijohn (34, p. 428), the larger, softer, and more dense minerals tend to be abraded or reduced more rapidly than those with opposite characteristics. Therefore, sands which have been subjected to repeated cycles of transportation and deposition would probably show the effect of appreciable abrasion.

In the last analysis, the net effect of the kind, amount and distribution of minerals in source rocks; the weathering at the source; and the abrasion history during transportation, determine the character of the sediment available for deposition. Under these conditions, a constant relative availability for deposit of the different sizes of each mineral is most unlikely.

CONCLUSIONS

Texture

(1) The median size of New Jersey ocean and bay beach samples shows a range of values. Coarse sand is found from Spring Lake to Bay Head and along the Delaware Bay shore; medium sand is abundant between Spring Lake and Sandy Hook Point, Bay Head and Tucker Island, and Cape May and Town Bank; and all the fine sand occurs between Pullen Island and Cape May.

(2) Coarse and medium sands are restricted to gentle and moderate inclined foreshores. Fine sands occur on nearly flat foreshores.

(3) Ocean beach sands show a decrease in size toward the north and south of the Point Pleasant area. In the vicinity of Sandy Hook and Cape May, this tendency is reversed and the sands grow coarser.

(4) Although there is a trend of decreasing size in the direction of littoral current movement over most of the New Jersey shore, there is no evidence that selective sorting is the primary mechanism. It is believed that beach texture is determined largely by exposure to wave attack and depth of the water offshore. However, in the vicinity of Sandy Hook and Cape May, increased current activity may account partially for the coarser sands.

(5) Sorting by waves and currents produces a well-sorted deposit. Coefficient of sorting values range between 1.10 and 1.40.

(6) Sorting and skewness are a function of median diameter. The best sorted and least skewed sands are fine sands.

(7) There is no definite trend in particle size gradation from the beaches to the continental shelf, although decreasing median diameters seaward were found in lower New York Bay and Delaware Bay.

(8) Variations in size of these continental shelf sediments are unrelated to depth of water or distance offshore.

(9) Generally, the nearshore bottom sediments show a patchy arrangement of coarse and fine material similar to that found at greater distances offshore.

Mineralogy

(1) On the basis of mineralogy, four areas of dissimilar mineral composition are established along the ocean and bay beaches. These areas extend from (a) Sandy Hook to Shark River (glauconite zone), (b) Shark River to Little Egg Inlet (black opaque zone), (c) Little Egg Inlet to Cape May (hornblende zone), and (d) Cape May to Reeds Beach (black opaque zone).

(2) The nearshore bottom sediments contain a mineral assemblage similar to that found on the beaches.

(3) The mineral distribution in Barnegat Bay sediments is comparable to that of offshore, beach and Delaware Bay sediments in the coastal region of southern New Jersey.

(4) The greatest percentage of heavy minerals and greatest abundance of feldspar are found in the fine beach sands, whereas the coarse and medium sands contain the smallest amounts of these minerals.

Origin of Beach Sands

(1) The ultimate source of the New Jersey beach sands is the Appalachian Province, particularly the sedimentary, metamorphic and igneous rock complex of the Piedmont and Highlands. In addition,several minerals of Coastal Plain origin, especially glauconite, occur in these littoral sediments.

(2) The immediate source material for the beach sands of the glauconite zone (Sandy Hook to Shark River) is the Tertiary, Quaternary, and Recent formations of the mainland. As glauconite is an abundant constituent in these sands, the Tertiary formations, which occur between Asbury Park and Monmouth, supply the greatest volume of sediment. This source material is moved predominately

toward the north by shore current although northerly storms have succeeded in moving large quantities southward as far as Shark River.

(3) The major contributor for the beach area between Shark River and Bay Head (northern part of the black opaque zone) is the Cape May formation which outcrops along the beach.

(4) The only source for the beaches between Bay Head and Cape May is the sediments of the continental shelf. In this region, these sediments are either (a) Cape May material, (b) more recently glacially derived sediment, or (c) a mixture of these two deposits. During the evolution of the present shoreline these sediments became a part of the shoreline features. The coarser Cape May material dominates the littoral sediment between Bay Head and Little Egg Inlet (the black opaque zone), whereas the beach sands along the southern shore are composed essentially of the fine glacial sands (the hornblende zone). The gradual offshore slope of the ocean bottom may be responsible for the fine sand beaches south of Little Egg Inlet.

(5) The Delaware Bay shore littoral sediment is supplied mainly by the Cape May formation which outcrops almost continuously along the bay from Cape May to Reeds Beach.

Transportation and Deposition of Heavy Minerals

(1) The size distribution of heavy minerals in this littoral environment is dependent primarily upon (a) the hydraulic conditions at each point along the beach, (b) the sizes of minerals available, and (c) the hydraulic equivalent size.

(2) The size distribution by weight of various heavy minerals within a single sample shows that an increase in fineness is not necessarily accompanied by an increase in specific gravity. The availability factor determines the relative position of each heavy mineral in any size distribution and this factor is affected by the range of sizes which are available for deposition.

(3) Hydraulic equivalent size appears to be related to density.

(4) Relative availability of each mineral is not constant over a range of sizes.

Hydraulic Ratios

(1) Hydraulic ratios are a complex method of comparing heavy minerals. Most problems involving heavy mineral correlation can be solved adequately by using conventional techniques.

(2) Local transportation and deposition conditions cause variations from place to place along the littoral zone. These variations affect the interpretation of hydraulic ratios.

(3) As relative availability changes with size, hydraulic ratios have limited application when heavy minerals of extreme textural differences are compared.

APPENDIX I Locations of Beach Samples

Sample	Date	Location	Position on Beach
5	6/22/50	480 ft. north of Sandy Hook Point Bell, Ft. Hancock.	5 ft. below berm crest on 8° slope.
6	6/22/50	450 ft. south of Sandy Hook Horn, Ft. Hancock.	3 ft. below berm crest on 5° slope.
7	6/22/50	0.23 miles north of garbage dump, Ft. Hancock.	6 ft. below berm crest on 12° slope.
8	6/22/50	1 mile north of Fire Rd. #10, Fort Hancock.	4 ft. below berm crest on 6° slope.
9	6/23/50	Fire Rd. #10, Ft. Hancock.	2 ft. below berm crest on 2° slope.
10	6/20/50	Fire Rd. #2, Ft. Hancock.	5 ft. below berm crest on 8° slope.
11	6/22/50	0.57 miles north of Sentry Gate House, Ft. Hancock.	Beach controlled by sea wall. Sample collected on 2° slope at base of wall.
12	10/2/50	Via Ripa, Seabright.	Beach controlled by sea wall. Sample collected 5 ft. in front of wall on 6° slope.
13	10/2/50	300 ft. north of Coast Guard Sta., Seabright	Beach controlled by sea wall. Sample collected 10 ft. in front of wall on 7° slope.
14	6/23/50	Penninsula House, Rumson Rd., Seabright. Site offset 30 ft. south of stone groin.	8 ft. below berm crest on 2° slope.

APPENDIX I Locations of Beach Samples

Sample	Date	Location	Position on Beach
15	10/2/50	210 ft. south of Imbrie Pl., Seabright.	Beach controlled by sea wall. Sample collected 5 ft. in front of wall on 6° slope.
16	6/8/50	0.2 of a mile north of Monmouth Beach Club, Monmouth Beach.	4 ft. below berm crest on 6° crest.
17	6/8/50	300 ft. north of Atlantic Ave., North Long Branch. Site offset 80 ft. south of stone groin.	5 ft. below berm crest on 5° slope.
18	6/8/50	North Broadway, Long Branch between two stone groins.	3 ft. below berm crest on 9° slope.
19	6/23/50	North Bath Ave., Long Branch between two stone groins.	Crest of berm.
20	6/8/50	450 ft. north of Coast Guard Sta., Long Branch between 2 stone groins.	3 ft. below berm crest on 8° slope.
21	10/2/50	Garfield Ter., Elberon, between 2, stone groins.	Beach controlled by sea wall and "L" shaped groins. Sample collected 5 ft. in front of wall on 8° slope.
22	10/2/50	Roseld St., Deal. Offset 50 ft. north of stone groin.	Beach controlled by sea wall and groin. Sample collected 5 ft. in front of wall on 7° slope.

APPENDIX I Locations of Beach Samples

Sample	Date	Location	Position on Beach
23	6/8/50	Allen Ave., Allenburst.	3 ft. below berm crest on 7° slope.
24	6/23/50	2nd Ave., Asbury Park.	6 ft. below berm crest on 7° slope.
25	6/7/50	Cliff Ave., Bradley Beach.	4 ft. below berm crest on 6° slope.
26	6/7/50	Sylvania Ave., Avon.	3 ft. below berm crest on 5° slope.
27	6/7/50	9th Ave., Belmar.	6 ft. below berm crest on 5° slope.
28	6/7/50	Ludlow Ave., Como Lake.	4 ft. below berm crest on 7° slope.
29	6/23/50	Warren Ave., Spring Lake.	8 ft. below berm crest on 5° slope.
30	6/6/50	Chicago Ave., Sea Girt.	4 ft. below berm crest on 8° slope.
31	10/2/50	750 ft. south of north fence of Camp Edison, Sea Girt.	3 ft. below berm crest on 5° slope.
32	6/6/50	0.26 miles north of Manasquan Inlet, Manasquan.	6 ft. below berm crest on 3° slope.
33	6/12/50	Havens Beach, near Arnold Ave., Point Pleasant.	6 ft. below berm crest on 8° slope.
34	6/26/50	Hotel Beacon by the Sea, Point Pleasant.	5 ft. below berm crest on 7° slope.
35	6/12/50	0.11 miles north of Johnson Ave., Bay Head.	5 ft. below berm crest on 3° slope.

APPENDIX I Locations of Beach Samples

Sample	Date	Location	Position on Beach
36	6/12/50	Lyman Ave., Mantoloking.	7 ft. below berm crest on 9° slope.
37	6/12/50	360 ft. south of Downers St., Mantoloking.	6 ft. below berm crest on 5° slope.
38	6/12/50	0.4 of mile north of Bay Head Fisheries, South Mantoloking.	25 ft. below berm crest on 1° slope.
39	6/13/50	0.6 of mile south of Bay Head Fishries, Camp Osborne.	15 ft. below berm crest on 1° slope.
40	6/13/50	0.37 miles north of Chadwick Coast Guard Sta., Chadwick.	6 ft. below berm crest on 1° slope.
41	6/13/50	225 ft. north of Ortley Ave., Lavallette.	16 ft. below berm crest on 6° slope.
42	6/13/50	New Jersey Ave., Lavallette.	8 ft. below berm crest on 9° slope.
43	6/14/50	0.11 miles south of Harding Ave., Ortley Beach.	6 ft. below berm crest on 5° slope.
44	6/26/50	Stockton Ave., Seaside Park.	15 ft. below berm crest on 0° slope.
45	6/14/50	3rd Ave., Seaside Park.	10 ft. below berm crest on 2° slope.
46	6/14/50	23rd Ave., Seaside Park.	5 ft. below berm crest on 10° slope.
47	7/19/50	0.3 of a mile south of Coast Guard Sta. #110, Island Beach.	3 ft. below berm crest on 7° slope.

APPENDIX I Locations of Beach Samples

Sample	Date	Location	Position on Beach
48	7/19/50	1.7 miles north of Coast Guard Sta. #111, Island Beach.	15 ft. below berm crest on 7° slope.
49	6/26/50	0.7 of a mile north of Coast Guard Sta. #111, Island Beach.	Crest of berm.
50	7/19/50	0.3 of a mile south of Coast Guard Sta. #111, Island Beach.	25 ft. below berm crest on 0° slope.
51	7/15/50	2.2 miles north of Coast Guard Sta. #112, Island Beach.	20 ft. below berm crest on 4° slope.
52	7/15/50	1.2 miles north of Coast Guard Sta. #112, Island Beach.	Crest of berm.
53	7/15/50	0.2 of a mile north of Coast Guard Sta. #112, Island Beach.	Crest of berm.
54	6/26/50	0.8 of a mile south of Coast Guard Sta. #112, Island Beach.	Crest of berm.
55	7/15/50	1.8 milessouth of Coast Guard Sta. #112, Island Beach.	25 ft. below berm crest on 6° slope.
56	7/31/50	500 ft. east of Barnegat Light, Barnegat City.	2 ft. below berm crest on 6° slope.
57	7/31/50	0.8 of a mile south of terminus of Long Beach Blvd. Barnegat City.	Crest of berm.
58	7/31/50	1.8 miles south of terminus of Long Beach Blvd., Barne-gat City.	Crest of berm.

APPENDIX I Locations of Beach Samples

Sample	Date	Location	Position on Beach
59	6/26/50	2.8 miles south of terminus of Long Beach Blvd., Long Beach Park.	Crest of berm.
60	7/31/50	1.6 miles north of Coast Guard Sta. #116, High Point.	Crest of berm.
61	7/31/50	0.6 of a mile north of Coast Guard Sta. #115, Harvey Cedars.	5 ft. below berm crest on 7° slope.
62	7/31/50	0.4 of a mile south of Coast Guard Sta. #115, Frazier.	Crest of berm.
63	7/31/50	1.4 miles south of Coast Guard Sta. #115, Frazier.	Crest of berm.
64	6/26/50	8th St., Surf City.	Crest of berm.
65	7/31/50	11th St., Ship-Bottom Beach.	Crest of berm.
66	8/2/50	32nd St., Brant Beach.	Crest of berm.
67	8/2/50	Selfridge Ave., Brant Beach.	Crest of berm.
68	8/2/50	Surf Ave., Beach Haven Crest.	Crest of berm.
69	6/26/50	Nebraska Ave., Beach Haven Park. Offset 125 ft. south of stone groin.	Crest of berm.
70	8/2/50	Delaware Ave., Beach Haven Terrace.	Crest of berm.

APPENDIX I Locations of Beach Samples

Sample	Date	Location	Position on Beach
71	8/2/50	14th St., North Beach Haven.	10 ft. below berm crest on 2° slope.
72	8/2/50	Marine St., Beach Haven.	2 ft. below berm crest on 9° slope.
73	8/2/50	Nelson Ave., Beach Haven.	2 ft. below berm crest on 6° slope.
74	8/4/50	Pershing Ave., Holgate.	Crest of berm.
75	8/4/50	0.9 of a mile south of Washington Ave., Holgate.	12 ft. below berm crest on 6° slope.
76	8/4/50	North point. Tucker Island.	Crest of berm.
77	8/4/50	0.3 of a mile south of north point on Tucker Island.	Crest of berm.
78	8/4/50	South point, Tucker Island.	3 ft. below berm crest on 6° slope.
79	8/4/50	North point, Pullen Island.	Crest of berm.
80	8/4/50	1 mile south of north point on Pullen Island.	Crest of berm.
81	8/4/50	2 miles south of north point on Pullen Island.	5 ft. below berm crest on 6° slope.
82	8/9/50	1.4 miles north of terminus of Brigantine Ave., Brigantine.	15 ft. below berm crest on 3° slope.

APPENDIX I Locations of Beach Samples

Sample	Date	Location	Position on Beach
83	6/27/50	0.37 miles north of terminus of Brigantine Ave., Brigantine,	High tide line on upper foreshore on 2° slope. Slope constant to dunes.
84	8/9/50	Roosevelt Ave., Brigantine.	10 ft. below berm crest on 5° slope.
85	8/9/50	20th St., Brigantine.	10 ft. below berm crest on 5° slope.
86	8/9/50	40th St., Brigantine,	5 ft. below berm crest on 7° slope.
87	8/9/50	1 mile south of 40th St., Brigantine.	10 ft. below berm crest on 6° slope.
88	6/26/50	300 ft. north of Absecon Light, Atlantic City.	10 ft. from berm crest on 0° slope.
89	8/9/50	150 ft. north of stone groin at Tennessee Ave., Atlantic City.	High tide line on upper foreshore on 3° slope.
90	8/9/50	Iowa Ave., Atlantic City.	High tide line on upper foreshore on 5° slope.
91	8/9/50	Kingston Ave., Atlantic City.	20 ft. below berm crest on 3° slope.
92	8/9/50	South Derby Ave., Ventnor.	10 ft. below berm crest on 5° slope.
93	6/27/50	South Andover Ave., Margate City.	10 ft. from sea wall on 3° slope.
94	8/8/50	Rumson Ave., Margate City.	15 ft. from sea wall on 4° slope.
95	8/8/50	30th St., Long Port.	Crest of berm.

APPENDIX I Locations of Beach Samples

Sample	Date	Location	Position on Beach
96	8/8/50	235 ft. north of stone groin at Great Egg Inlet, Long Port.	20 ft. below berm crest on 4° slope.
97	6/27/50	1st St., Ocean City.	30 ft. below berm crest on 3° slope.
98	8/8/50	225 ft. south of 10th St., Ocean City.	20 ft. below berm crest on 4° slope.
99	8/8/50	300 ft. north of 21st St., Ocean City.	Crest of berm.
100	8/8/50	29th St., Ocean City.	Crest of berm.
101	8/8/50	0.4 of a mile north of 42nd St., Ocean City.	Crest of berm.
102	6/27/50	150 ft. south of 47th St., Ocean City.	20 ft. below berm crest on 3° slope.
103	8/8/50	57th St., Ocean City.	Crest of berm.
104	8/12/50	1 mile north of Vincent Ave., Strathmere.	Crest of berm.
105	8/12/50	Vincent Ave., Strathmere.	5 ft. below berm crest on 3° slope.
106	8/21/50	Johnson Ave., Strathmore.	10 ft. below berm crest on 3° slope.
107	6/27/50	0.9 of a mile north of Ludlam Beach Light, Sea Isle City.	15 ft. below berm crest on 3° slope.

APPENDIX I Locations of Beach Samples

Sample	Date	Location	Position on Beach
108	8/12/50	0.11 miles south of Ludlam Beach Light, Sea Isle City.	5 ft. below berm crest on 3° slope.
109	8/7/50	52nd St., Sea Isle City.	Berm crest.
110	8/7/50	1 mile south of 52nd St., Sea Isle City.	Berm crest.
111	8/7/50	93rd St., Towns-ends Inlet.	Berm crest.
112	6/27/50	10th St., Avalon.	Berm crest.
113	8/10/50	28th St., Avalon.	10 ft. below berm crest on 3° slope.
114	8/10/50	1 mile north of 61st St., Avalon.	Berm crest.
115	8/10/50	61st St., Avalon.	15 ft. below berm crest on 3° slope.
116	8/10/50	80th St., Stone Harbor.	15 ft. below berm crest on 3° slope.
117	6/27/50	102nd St., Stone Harbor.	Berm crest.
118	8/10/50	0.21 miles south of Stone Harbor Coast Guard Sta., Stone Harbor.	15 ft. below berm crest on 3° slope.
119	8/10/50	1.2 miles south of Stone Harbor Coast Guard Sta., Stone Harbor.	10 ft. below berm crest on 2° slope.
120	8/15/50	1 mile north of 9th St., Wildwood.	Berm crest.

APPENDIX I Locations of Beach Samples

Sample	Date	Location	Position on Beach
121	8/15/50	9th St., Wildwood.	15 ft. belw berm crest on 1° slope.
122	6/27/50	Magnolia Ave., Wildwood.	Berm crest.
123	8/15/50	Rio Grande Ave., Wildwood.	10 ft. from berm crest on 3° slope.
124	8/15/50	Lotus Rd., Wild-wood.	15 ft. below berm crest on 1° slope.
125	8/15/50	0.34 miles south of Denver Ave., Wildwood Gables.	20 ft. below berm crest on 1° slope.
126	8/15/50	1.3 miles south of Denver Ave., Wildwood Gables.	25 ft. below berm crest on 0° slope.
127	8/15/50	0.17 miles south of harbor jetty, Sewell Pt., Cape May.	Berm crest.
128	7/24/50	0.31 miles north of Wilmington Ave., Cape May.	20 ft. below berm crest on 6° slope.
129	7/24/50	0.28 miles north of Madison Ave., Cape May.	Beach controlled by sea wall. Sample collected 15 ft. from wall on 3° slope.
130	7/24/50	Perry St., Cape May.	15 ft. below berm crest on 4° slope.
131	7/24/50	Bay Shore Rd., South Cape May.	6 ft. below berm crest on 6° slope.
132	6/27/50	Coast Guard Sta., Cape May Point. Offset 80 ft. east.	Berm crest.

APPENDIX I Locations of Beach Samples

Sample	Date	Location	Position on Beach
133	8/14/50	Alexander Ave., Cape May Pt. Offset 200 ft. east of stone groin.	10 ft. below berm crest on 7° slope.
134	8/14/50	0.85 miles south of Cape May Canal Jetty, Sunset Beach.	5 ft. below berm crest on 7° slope.
135	8/14/50	300 ft. north of Cape May Canal Jetty, North Cape May.	5 ft. below berm crest on 3° slope.
136	8/14/50	Washington Ave., North Cape May.	15 ft. from bank on 5° slope.
137	6/27/50	Cox Hall Creek, Town Bank.	10 ft. from dunes on 6° slope.
138	8/11/50	0.3 of a mile south of Wildwood Ave., Wildwood Highlands Beach.	25 ft. from dunes on 6° slope.
139	8/11/50	0.3 miles south of New York Ave., Wild- wood Villas.	20 ft. from dunes on 5° slope.
140	8/11/50	Miami Ave., Miami Beach.	15 ft. from dunes on 6° slope.
141	8/11/50	Norburys Landing Rd., Del Haven.	25 ft. from dunes on 5° slope.
142	8/11/50	1 mile north of Norburys Landing Rd., Del Haven.	20 ft. below dunes on 6° slope.
143	8/11/50	0.2 of a mile north of Pierces Point.	10 ft. below berm crest on 9° slope.
144	6/27/50	Reeds Beach Rd., Reeds Beach.	10 ft. below berm crest on 4° slope.

APPENDIX II Grain Size Analyses of Beach Sands

Distribution by grade sizes (Mm.) in percent

Sample	6.680	4.780	3.360	2.380	1.680	1.190	.840	.590	.420	.297	.210	.149	.105	.074	.053	Pan
5			.2	.1	.3	6.5	1.6	19.8	31.6	30.3	8.9	.7				
6					.1	.3	1.7	7.5	26.6	49.6	13.2	1.0				
7				.7	.8	1.6	4.5	18.4	33.6	31.3	7.8	1.1	.1			
8								.1	7.7	44.3	38.0	9.5	.4			
9						.1	2.0	5.6	17.3	38.5	25.5	9.6	1.3	.1		
10				.2	.1	.5	3.6	17.8	32.5	32.7	10.5	1.9	.2			
11		.2	.1	.2	.5	.8	2.3	6.3	11.7	29.5	33.1	13.5	1.7	.1		
12							.3	1.2	6.1	37.4	46.1	8.6	.3			
13		.4	-	-	.2	.6	1.8	7.1	21.4	47.0	19.3	2.1	.1			
14		.4	.5	1.4	1.4	3.6	7.7	13.7	21.4	32.4	15.1	2.3	.2			
15				.4	.4	1.2	3.4	9.6	21.6	39.0	19.7	3.9	.7	.1		
16		.3	.4	.9	2.9	6.1	10.5	15.9	20.7	27.7	12.6	1.7	.3			
17			.1	.1	.1	.9	3.1	8.4	20.7	42.2	21.8	2.4	.1			
18					.1	.4	2.6	12.4	28.2	39.7	15.2	1.4				
19				.3	.6	1.4	3.3	9.4	20.0	39.1	22.9	2.9	.1			
20				.3	.1	.8	3.8	15.8	35.1	36.4	7.4	.3				
21					.1	.3	1.3	3.9	10.0	31.9	40.5	11.3	.6			
22					.1	.8	5.1	20.9	37.0	29.7	5.9	.5				
23					.1	.8	6.9	25.4	32.5	26.1	7.5	.7				
24					.1	.2	1.9	14.4	37.9	35.9	8.7	.8				
25						.2	1.6	13.8	55.0	27.7	1.6					
26						.1	.7	3.9	20.0	57.9	16.3	1.1				
27						.3	3.1	15.0	31.9	39.2	10.0	.5				
28			.2	.2	.2	.8	8.5	36.2	41.4	11.3	1.0	.2				
29	10.0	3.8	3.2	2.9	2.2	1.8	3.1	7.5	17.5	26.5	16.7	4.4	.3			

APPENDIX II Grain Size Analyses of Beach Sands

Distribution by grade sizes (Mm.) in percent

Sample	6.680	4.780	3.360	2.380	1.680	1.190	.840	.590	.420	.297	.210	.149	.105	.074	.053	Pan
30		.6	.3	..3	.9	5.4	9.1	19.8	39.6	20.6	3.1	.3				
31				.2	-	.2	1.7	13.1	48.2	32.9	3.5	.2				
32		.7	.2	.1	.1	2.3	.4	15.4	50.0	27.7	2.8	.2				
33		.3	.l	.5	1.1	4.4	18.3	28.3	27.4	17.0	2.5	.1				
34						.3	2.6	11.7	33.6	39.2	11.0	1.6				
35				.1	.1	.4	4.7	29.4	46.8	17.9	.6					
36		2.6	.3	.1	.1	.6	3.9	26.3	47.3	18.4	.4					
37		.1	-	-	-	.4	2.6	14.3	34.6	45.6	2.4					
38						.4	3.2	11.5	25.4	54.3	5.1	.l				
39						.1	.5	3.5	15.0	68.6	11.8	.4				
40						.7	5.2	10.7	17.5	52.2	13.5	.2				
41					.2	.7	5.5	18.6	25.7	39.1	10.0	.2				
42					.2	1.4	5.0	14.4	20.2	41.9	16.3	.6				
43			.2	-	.3	.9	4.3	16.0	23.0	39.7	14.9	.6	.1			
44							.6	4.9	13.0	47.6	31.5	2.0	.l			
45						.3	2.3	17.8	27.8	33.6	17.5	.6				
46					.2	.4	3.2	15.7	24.0	31.1	24.2	1.2				
47							.3	3.1	10.5	30.9	49.8	5.2	.2			
48							.8	6.4	17.7	33.9	37.5	3.3	.4			
49						.1	.9	9.8	29.9	38.3	19.8	1.1				
50							.1	4.1	27.1	40.3	25.2	2.5	.7			
51							.4	6.0	27.4	40.8	22.9	2.4	.1			
52							1.6	13.4	32.8	35.0	15.3	1.9				
53							.4	5.2	24.6	42.5	24.1	3.1	.1			
54				.3	.l	.1	.6	5.8	28.3	45.3	16.8	2.1	.1			

APPENDIX II Grain Size Analyses of Beach Sands

Distribution by grade sizes (Mm.) in percent

Sample	6.680	4.780	3.360	2.380	1.680	1.190	.840	.590	.420	.297	.210	.149	.105	.074	.053	Pan
55							.1	2.2	12.9	35.6	39.4	8.9	.8	.1		
56							.1	.7	4.1	25.3	49.9	17.4	2.2	.3		
57							1.9	8.0	17.6	36.8	28.3	6.4	.9	.1		
58							.3	2.3	15.8	51.5	26.5	3.3	.3			
59							.6	6.5	23.9	49.5	17.4	1.9	.1			
60			.1	-	-	-	.4	3.9	15.8	39.2	34.6	5.7	.3			
61							.6	4.6	14.7	32.8	37.5	9.0	.7	.1		
62							.5	5.9	20.9	45.0	23.6	3.7	.4			
63							.4	4.6	19.2	41.9	29.0	4.5	.3			
64							.7	6.9	21.7	42.3	23.5	4.3	.3	.3		
65							.8	8.2	25.8	40.3	21.2	3.4	.2	.1		
66							.3	3.6	20.0	48.4	23.2	4.1	.4			
67							.4	4.8	15.7	34.5	35.0	8.6	.9	.1		
68							.2	5.8	23.6	45.0	20.2	4.5	.7			
69								.3	7.1	35.3	41.8	14.3	1.1	.1		
70							1.6	13.9	26.4	30.5	22.0	5.2	.4			
71							.1	3.3	16.2	33.3	32.5	13.3	1.2	.1		
72							.4	7.2	25.4	44.9	18.7	3.2	.2			
73							.1	.5	5.0	23.8	46.8	21.1	2.4	.3		
74							.4	4.9	23.2	46.5	18.7	5.6	.6			
75							.1	1.2	8.5	28.6	42.5	17.5	1.4	.2		
76									1.4	14.8	38.3	32.9	11.2	1.4		
77									2.4	26.6	50.5	18.3	2.1	.1		
78								.1	1.0	9.6	39.8	36.7	11.6	1.2		
79									.1	2.0	17.9	57.5	18.1	4.2	.2	

APPENDIX II Grain Size Analyses of Beach Sands

Distribution by grade sizes (Mm.) in percent

Sample	6.680	4.780	3.360	2.380	1.680	1.190	.840	.590	.420	.297	.210	.149	.105	.074	.053	Pan
80									1.2	11.0	31.0	42.0	11.8	2.8	.2	
81								.3	2.4	13.0	29.8	34.3	15.0	5.0	.2	
82								.1	.1	1.3	6.1	51.4	37.3	3.5	.1	.1
83									.3	1.5	12.6	58.7	23.9	2.9	.1	
84							.1	3.1	14.4	27.9	25.0	22.2	6.3	.9		
85							.1	3.3	6.4	14.3	27.2	33.4	12.6	2.5	.2	
86							.1	.7	5.8	23.4	33.7	25.7	9.2	1.3	.1	
87							.2	1.1	5.1	20.8	36.1	24.5	9.4	2.4	.3	.1
88									.5	10.0	35.4	46.9	6.8	.4		
89									.1	1.4	12.4	51.0	26.2	7.7	1.1	.1
90				.4	-	-	.1	-	.1	3.4	19.9	48.6	21.3	5.5	.6	.1
91										1.6	7.2	34.8	46.9	8.9	.5	.1
92									.1	4.5	20.1	49.7	21.6	3.6	.3	.1
93										3.6	27.4	50.6	16.7	1.6	.1	
94									.1	2.2	14.6	58.2	21.7	3.0	.2	
95										1.0	12.1	59.4	24.5	2.9	.1	
96									.1	3.6	15.8	46.5	20.3	3.3	.4	
97										1.4	15.5	54.0	27.7	1.5		
98									.4	5.3	19.4	56.4	16.4	2.0	.1	
99									.2	3.6	15.4	55.6	21.8	3.2	.2	
100									.1	4.8	25.1	52.5	14.7	2.6	.2	
101										4.3	30.6	52.4	11.3	1.3	.1	
102									.1	4.2	25.6	55.0	13.5	1.6		
103							.1	.2	1.5	11.1	36.6	41.4	7.9	1.1	.1	
104										1.2	14.0	62.4	19.4	2.9	.1	

APPENDIX II Grain Size Analyses of Beach Sands

Distribution by grade sizes (Mm.) in percent

Sample	6.680	4.780	3.360	2.380	1.680	1.190	.840	.590	.420	.297	.210	.149	.105	.074	.053	Pan
105									.1	.8	4.3	54.3	34.7	5.4	.3	.1
106									.1	.6	5.7	52.1	36.6	4.6	.2	.1
107										.2	9.7	60.0	26.8	3.1	.1	
108								.2	.9	5.1	20.1	55.8	15.4	2.3	.2	
109									.1	.3	5.0	63.8	26.4	4.0	.3	.l
110										.5	6.4	55.0	32.0	5.5	.6	
111									.1	1.9	11.4	56.6	23.9	5.4	.6	.1
112										2.5	21.4	62.5	12.5	1.0		
113									.1	1.0	8.4	56.6	29.6	3.9	.2	.1
114										.7	6.3	48.1	38.7	6.0	.2	
115									.1	1.5	6.3	61.4	26.4	4.0	.3	
116										.3	6.2	58.5	30.1	4.6	.3	
117										.1	2.9	45.7	38.1	13.1	0.1	
118										.4	4.5	45.8	38.9	9.0	1.3	.l
119									.1	1.0	8.7	56.7	29.3	3.9	.2	.l
120									.1	1.3	11.8	50.2	27.0	9.2	.4	
121									.1	1.3	11.7	67.5	17.3	1.9	.l	
122										.2	5.5	53.7	36.5	4.0	.1	
123										.2	4.5	63.3	27.6	4.0	.3	.1
124										.2	3.5	65.3	27.4	3.5	.l	
125										.7	4.9	52.9	37.7	3.7	.1	
126									.1	5.5	15.9	54.9	21.6	1.9	.1	
127										.l	1.5	29.7	50.0	17.8	.8	
128			.3	.7	1.1	.l	6.0	10.4	16.6	31.4	22.3	9.0	1.9	.2		
129									.3	2.4	10.4	54.8	27.5	4.3	.3	

APPENDIX II Grain Size Analyses of Beach Sands

Distribution by grade sizes (Mm.) in percent

Sample	6.680	4.780	3.360	2.380	1.680	1.190	.840	.590	.420	.297	.210	.149	.105	.074	.053	Pan
130									.1	2.0	25.0	54.8	15.6	2.4	.1	
131		4.3	4.7	5.5	3.5	3.0	3.8	5.1	11.6	18.3	20.3	16.4	3.3	.2		
132						.1	.3	3.0	22.0	33.7	24.5	12.9	3.2	.3		
133			.1	-	.1	.1	.4	3.6	22.0	40.3	24.6	8.1	.5	.1		
134	1.6	2.1	.2	.9	1.8	8.0	23.8	35.5	23.1	2.5	.4	.1				
135	3.7	.5	1.1	.9	3.0	8.0	13.3	9.6	11.0	32.4	14.9	1.4	.1			
136		.7	-	.1	.1	.2	.9	5.7	35.1	50.5	4.3	2.2	.2			
137						.1	.5	3.4	28.0	64.2	3.0	.7	.1			
138		.4	.1	.1	-	.2	.4	1.9	27.5	65.5	3.6	.3				
139		1.9	.4	1.0	1.2	2.5	7.1	19.7	42.6	18.1	4.7	.6	.1			
140				.4	.4	1.8	7.8	43.0	44.7	1.2	.5	.2				
141		1.7	.2	1.3	3.7	7.1	17.4	50.0	16.9	1.3	.2	.1				
142		2.9	.7	1.2	2.2	4.5	11.9	32.1	16.9	19.3	6.1	2.2	.2			
143	2.7	1.3	2.4	4.3	5.2	8.1	12.7	30.8	26.6	4.4	.7	.5	.2			
144		8.2	4.3	2.4	3.0	4.2	11.7	25.0	31.4	6.6	.8					

APPENDIX III Derived Values of Grain Size Analyses for Beach Sands

Sample	Q_3	Median Size	Q_1	So	Sk
5	.615	.469	.357	1.31	1.00
6	.469	.381	.319	1.21	1.03
7	.610	.456	.373	1.28	1.09
8	.366	.299	.242	1.23	.99
9	.420	.332	.255	1.28	.97
10	.585	.444	.337	1.32	1.00
11	.407	.301	.232	1.32	1.04
12	.392	.289	.255	1.24	1.12
13	.444	.366	.308	1.20	1.02
14	.649	.420	.321	1.42	1.17
15	.625	.504	.423	1.22	1.04
16	.770	.473	.337	1.61	1.16
17	.465	.368	.301	1.24	1.03
18	.521	.398	.319	1.28	1.05
19	.480	.368	.301	1.26	1.07
20	.584	.435	.366	1.26	1.13
21	.371	.291	.234	1.26	1.03
22	.607	.465	.384	1.26	1.08
23	.655	.500	.384	1.31	1.01
24	.554	.438	.347	1.26	1.00
25	.578	.484	.415	1.18	1.02
26	.420	.360	.310	1.16	1.00
27	.555	.414	.340	1.28	1.18
28	.712	.575	.465	1.28	1.10
29	1.030	.432	.312	1.82	1.73
30	.712	.535	.429	1.30	1.07
31	.532	.441	.392	1.17	1.07
32	.585	.484	.407	1.20	1.02
33	.835	.609	.472	1.33	1.06
34	.520	.412	.332	1.25	1.02
35	.620	.530	.441	1.19	.97
36	.655	.530	.441	1.22	1.03
37	.540	.426	.371	1.21	1.10
38	.500	.398	.337	1.22	1.06
39	.409	.357	.317	1.14	1.02
40	.500	.376	.321	1.25	1.14
41	.590	.426	.342	1.32	1.11
42	.540	.390	.319	1.30	1.13
43	.558	.398	.321	1.32	1.13
44	.401	.334	.280	.120	1.01

APPENDIX III Derived Values of Grain Size Analyses for Beach Sands

Sample	Q_3	Median Size	Q_1	So	Sk
45	.555	.412	.319	1.32	1.05
46	.565	.389	.297	1.38	1.11
47	.354	.289	.265	1.16	1.12
48	.420	.319	.273	1.24	1.13
49	.494	.386	.308	1.26	1.02
50	.441	.354	.291	1.23	1.02
51	.459	.351	.297	1.25	1.32
52	.500	.390	.312	1.26	1.03
53	.444	.353	.291	1.23	1.04
54	.456	.378	.299	1.24	.96
55	.373	.297	.242	1.24	1.02
56	.315	.259	.220	1.20	1.03
57	.435	.342	.274	1.26	1.02
58	.401	.349	.283	1.19	.93
59	.444	.368	.332	1.16	1.09
60	.400	.315	.264	1.23	1.06
61	.384	.301	.245	1.25	1.04
62	.429	.342	.291	1.22	1.07
63	.415	.349	.283	1.21	.97
64	.438	.351	.289	1.23	1.03
65	.453	.366	.297	1.24	1.00
66	.412	.349	.279	1.22	.95
67	.398	.310	.255	1.25	1.06
68	.435	.346	.283	1.24	1.03
69	.360	.289	.230	1.25	.99
70	.510	.384	.289	1.33	1.00
71	.392	.304	.242	1.27	1.03
72	.450	.370	.304	1.21	1.00
73	.313	.262	.214	1.21	.97
74	.432	.354	.297	1.20	1.02
75	.337	.271	.222	1.23	1.02
76	.274	.219	.172	1.26	.98
77	.306	.257	.217	1.19	1.01
78	.262	.211	.168	1.25	.99
79	.204	.178	.152	1.16	.98
80	.253	.199	.163	1.24	1.04
81	.267	.201	.157	1.30	1.04
82	.186	.158	1.34	1.18	1.00
83	.198	.170	.148	1.16	1.01
84	.393	.280	.200	1.40	1.00

APPENDIX III Derived Values of Grain Size Analyses for Beach Sands

Sample	Q_3	Median Size	Q_1	So	Sk
85	.293	.213	.170	1.32	1.10
86	.313	.244	.186	1.30	.98
87	.308	.242	.168	1.35	.89
88	.252	.204	.171	1.21	1.04
89	.190	.164	.137	1.18	.97
90	.209	.174	.145	1.20	1.00
91	.180	.139	.120	1.22	1.12
92	.208	.177	.147	1.19	.98
93	.220	.187	.157	1.18	.99
94	.201	.174	.150	1.16	1.00
95	.197	.171	.147	1.16	.99
96	.203	.175	.152	1.16	1.01
97	.201	.171	.145	1.18	.99
98	.211	.181	.156	1.16	1.00
99	.203	.174	.150	1.16	1.01
100	.217	.183	.157	1.17	1.02
101	.225	.191	.162	1.18	1.00
102	.217	.185	.159	1.17	1.01
103	.265	.210	.170	1.23	1.02
104	.199	.174	.152	1.15	1.00
105	.167	.151	.141	1.09	1.03
106	.175	.157	.143	1.14	.95
107	.192	.168	.144	1.15	.98
108	.211	.179	.152	1.18	1.00
109	.189	.166	.143	1.16	.98
110	.187	.160	.135	1.18	.99
111	.197	.168	.144	1.17	1.01
112	.209	.182	.159	1.15	1.01
113	.183	.162	.142	1.13	.99
114	.168	.152	.135	1.12	.98
115	.184	.164	.144	1.13	.99
116	.190	.162	.140	1.17	1.01
117	.178	.149	.121	1.21	1.02
118	.181	.152	.124	1.21	.97
119	.181	.161	.143	1.13	.99
120	.193	.164	.132	1.21	.95
121	.199	.175	.155	1.13	1.01
122	.185	.159	.135	1.18	.99
123	.175	.160	.145	1.10	.99
124	.190	.166	.144	1.15	.99

APPENDIX III Derived Values of Grain Size Analyses for Beach Sands

Sample	Q_3	Median Size	Q_1	So	Sk
125	.174	.153	.139	1.12	1.03
126	.206	.177	.151	1.17	.99
127	.156	.130	.110	1.19	1.02
128	.510	.357	.275	1.37	1.10
129	.183	.157	.144	1.13	1.07
130	.212	.182	.156	1.17	1.00
131	.815	.351	.230	1.88	1.53
132	.420	.326	.246	1.33	.97
133	.426	.335	.270	1.26	1.03
134	.975	.760	.590	1.29	1.00
135	.970	.435	.332	1.72	1.70
136	.465	.415	.378	1.11	1.12
137	.435	.381	.334	1.14	1.00
138	.450	.398	.360	1.12	1.02
139	.670	.520	.425	1.26	1.05
140	.700	.600	.570	1.11	1.11
141	.910	.750	.630	1.20	1.02
142	.815	.633	.415	1.39	.85
143	1.140	.708	.570	1.41	1.30
144	.810	.459	.390	1.44	1.50

APPENDIX IV Grain Size Analyses of Sea Bottom Sediments

Distribution by grade sizes (Mm.) in percent

Sample	6.680	4.780	3.360	2.380	1.680	1.190	.840	.590	.420	.297	.210	.149	.105	.074	.053	Pan
B-11	1.1	.8	.4	1.5	1.4	2.6	2.9	6.3	20.7	39.5	19.1	3.2	.3	.1	-	.1
B-13			.2	.2	.3	1.8	7.8	10.4	9.9	26.7	35.6	6.6	.3	.1	.1	.1
B-21	.7	1.4	1.9	1.8	1.9	2.2	2.0	3.7	13.4	45.8	22.5	2.6	.1			
B-23						.1	1.0	5.7	30.2	55.5	6.1	1.1	.1			
B-31			1.7	3.4	6.6	18.0	26.3	23.2	12.9	6.5	.8	.1	.2	.2	-	.2
B-32		.3	.1	.3	.3	17	17	2.1	9.5	26.7	32.1	21.5	4.0	.9	.2	.2
B-41										.5	1.3	14.6	53.3	24.4	4.1	1.9
B-42	15.2	7.9	7.2	4.4	3.1	5.4	10.1	15.6	16.5	11.3	1.9	.5	.3	.2	.1	.2
B-51				.5	.2	.6	1.0	3.6	9.4	31.4	33.1	14.3	4.8	1.1	.2	
B-53								.3	1.2	11.3	27.8	47.7	10.6	1.2		
B-61							.1	.1	2.2	6.9	22.0	46.6	19.4	2.2	.1	
B-64							.1	1.9	12.0	32.4	35.0	16.4	2.1	.1		
B-71				.2	.1	.2	.2	.5	1.0	1.5	4.6	32.9	46.3	10.7	1.7	.3
B-72								.1	.2	.7	1.1	5.9	53.3	31.6	5.2	2.0
B-73	5.7	1.0	.1	.3	.2	.4	1.0	3.7	11.7	45.3	20.6	5.0	3.3	1.3	.2	.1
B-81		.3	.4	1.2	2.7	8.3	16.9	25.5	25.0	13.4	1.4	1.0	1.5	1.5	.5	.5
B-82			1.4	1.0	.9	1.9	4.1	9.7	12.8	14.5	18.0	22.1	5.1	2.2	.8	1.3
B-83	4.0	.3	.2	.4	.2	.6	1.2	3.1	8.5	27.9	30.8	14.3	4.3	2.8	.9	.5
B-91		.7	.2	1.8	3.0	4.8	5.1	5.8	6.7	10.5	13.8	15.2	19.2	7.8	1.1	4.2
B-93		.5	.1	.1	.3	.2	.1	.2	.3	.4	.7	4.3	29.9	25.7	8.4	28.7
C-1							.1	-	.1	.1	.4	2.9	44.6	31.7	9.4	6.7
C-6							.1	.5	3.2	11.2	13.1	13.4	26.0	16.4	4.8	11.1
C-7										.2	.3	2.8	22.8	35.9	13.2	25.0

APPENDIX V Derived Values of Grain Size Analyses for Sea Bottom Sediments

Sample	Q_3	Median Size	Q_1	So	Sk
B-11	.563	.378	.301	1.37	1.18
B-13	.508	.317	.252	1.42	1.27
B-21	.447	.347	.297	1.23	1.10
B-23	.459	.389	.332	1.17	1.01
B-31	1.220	.908	.636	1.38	.94
B-32	.353	.269	.201	1.33	.98
B-41	.142	.120	.103	1.17	1.02
B-42	4.40	.936	.531	2.86	2.77
B-51	.373	.287	.220	1.30	1.00
B-53	.244	.198	.166	1.21	1.04
B-61	.227	.184	.154	1.21	1.03
B-64	.366	.287	.223	1.26	.99
B-71	.168	.139	.116	1.20	1.01
B-72	.130	.114	.101	1.14	1.01
B-73	.417	.345	.280	1.22	.98
B-81	.910	.640	.453	1.42	1.01
B-82	.500	.278	.180	1.67	1.16
B-83	.384	.287	.216	1.33	1.01
B-91	.520	.224	.134	1.97	1.39
B-93	.109	.095	.047	1.52	.57
C-1	.126	.104	.079	1.26	.92
C-6	.229	.130	.095	1.55	1.29
C-7	.105	.087	.052	1.42	.72

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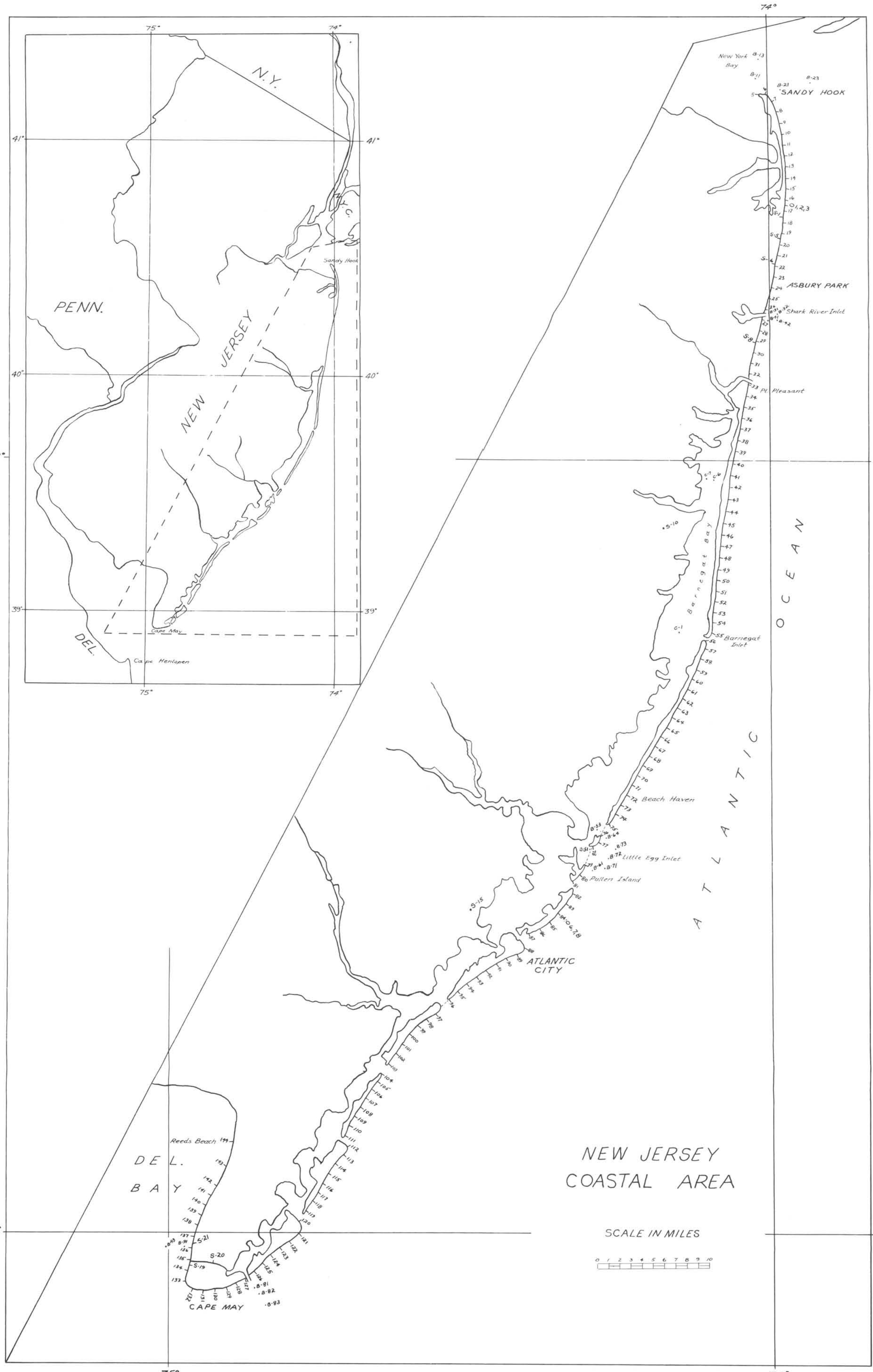
NEW JERSEY
COASTAL AREA
SCALE IN MILES
0 1 2 3 4 5 6 7 8 9 10
SANDY HOOK
New York Bay
ASBURY PARK
Shark River Inlet
Pt. Pleasant
Barnegat Bay
Barnegat Inlet
Beach Haven
Little Egg Inlet
Pullen Island
ATLANTIC CITY
Reeds Beach
DEL. BAY
CAPE MAY
ATLANTIC OCEAN
74°
75°
40°
39°
N.Y.
PENN.
NEW JERSEY
N.Y.C.
Sandy Hook
Cape May
Cape Henlopen
DEL.
41°