GENERALIZED STRUCTURAL CONTOUR MAPS OF THE NEW JERSEY COASTAL PLAIN

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Division of Resource Development
Kenneth H. Creveling, *Director*

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by

Horace G. Richards
F. H. Olmsted
James L. Ruhle

prepared by the
U. S. Geological Survey
in cooperation with the
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George R. Shanklin, *Director*

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GENERALIZED STRUCTURAL CONTOUR MAPS OF THE NEW JERSEY COASTAL PLAIN

By

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ABSTRACT

Twelve generalized structural contour maps were prepared from a study of 169 well logs or sample logs of drill cuttings from the Coastal Plain of New Jersey, Delaware, and the Eastern Shore of Maryland. The configuration of the tops of the nonmarine Cretaceous deposits (Patuxent, Patapsco, Raritan, and Magothy formations) and the Piney Point Formation (Eocene) show the known subsurface extent of these formations in both New Jersey and Delaware. The structural contour maps show the tops of the Merchantville Formation and Woodbury Clay, the Englishtown Formation, the Marshalltown Formation, the Wenonah Formation and Mount Laurel Sand, the Navesink Formation, and the Red Bank Sand which are all of Late Cretaceous age. The maps of the Hornerstown Sand, the Vincentown Formation, and the Manasquan Formation and Shark River Marl of early Tertiary age show the subsurface extent of these formations only in New Jersey. Also included is an outline map showing the locations of wells and seismic stations and a structural contour map showing the configuration of the bedrock surface of the report area.

Structural contours on top of the Magothy Formation, or on the top of the Raritan Formation where the Magothy formation is absent, show the configuration of the nonmarine deposits of Cretaceous age. Isopachs of the nonmarine deposits are derived by interpolation between contours on top of the bedrock and the top of either the Magothy Formation or the Raritan Formation where the Magothy is absent.

The Merchantville Formation and Woodbury Clay are difficult to separate in the subsurface, and therefore the contours are drawn on top of the Woodbury Clay. In New Jersey, the thickness of the combined Merchantville Formation and Woodbury Clay ranges from about 100 to 140 feet near the outcrop, but exceeds 250 feet in the subsurface along the coast in Ocean County.

The top of the Englishtown Formation is easy to recognize because it generally consists of a micaceous white and yellow sand, although locally it is a silty clay. The formation thins toward the southwest from about 160 feet in central Ocean County to less than 20 feet in Salem County. It has not been recognized in Delaware.

The Marshalltown Formation varies from black clay to a glauconitic sand. It usually ranges in thickness from 20 to 60 feet. It is very thin or absent in Delaware.

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The Wenonah Formation and Mount Laurel Sand are difficult to separate in New Jersey, and therefore are shown as a unit. The combined thickness ranges from 60 to 100 feet. In Delaware the two formations are easily separated.

The Navesink Formation is generally highly glauconitic and it is difficult to determine the upper limit where overlain by the Hornerstown Sand which is also glauconitic. The contour map on the top of the Navesink is based upon relatively little control.

The Red Bank Sand reaches a thickness of about 160 feet in Monmouth County. It thins southwestward and is absent in outcrop in the southern part of the Coastal Plain of New Jersey. A probable equivalent of the Red Bank has been recognized in Delaware. The Tinton Sand Member is the topmost unit of the Red Bank Sand in Monmouth County.

The Hornerstown Sand is mostly glauconitic and is about 30 feet thick in outcrop. This is overlain by the Vincentown Formation which consists of two facies (1) calcareous sand facies and (2) quartz sand facies. These are overlain by the Manasquan Formation and Shark River Marl which are here treated as a unit. In outcrop the combined thickness of the Manasquan Formation and Shark River Marl is about 40 feet, but in the subsurface they thicken to about 200 feet. The Piney Point Formation of Jackson age occurs in the subsurface in Cape May and Atlantic Counties, N. J., and in southern Delaware but is not exposed in these States.

Brief notes are given on formations of later Tertiary and Pleistocene age, but no contour maps were constructed.

INTRODUCTION

Scope and purpose.—This report summarizes briefly the structure and stratigraphy of the sedimentary rocks of Cretaceous and Tertiary age in the Coastal Plain of New Jersey, Delaware, and southeastern Pennsylvania. Twelve structure contour maps are included. These illustrations are generalized because the subsurface data were obtained from various sources, and in many wells formational identifications were uncertain.

It is hoped that this report will serve as a useful basis for later, more detailed studies. In fact, it is understood that the Ground Water Branch of the U. S. Geological Survey and the New Jersey Geological Surveys are presently attempting to obtain more detailed information on the subsurface geology of parts of the New Jersey Coastal Plain. It is expected that these interpretations will be refined or modified as more subsurface information becomes available.

A preliminary set of maps was prepared by Mr. Ruhle in 1957-1958 at the University of Pennsylvania under the direction of the senior author. The work was continued at the Academy of Natural Sciences of Philadelphia and at the University of Massachusetts.

The present set of maps represents refinement of the original maps, based upon additional well logs. The basic data upon which the structure contour maps are based were obtained from many sources, and are of varying degrees of accuracy. The published sources include reports by Woolman (1890-1902), and Richards (1945, 1948). Unpublished data were obtained from the Ground Water Branch of the U. S. Geological Survey in Trenton, N. J., and from the New Jersey Geological Survey, Trenton, N. J.

The report was prepared under the general supervision of Allen Sinnott, District Geologist for the Ground Water Branch of the U. S. Geological Survey in Trenton, N. J. Paul R. Seaber, Jack Rosenau, Harold E. Gill, Leo A. Jablonski, and other personnel of the district office in Trenton, supplied information on well logs and stratigraphic correlations, and also critically reviewed the report.

Acknowledgments.—Kemble Widmer, State Geologist of New Jersey, supplied data from the files of the New Jersey Geological Survey and assisted in many other ways. Frank J. Markewicz, Principal Geologist with the New Jersey Geological Survey, gave us the benefit of his knowledge of several critical wells. Meredith E. Johnson, former State Geologist of New Jersey, critically reviewed the manuscript.

Samples and electric logs from a series of test wells drilled in Burlington and Ocean Counties were made available through the courtesy of the Transcontinental Gas Pipe Line Corporation and the New Jersey Geological Survey.

Information pertaining to the Delaware parts of the structure contour maps was obtained from Johan J. Groot, State Geologist of Delaware, Newark, Del., and from William C. Rasmussen, U. S. Geological Survey, Newark, Del. Dr. Groot critically reviewed the parts of the manuscript dealing with Delaware.

Mr. Ruhle's work was aided by a grant from the Jessup Fund of the Academy of Natural Sciences of Philadelphia.

PREVIOUS WORK

Although considerable pioneer work on the geology and paleontology of the Atlantic Coastal Plain had been done by Rogers, Conrad, Cook, Whitfield, and others, it was the work of Clark, published in the Annual Reports of the New Jersey Geological Survey in 1892, 1893, and 1897, which may be thought of as containing the first modern classification of the Cretaceous system of New Jersey. (See especially Clark, Bagg, and Shattuck, 1898.)

Clark's work was continued by Knapp, who named most of the currently used formational units of the Matawan Group. This work was summarized by Kümmel and Knapp (1904). Knapp's later work formed the basis for the classification used by Weller (1907) in his report on the invertebrate fossils of the Cretaceous of New Jersey. In Weller's report, as in previous work, the Hornerstown Marl, Vincentown Sand, and Manasquan Marl were considered to be of Cretaceous age.

Lewis and Kümmel (1915) summarized the information on the various formations in a report issued to accompany a geologic map of the State. This report was revised by Kümmel (1940).

In 1928, Cooke and Stephenson restudied the macrofossils of the Hornerstown Marl, Vincentown Sand, and Manasquan Marl and changed their age assignment from Cretaceous to Eocene. At that time the Paleocene was not recognized in this area. Later work by McLean (1952, 1953), Loeblich and Tappan (1957), and others has shown that the Hornerstown and the Vincentown are of Paleocene age.

Spangler and Peterson (1950) discussed the geology of the Coastal Plain of New Jersey and differed from previous interpretations in several important respects: (1) they reduced the rank of the Matawan and Monmouth groups to formations, and at the same time reduced the several formational subdivisions of the Matawan and Monmouth to members; (2) they changed the dividing line between the Matawan and Monmouth groups from the top of the Wenonah Formation to the top of the overlying Mount Laurel Sand; and (3) they regarded the Raritan Formation as both basal Upper Cretaceous (Cenomanian) and Lower Cretaceous (Albian) instead of all Upper Cretaceous, as believed previously. Spangler and Peterson included several structural contour and isopach maps.

Johnson and Richards (1952) reviewed the arguments presented by Spangler and Peterson and gave reasons for the retention of the previously accepted views. Dorf (1952) also reviewed some of the arguments of Spangler and Peterson, especially those based upon paleobotany, and presented evidence to show that the Raritan and Magothy formations are of Late Cretaceous age, but that the formations of the Potomac Group, as exposed in Delaware, Maryland, and Virginia, are of Early Cretaceous age.

The stratigraphy of the New Jersey Coastal Plain was reviewed by Richards (1956). Barksdale, and others (1958) discussed the hydrology and geology of the various formations in the region adjacent to the lower Delaware River.

In 1958, the New Jersey Geological Survey issued the first volume of a two-volume revision of the Cretaceous faunas of the State that included chapters on stratigraphy, previous investigations, and correlations by Richards and Ramsdell (Richards and others, 1958).

Recently a report on the geology and hydrology of the Delaware River basin was prepared by the General Hydrology Branch of the U. S. Geological Survey (Parker and others, in press).

Owens and Minard (1960) in a recent field trip guidebook reviewed the Cretaceous and Tertiary formations in the north-central part of the New Jersey Coastal Plain and made several changes in terminology, mainly the substitution of the more general term "formation" for such terms as "sand", "clay", or "marl". These new designations are used in the present report.

GEOLOGICAL SETTING

The Coastal Plain of New Jersey and Delaware is underlain by a wedge of unconsolidated sedimentary rocks that thickens seaward from a veneer at the Fall Line to 6,000 feet beneath the mouth of Delaware Bay and to about 8,000 feet beneath the southeastern corner of Delaware. These sediments lie unconformably on consolidated rocks of pre-Cretaceous age similar to those exposed northwestward of the Fall Line.

The unconsolidated sedimentary rocks range in age from Cretaceous to Recent and consist of clay, silt, sand, and gravel, of both marine and nonmarine origin, deposited as the ancient shoreline fluctuated across the gently sloping continental margin. The southeasterly to easterly dips of the beds decrease upward from more than 60 feet per mile near the base of the section to about 10 feet per mile at the top. In New Jersey, the average grain size of the deposits decreases southeastward or eastward. The sandy formations which can be delineated readily in outcrop tend to become finer grained and more difficult to distinguish from adjacent clayey and silty formations downdip. Most formations appear to thicken downdip.

Approximately half the total thickness of coastal plain deposits in New Jersey and Delaware are represented by nonmarine sediments of Early and Late Cretaceous age which form the basal part of the section. Marine tongues appear in the seaward portion; they are very difficult to correlate within distances of only a few miles. Overlying the nonmarine sediments is a sequence of mostly marine strata of Late Cretaceous and early Tertiary age (pre-Miocene) ranging in thickness from about 400 feet near the outcrop to more than 1,000 feet near the coast. These marine beds are in turn overlain by late Tertiary marine and nonmarine deposits which reach a thickness of about 1,000 feet in southern New Jersey and southern Delaware. A series of complex Quaternary deposits caps the older sediments forming blanket-like masses which are generally less than 50 feet thick but which are as much as 200 feet thick in local channel fills.

Table 1 lists the formations of the coastal plain of New Jersey and Delaware. The column for New Jersey is largely adapted from Kümmel (1940), Johnson and Richards (1952), and Richards and others (1958). The classification for Delaware is that accepted by the Delaware Geological Survey.

Figure 1 shows the location of the wells studied in the preparation of this report. Data concerning these wells are given in Table 2.

Table 1.—Coastal Plain Formations of New Jersey and Delaware

Age		Formation: New Jersey	Formation: Delaware
Recent		Alluvial deposits	Alluvial deposits
Pleistocene	Columbia Group	Cape May Formation	Pleistocene undifferentiated
		Pensauken Formation	
		Bridgeton Formation	
Pliocene(?)		Beacon Hill Gravel	Bryn Mawr Gravel
Miocene(?)		Cohansey Sand	Undifferentiated
Miocene		Kirkwood Formation	
Eocene		Piney Point Formation	Piney Point Formation
		Shark River Marl	Pamunkey Group
		Manasquan Formation	
Paleocene	Rancocas Group	Vincentown Formation	
		Hornerstown Sand	Brightseat Formation
Upper Cretaceous	Monmouth Group	Red Bank Sand including Tinton Sand Member	Red Bank Sand
		Navesink Formation	Mount Laurel and Navesink undifferentiated
		Mount Laurel Sand	
	Matawan Group	Wenonah Formation	Wenonah Formation
		Marshalltown Formation	Not recognized in Delaware
		Englishtown Formation	
		Woodbury Clay	
		Merchantville Formation	Merchantville Formation
		Magothy Formation	Magothy Formation
		Raritan Formation	Raritan Formation
Lower Cretaceous	Potomac Group	Undifferentiated	Patapsco and Patuxent Formations. undifferentiated [1]

[1] The U. S. Geological Survey regards the Patapsco as Upper Cretaceous and the Patuxent as Lower Cretaceous. The New Jersey Geological Survey regards both formations as Lower Cretaceous; this is also the opinion of the present writers. The Patuxent, Patapsco, Raritan, and Magothy Formations are treated as a unit in this report. The Potomac Group has been mapped in Delaware as the Patuxent and Patapsco Formations. The Potomac Group has not been recognized in outcrops in New Jersey.

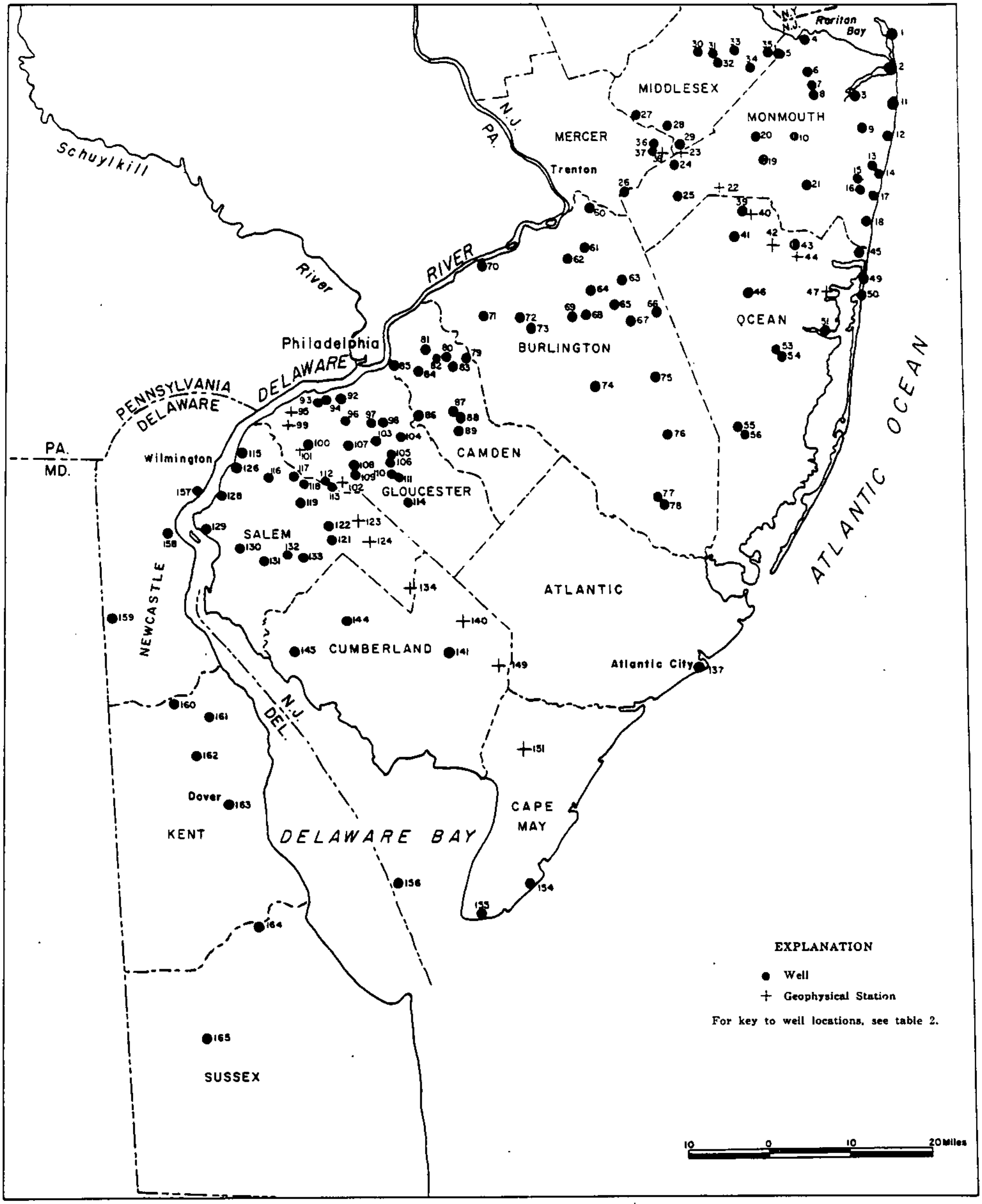

FIGURE 1.—MAP SHOWING LOCATION OF WELLS STUDIED IN THE PREPARATION OF THIS REPORT

Table 2.—Wells studied in the preparation of contour maps shown in figures 2-13.

Altitude: Altitude of land surface at well.

TD: Total depth of well.

Source of information: ANSP, Academy of Natural Sciences, Philadelphia, Pa.; DGS, Delaware Geological Survey; NJGS, New Jersey Geological Survey; TCPL, Transcontinental Gas Pipe Line Corp., Newark, N. J.; USGS, U. S. Geological Survey.

*Seismic data; ¢ Approximate location.

No. Location	Lat. North	Long. West	Altitude (feet)	TD (feet)	Source of information
Monmouth County, N. J.					
1 Sandy Hook	40° 27.7′	74° 00.1′	10	804	NJGS
2 Highlands	40° 23.2′	73° 59.4′	120	344	Do.
3 Red Bank	40° 20.8′	74° 04.3′	40	702	Do.
4 Union Beach	40° 26.6′	74° 10.8′	10	331	USGS
5 Matawan	40° 25.2′	74° 14.8′	90	457	Do.
6 Telegraph Hill	40° 23.2′	74° 10.6′	230	1,044	NJGS
7 Imlaystown	40° 21.7′	74° 09.9′	130	158	Do.
8 Holmdel	40° 21.3′	74° 09.8′	125	210	Do.
9 Eatontown	40° 17.4′	74° 03.2′	60	891	Do.
10 Colts Neck	40° 16.7′	74° 12.5′	125	680	Richards (1945)
11 Monmouth Beach	40° 19.9′	73° 58.6′	10	420	Richards (1948)
12 W. Long Branch	40° 16.7′	73° 59.6′	10	981	NJGS
13 Whitesville	40° 13.4′	74° 01.9′	20	629	Do.
14 Asbury Park	40° 12.5′	74° 01.0′	20	580	Richards (1945)
15 Neptune Township	40° 12.2′	74° 04.2′	85	475	Richards (1948)
16 Belmar	40° 11.0′	74° 03.9′	75	453	NJGS
17 Belmar	40° 10.6′	74° 01.8′	20	480	Woolman (1896)
18 Sea Girt	40° 08.0′	74° 02.5′	20	755	Richards (1948)
19 Freehold	40° 14.3′	74° 16.6′	140	650	Richards (1945)
20 Freehold	40° 16.6′	74° 17.4′	115	500	NJGS
21 Farmingdale	40° 11.8′	74° 10.8′	100	480	Do.
22 Charleston Springs*	40° 11.6′	74° 22.6′	175	—	Ewing (1939)
23 Disbrows Hill*	40° 15.3′	74° 28.1′	120	—	Ewing (1939)
24 Elys Corner	40° 13.8′	74° 29.0′	178	345?	Ewing (1939)
25 Smithburg	40° 10.8′	74° 28.3′	190	712	NJGS
26 Allentown	40° 11.2′	74° 35.4′	100	238	NJGS

Table 2.—Wells studied in the preparation of contour maps shown in figures 2-13.

No. Location	Lat. North	Long. West	Altitude (feet)	TD (feet)	Source of information
Middlesex County, N. J.					
27 Plainsboro	40° 19.0′	74° 33.9′	95	160	Ewing (1939)
28 Cranbury Station	40° 18.1′	74° 29.5′	120	180	Richards (1948)
29 Hightstown (Heider)	40° 16.1′	74° 27.9′	100	472	USGS
30 Dunhams Corner	40° 25.4′	74° 25.4′	90	565	Richards (1945)
31 Old Bridge	40° 25.2′	74° 23.2′	150	355	ANSP
32 Spotswood	40° 24.1′	74° 22.6′	30	355	Richards (1948)
33 Runyon	40° 25.6′	74° 20.3′	7	310	Richards (1948)
34 Browntown	40° 24.1′	74° 18.6′	60	221	NJGS
35 Cheesequake	40° 25.4′	74° 16.8′	135	254	NJGS
Mercer County, N. J.					
36 Hightstown	40° 15.9′	74° 31.4′	108	482	Ewing (1939)
37 Hightstown, 1 mi S	40° 15.5′	74° 31.6′	130	251	NJGS
38 Hightstown*	40° 15.3′	74° 30.5′	100	—	Ewing (1939)
Ocean County, N. J.					
39 Jacksons Mills	40° 09.0′	74° 19.4′	110	5,022	Richards (1945)
40 Jacksons Mills*	40° 09.1′	74° 19.1′	115	—	Ewing (1939)
41 Van Hiseville	40° 06.7′	74° 20.6′	100	184	NJGS
42 Lakewood*	40° 05.8′	74° 15.5′	130	—	Ewing (1939)
43 Lakewood	40° 05.7′	74° 12.5′	50	612	NJGS
44 Cedar Bridge*	40° 04.5′	74° 12.3′	60	—	Ewing (1939)
45 Point Pleasant	40° 04.8′	74° 03.9′	20	800	ANSP
46 Lakehurst	40° 00.8′	74° 18.8′	62	1,038	USGS
47 Silverton*	40° 00.9′	74° 08.1′	10	—	Ewing (1939)
49 Mantoloking	40° 02.1′	74° 03.2′	40	1,207	Ewing (1939)
50 Normandy Beach	40° 00.5′	74° 03.6′	5	1,507	NJGS
51 Island Heights	39° 56.5′	74° 08.5′	5	1,145	Richards (1945)
53 TCPL 20	39° 54.8′	74° 14.9′	38	1,728	TCPL
54 " 19	39° 54.4′	74° 14.4′	29	1,680	TCPL
55 " 17	39° 46.9′	74° 20.6′	155	1,710	TCPL
56 " 18	39° 46.3′	74° 19.8′	138	1,733	TCPL

Table 2.—Wells studied in the preparation of contour maps shown in figures 2-13.

No. Location	Lat. North	Long. West	Altitude (feet)	TD (feet)	Source of information
Burlington County, N. J.					
60 Bordentown	40° 09.6′	74° 55.4′	100	397	NJGS
61 Georgetown	40° 05.7′	74° 41.0′	90	263	ANSP
62 Columbus	40° 04.4′	74° 43.2′	80	715	Woolman? (1892)
63 McGuire AFB	40° 02.3′	74° 35.9′	125	1,060	NJGS
64 Juliustown	40° 01.3′	74° 40.1′	85	988	NJGS
65 Fort Dix	39° 59.9′	74° 37.0′	145	1,096	NJGS
66 Hanover Lake	39° 59.0′	74° 31.2′	95	485	Richards (1945)
67 Browns Mills	39° 58.1′	74° 34.8′	75	430	NJGS
68 Pemberton	39° 58.8′	74° 41.0′	50	147	Richards (1948)
69 Birmingham	39° 58.6′	74° 42.6′	38	105	NJGS
70 Beverly	40° 03.9′	74° 55.4′	20	123	NJGS
71 Moorestown	39° 58.6′	74° 55.0′	70	220	NJGS
72 Mount Holly	39° 58.3′	74° 49.9′	40	562	NJGS
73 Lumberton	39° 57.2′	74° 48.3′	10	404	NJGS
74 TCPL 12	39° 51.2′	74° 39.7′	93	820	TCPL
75 " 8	39° 52.3′	74° 31.3′	125	880?	TCPL
76 " 13	39° 46.2′	74° 30.1′	90	1,450	TCPL
77 " 15	39° 39.6′	74° 31.3′	20	1,625	TCPL
78 " 16	39° 39.0′	74° 30.6′	11	1,600	TCPL
79 Marlton	39° 54.3′	74° 57.4′	72	322	ANSP
Camden County, N. J.					
80 Ellisburg	39° 54.3′	75° 00.1′	35	200	NJGS
81 Collingswood	39° 55.4′	75° 03.0′	25	168	NJGS
82 Haddonfield	39° 54.3′	75° 01.2′	8	120	NJGS
83 Haddonfield	39° 53.4′	74° 59.4′	110	135	NJGS
84 Haddon Heights	39° 52.8′	75° 03.9′	85	276	NJGS
85 Gloucester	39° 53.8′	75° 07.3′	5	299	NJGS
86 Blackwood	39° 48.1′	75° 04.3′	8	387	NJGS
87 Clementon	39° 48.7′	74° 59.1′	90	652	Richards (1945)
88 Clementon	39° 48.1′	74° 58.1′	160	457	USGS
89 Pine Valley	39° 47.0′	74° 58.4′	170	370	NJGS
90 New Brooklyn	39° 42.3′	74° 57.3′	110	2,090	USGS

Table 2.—Wells studied in the preparation of contour maps shown in figures 2-13.

No. Location	Lat. North	Long. West	Altitude (feet)	TD (feet)	Source of information
Gloucester County, N. J.					
92 Paulsboro	39° 50.4′	75° 14.7′	8	277	Richards (1948)
93 Gibbstown	39° 47.7′	75° 17.0′	8	105	USGS
94 Gibbstown	39° 49.9′	75° 16.8′	11	220	NJGS
95 Bridgeport*	39° 48.4′	75° 21.3′	10	—	Ewing (1940)
96 Clarksboro	39° 47.9′	75° 13.7′	70	223	USGS
97 Mantua	39° 47.7′	75° 10.3′	22	240	USGS
98 Wenonah	39° 47.7′	75° 09.0′	85	320	USGS
99 Prospect*	39° 47.2′	75° 22.0′	8	—	Ewing (1940)
100 Swedesboro	39° 45.2′	75° 18.6′	36	439	NJGS
101 Swedesboro*	39° 44.7′	75° 19.5′	45	—	Ewing (1940)
102 Lincoln*	39° 41.3′	75° 14.2′	110	—	Ewing (1940)
103 Barnsboro	¢39° 45.7′	75° 09.5′	140	110+	NJGS
104 Hurffville	39° 46.1′	75° 06.3′	90	128	USGS & NJGS
105 Pitman	39° 44.1′	75° 07.8′	142	525	USGS
106 Pitman	39° 43.7′	75° 07.9′	142	250	USGS
107 Mullica Hill	39° 45.2′	75° 13.4′	108	286	NJGS
108 Mullica Hill	39° 43.0′	75° 12.6′	120	168?	NJGS
109 Mullica Hill	39° 42.3′	75° 12.6′	100	106	NJGS
110 Glassboro	39° 42.3′	75° 07.4′	149	654	NJGS
111 Glassboro	39° 42.1′	75° 06.6′	145	360	USGS
112 Harrisonville	39° 41.1′	75° 15.8′	80	—	Ewing (1940)
113 Harrisonville	39° 40.7′	75° 14.9′	80	110+	NJGS
114 Clayton	39° 39.2′	75° 05.4′	133	—	USGS
Salem County, N. J.					
115 Penns Grove	¢39° 43.8′	75° 28.3′	5	350	USGS
116 N. J. Turnpike	39° 41.9′	75° 24.1′	35	344	NJGS
117 Auburn	39° 41.8′	75° 20.9′	110	301	NJGS
118 Seven Stars	39° 41.1′	75° 19.7′	92	316	NJGS
119 Woodstown	39° 39.0′	75° 19.9′	45	694	NJGS
121 Daretown	¢39° 35.3′	75° 15.7′	140	355?	Woolman (1897)
122 Daretown	39° 36.8′	75° 16.3′	144	336	NJGS
123 Pittsgrove*	39° 37.4′	75° 12.1′	132	—	Ewing (1940)

Table 2.—Wells studied in the preparation of contour maps shown in figures 2-13.

No. Location	Lat. North	Long. West	Altitude (feet)	TD (feet)	Source of information
Salem County, N. J.					
124 Elmer*	39° 35.5′	75° 10.2′	125	—	Ewing (1940)
126 Carneys Point	39° 43.0′	75° 28.3′	10	418	Richards (1948)
128 Pennsville	39° 39.9′	75° 30.8′	8	600	NJGS
129 Fort Mott	39° 36.3′	75° 33.0′	10	320	Woolman (1900)
130 Salem	39° 34.3′	75° 28.0′	12	1,440	Richards (1945)
131 Quinton	39° 33.0′	75° 24.6′	10	248	USGS
132 Alloway	39° 33.7′	75° 21.7′	40	115	NJGS
133 Alloway	39° 33.5′	75° 19.3′	40	240	Woolman (1901)
134 Norma*	39° 30.0′	75° 04.6′	60	—	Ewing (1940)
Atlantic County, N. J.					
137 Atlantic City	39° 21.2′	74° 25.9′	5	2,306	Woolman (1901) Richards (1945) Richards (1948)
Cumberland County, N. J.					
140 Millville*	39° 26.6′	74° 57.9′	70	—	Ewing (1940)
141 Millville	39° 24.3′	75° 02.8′	40	705	Richards (1945)
144 Bridgeton	39° 26.7′	75° 13.5′	80	1,651	Richards (1945)
145 Greenwich	39° 23.5′	75° 20.8′	20	—	Woolman
149 Port Elizabeth*	39° 21.8′	74° 53.0′	60	—	Ewing (1940)
Cape May County, N. J.					
151 Woodbine*	39° 14.5′	74° 48.1′	32	—	Ewing (1940)
154 Wildwood	38° 59.0′	74° 49.0′	10	1,244	Richards (1945) (1948)
156 Cape May	38° 56.0′	74° 55.5′	10	1,313	Richards (1945) (1948)
157 Brandywine Lighthouse	38° 59.2′	75° 06.7′	0	825	Richards (1945)
New Castle County, Del.					
158 New Castle	39° 40.2′	75° 33.7′	11	515	DGS
159 Delaware City	39° 35.8′	75° 37.9′	55	781	DGS
160 Middletown	39° 25.3′	75° 45.0′	65	1,478	Richards (1945)

Table 2.—Wells studied in the preparation of contour maps shown in figures 2-13.

No. Location	Lat. North	Long. West	Altitude (feet)	TD (feet)	Source of information
Kent County, Del.					
161 Smyrna	39° 17.8′	75° 36.8′	40	320	DGS
162 Leipsic	39° 16.5′	75° 38.1′	20	270	DGS
163 Cheswold	39° 12.5′	75° 33.9′	42	515	DGS
164 Dover	39° 07.6′	75° 29.6′	24	1,422	DGS
Sussex County, Del.					
165 Milford	38° 54.8′	75° 25.6′	15	770	Richards (1948)
166 Bridgeville	38° 43.2′	75° 32.2′	45	3,010	Richards (1945)
Wicomico County, Md.					
167 Salisbury (Hammond)	38° 20.8′	75° 29.1′	57	5,563	Richards (1945)
Worcester County, Md.					
168 Berlin (Bethards)	38° 18.2′	75° 16.7′	45	7,168	Richards (1948)
169 Ocean City (Esso)	38° 24.3′	75° 03.7′	13	7,710	Richards (1948)

PRE-CRETACEOUS ROCKS

The consolidated rocks beneath the Coastal Plain deposits are believed to consist chiefly of crystalline rocks of Precambrian and early Paleozoic(?) age, but locally they include sedimentary rocks and possibly basalt or diabase of Late Triassic age. Few wells in the Coastal Plain penetrate these rocks, except near the Fall Line where the pre-Cretaceous bedrock surface is relatively shallow. The nature of most of the bedrock is inferred from geophysical evidence, which at most places indicates seismic velocities similar to those of the crystalline rocks exposed northwestward of the Fall Line (Ewing, Woollard, and Vine, 1939, 1940).

Southeastward of the Fall Line, most wells that have penetrated the pre-Cretaceous bedrock have encountered schist and gneiss similar to much of that in the Wissahickon Formation of early Paleozoic age. Gneiss like that in the Wissahickon was encountered between depths of 1,336 feet (-1,226 feet, sea-level datum) and 5,022 feet (-4,912 feet) in an oil test well at Jacksons Mills in Ocean County, N. J. (Well 39, Table 2).

Shale and sandstone of the Newark Series (Upper Triassic) occur in the subsurface in parts of Middlesex and Mercer Counties, N. J. as well as some diabase near Perth Amboy, Middlesex County. A buried Triassic basin (Salisbury embayment), which extends from Ocean City to Salisbury, Md., lies just outside the area of the present report. Triassic rocks may underlie the Cretaceous deposits elsewhere in the Coastal Plain. Because of insufficient information, no attempt has been made to map the extent of the buried Triassic rocks.

Figure 2 shows the generalized configuration of the pre-Cretaceous bedrock surface beneath the coastal plain of New Jersey and Delaware. The control consists in large part of two refraction seismic profiles across New Jersey (Ewing, Woollard, and Vine, 1939, 1940; Woollard, 1941); logs of deep water wells and oil-test wells were used to supplement the seismic data and aid in the interpretation of the seismic results. The contours on the bedrock surface are somewhat more generalized than those on the other maps (figs. 4-14), owing to the fact that the control points are too far apart and unequally spaced to determine the buried topography more precisely. Moreover, the depths determined by the seismic method are somewhat inaccurate, although the probable error is less than 10 percent (Ewing, Woollard, and Vine, 1939, p. 294). Local relief of the bedrock surface probably exceeds 200 feet —comparable to that immediately northwest of the Fall Line.

NONMARINE CRETACEOUS SEDIMENTS, UNDIFFERENTIATED

The dominantly nonmarine sediments of Cretaceous age, which make up approximately the lower half of the coastal plain sequence, are divided into the Patuxent, Patapsco, Raritan, and Magothy formations. Accurate mapping of these formations is difficult, both in outcrop and in the subsurface. Rapid lateral changes in lithology are the rule; it is seldom possible to trace individual beds from one well or outcrop to the next. Although distinctive heavy mineral suites have been correlated with existing formations in some places, attempts

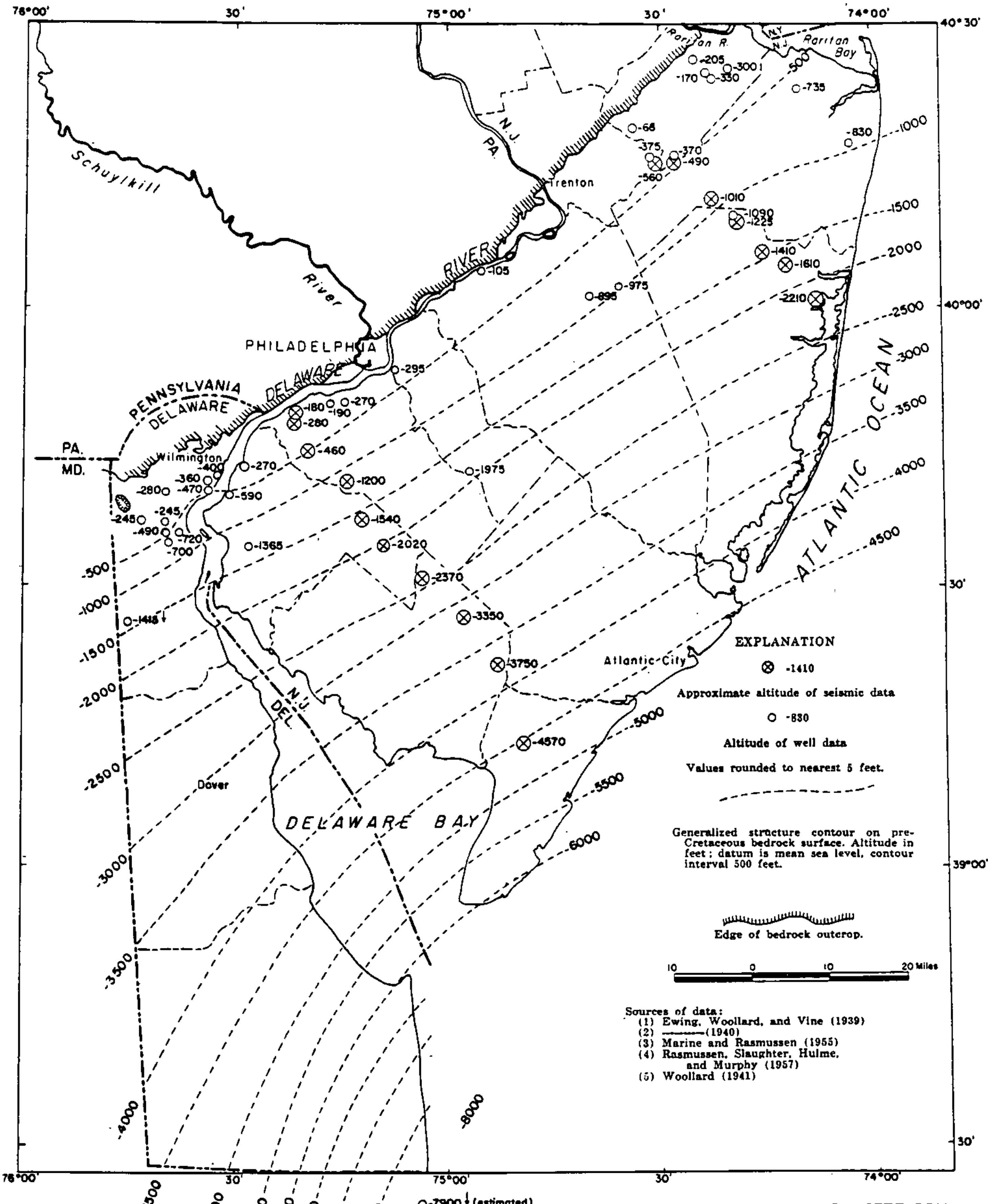

FIGURE 2.—MAP SHOWING GENERALIZED CONFIGURATION OF PRE-CRETACEOUS BEDROCK SURFACE IN NEW JERSEY AND DELAWARE

at regional correlations on the basis of heavy minerals have not yet been conspicuously successful. Fossils, except plants, spores, and pollen, generally are absent. Accordingly, the Patuxent, Patapsco, Raritan, and Magothy formations are treated as a unit in this report. (See fig. 3.)

Figure 3 shows structural contours on the top of the Magothy Formation, or on the top of the Raritan where the Magothy is absent; the isopachs indicate the total thickness of the combined unit and were derived by interpolation between contours on the top of the pre-Cretaceous bedrock and the top of either the Magothy Formation or the Raritan Formation where the Magothy is absent.

The following paragraphs summarize very briefly the stratigraphy of the nonmarine sediments.

In Maryland the lowermost formations of the Cretaceous form the Potomac Group. The Potomac Group has been mapped in Delaware as the Patuxent and overlying Patapsco Formation; the intervening Arundel Clay of the type area in Maryland is absent or has not been identified. The Potomac Group has not been recognized in outcrop in New Jersey although its presence in the subsurface of New Jersey was recognized by Dryden (quoted by Richards, 1945, p. 895) in a well at Salem, N. J. (Well 130, Table 2).

The Patuxent Formation was named by Clark (1897) for basal sand and clay of Cretaceous age exposed in the upper tributaries of the Little Patuxent and Patuxent Rivers in Maryland. The Patapsco Formation was also named by Clark (1897), for variegated clay and lenticular clayey sand typically exposed along the Patapsco River, Maryland.

Berry (1911) regarded all three formations of the Potomac Group as of Early Cretaceous age on the basis of fossil plants. On the other hand, Spangler and Peterson (1950) and Anderson (1948) considered the Patuxent of Early Cretaceous age and the Patapsco of Late Cretaceous age. Dorf (1952) reviewed the paleobotanical evidence and reassigned the Patapsco Formation to the Lower Cretaceous. The U. S. Geological Survey considers the Patapsco Formation Late Cretaceous.

Recent studies of plant microfossils by Groot and Penny (1960) have resulted in the differentiation of biostratigraphic units. While these do not always coincide with stratigraphic units as mapped, the age assignment based upon palynological data is in general agreement with that based on plant megafossils (Berry, 1911, Dorf, 1952), and is in disagreement with that of Spangler and Peterson (1950).

The problem of the age of the nonmarine Cretaceous deposits is being studied by the Delaware Geological Survey. The following is quoted from a personal communication (1960) from Dr. Johan J. Groot, State Geologist of Delaware:

> "Areas mapped as Patuxent, Arundel and Patapsco appear to be of Early Cretaceous age on the basis of pollen. The Raritan of New Jersey is of Late Cretaceous age. It must be recognized, however, that the geologic maps showing the geographic distribution of these formations are not always correct because the lithology of the nonmarine Cretaceous sediments is so similar that no formations can be rec-

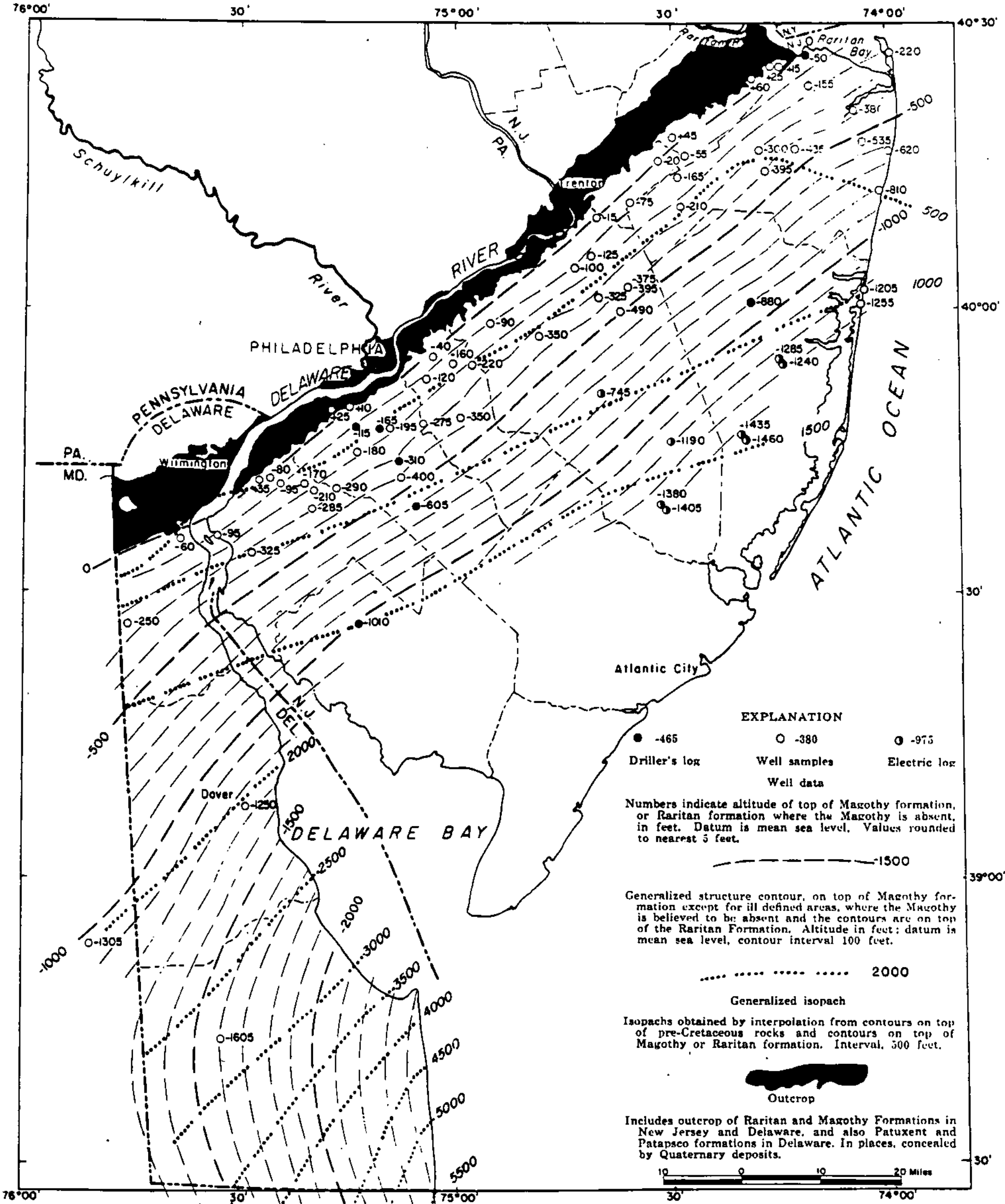

FIGURE 3.—MAP OF RARITAN AND MAGOTHY FORMATIONS IN NEW JERSEY, DELAWARE, AND PENNSYLVANIA, AND PATUXENT AND PATAPSCO FORMATIONS IN DELAWARE SHOWING THEIR EXTENT, COMBINED THICKNESS AND SUBSURFACE CONFIGURATION

ognized with any certainty. As a result, some areas mapped as Patuxent will turn out to be Upper Cretaceous, and some areas mapped as Raritan will turn out to be Lower Cretaceous. The only thing we can say with great certainty is that sediments which have been mapped as Patuxent, Arundel, Patapsco, and Raritan range in age from Early Cretaceous to early Late Cretaceous, probably from Neocomian to Cenomanian, although it is not impossible that some Turonian material is present also."

The Raritan was named by Conrad (1869, p. 360) for clay deposits in the valley of the Raritan River in New Jersey. The term Raritan Formation was first used by Cook (1888), but as used by both Conrad and Cook, the Raritan included material now assigned to the Magothy Formation. The term Raritan Formation was restricted to its present meaning by Clark (1893, p. 181-186). The present geologic map of New Jersey (Lewis and Kümmel, 1910-12; revised by Kümmel, 1931, and Johnson, 1950) groups the Raritan and Magothy formations.

The Raritan Formation consists of lenticular beds of white and buff sand and pink, brown, green, yellow, and variegated clay, locally containing considerable lignite. In Middlesex County, seven units have been recognized (Barksdale and others, 1943, p. 18):

7. Amboy stoneware clay
6. Old Bridge sand member
5. South Amboy fire clay
4. Sayreville sand member
3. Woodbridge clay
2. Farrington sand member
1. Raritan fire clay

Whereas alternating layers of sand and clay occur in the Raritan Formation elsewhere—for example, near Trenton and Camden, N. J.—it has not been possible to trace the Middlesex County units very far to the southwest.

Insufficient information is available to indicate downdip facies changes in the Raritan Formation. However, a test well (55, table 2) drilled by the Transcontinental Gas Pipe Line Corporation in 1951 near Manahawkin in Ocean County, N. J., penetrated fossiliferous marine limestone at a depth of 1,710 feet. This was overlain and underlain by fossiliferous marine silt (Richards, 1961). The fauna in these beds suggests that they may be of Raritan age.

The Raritan Formation is largely nonmarine and carries a flora that suggests a basal Late Cretaceous age (Cenomanian). Marine mollusks in the Woodbridge clay at Sayreville, N. J., also suggests a basal Late Cretaceous age and a correlation with the Woodbine Formation of Texas (Richards, 1943, and Stephenson, 1954). The marine fossils from the test wells near Manahawkin and Harrisville, N. J. (wells 55 and 56, table 2) confirm this correlation (Richards, 1960).

The Magothy Formation was named by Darton (1893) from exposures along the Magothy River in Maryland. The term was extended to New Jersey by Clark (1893, p. 181-186) for part of what had previously been referred to as the Raritan Formation.

The Magothy Formation consists of white micaceous sand and lenses of dark lignitic clay. Near Cliffwood, N. J., the Magothy carries a marine fauna and is separated from the Raritan by a disconformity. Elsewhere in New Jersey, the Magothy is practically indistinguishable from the Raritan, although in Delaware the two are fairly distinctive.

Ewing, Woollard, and Vine (1939, 1940) interpreted the M-Zone reflecting horizon of their seismic profiles as the contact between the Raritan and Magothy formations. However, because the two formations are usually transitional, the M-Zone probably represents only a locally cemented layer that may occur at different horizons. In any case, the M-Zone is not used for control in this report.

The Magothy is considerably thinner than the underlying formations, its average thickness probably is less than 100 feet, and it may be missing in the subsurface at some places.

MERCHANTVILLE FORMATION AND WOODBURY CLAY

The Merchantville Formation and Woodbury Clay are difficult to differentiate in the subsurface without careful lithologic or paleontologic studies. Hence, the structural contours were drawn on the top of the Woodbury (fig. 4). The two formations have been mapped separately in the New Jersey outcrop (Lewis and Kümmel, 1910-12), but in Delaware they have been combined into the Crosswicks Clay, as originally done in New Jersey. Recent work of Groot, Organist, and Richards (1954) suggested that the beds assigned to the Crosswicks Clay along the Chesapeake and Delaware Canal belong largely or entirely to the Merchantville Formation. However, because of the lack of sufficient subsurface data, the distribution of these clays in Delaware has not been shown on the accompanying map (fig. 4).

The Merchantville, basal formation of the Matawan Group, was named by Knapp in 1895 (Kümmel and Knapp, 1904) for exposures at Merchantville in Camden County, N. J. The Merchantville is a black, glauconitic, micaceous clay, generally greasy in appearance, commonly massive in structure, especially in the lower part, and is distinguished from the Woodbury clay by the presence of significant quantities of glauconite. In some places the Merchantville contains considerable quantities of silt and fine-grained sand. In some wells, the contact of the Merchantville Formation and the underlying Magothy Formation appears to be transitional. However, the Merchantville may be distinguished from the Magothy by the presence of glauconite and locally by abundant marine fossils.

The Woodbury Clay, which overlies the Merchantville Formation gradationally, was originally combined with the Merchantville to form the Crosswicks Group of Conrad

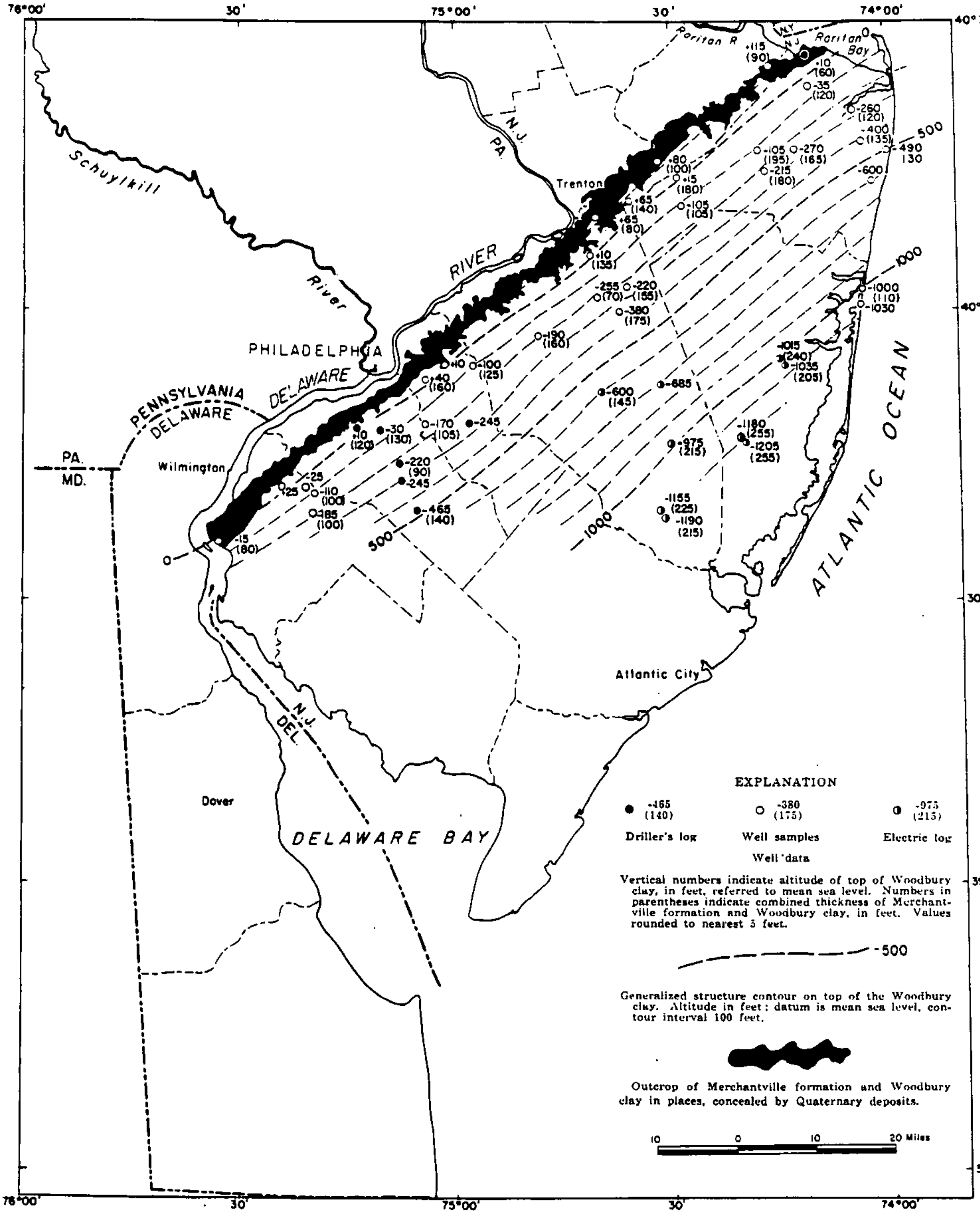

FIGURE 4.—MAP OF MERCHANTVILLE FORMATION AND WOODBURY CLAY SHOWING THEIR EXTENT AND SUBSURFACE CONFIGURATIONS IN NEW JERSEY

(1869). The Woodbury was first described as a distinct unit by Knapp (in Salisbury, 1899, p. 35) and was named from exposures near Woodbury in Gloucester County. It is principally a black, somewhat micaceous clay having generally a low sand content. It is distinguishable from the Merchantville Clay by the scarcity of glauconite, the characteristic light-brown color of its weathered product, and a distinctive fauna.

In New Jersey, the thickness of the combined Merchantville and Woodbury commonly ranges from about 100 to 140 feet near the outcrop, but exceeds 250 feet in the subsurface in coastal Ocean County.

ENGLISHTOWN FORMATION

The Englishtown Formation, originally named by Kümmel (footnote, p. 17, in Weller, 1907) for exposures near the town of that name in Monmouth County, N. J., lies comformably on the Woodbury Clay and is overlain conformably by the Marshalltown Formation.

In outcrop, the Englishtown consists typically of white, yellow, or brown quartz sand that is slightly micaceous and glauconitic and locally lignitic; lenses of clay and silt are significant in places, and crossbedding is characteristic of some phases of the formation. Downdip the formation becomes increasingly silty and clayey. The yellows and browns characteristic of weathering in the outcrop give way in the subsurface to shades of gray which are more representative of the formation as a whole. The Englishtown thins southwestward from about 160 feet in coastal Ocean County to less than 20 feet in northeastern Salem County, N. J. (fig. 5), and the formation is unknown in Delaware and southernmost New Jersey.

Although the Englishtown Formation was originally regarded as nonmarine, marine fossils consisting of shell fragments and foraminifera have been found at several subsurface localities, including Fort Dix, Holmdel, Mantoloking, Lavallette, and nearby Woodbury Heights (Richards and others, 1958, p. 23).

MARSHALLTOWN FORMATION

The Marshalltown Formation was named by Knapp (reported by Salisbury, 1899, p. 35, 36) for exposures near a small town in Salem County, N. J., of a bed of "marly clay sand" overlying the Englishtown Formation and underlying the Wenonah Formation. The Marshalltown ranges from a black sandy clay, which is dominant to the northeast, to an argillaceous, glauconitic sand, which is dominant to the southwest. Some of the glauconite-rich beds were formerly dug for fertilizer. Fossils are present locally, the most conspicuous species being *Exogyra ponderosa* Roemer and *Gryphaea convexa* (Say).

At most places the Marshalltown ranges in thickness from 20 to 60 feet, but it apparently thins toward the southwest, for it is absent or very thin in Delaware. Its greatest known thickness is 125 feet, in the coastal part of Ocean County, N. J. as shown on figure 6.

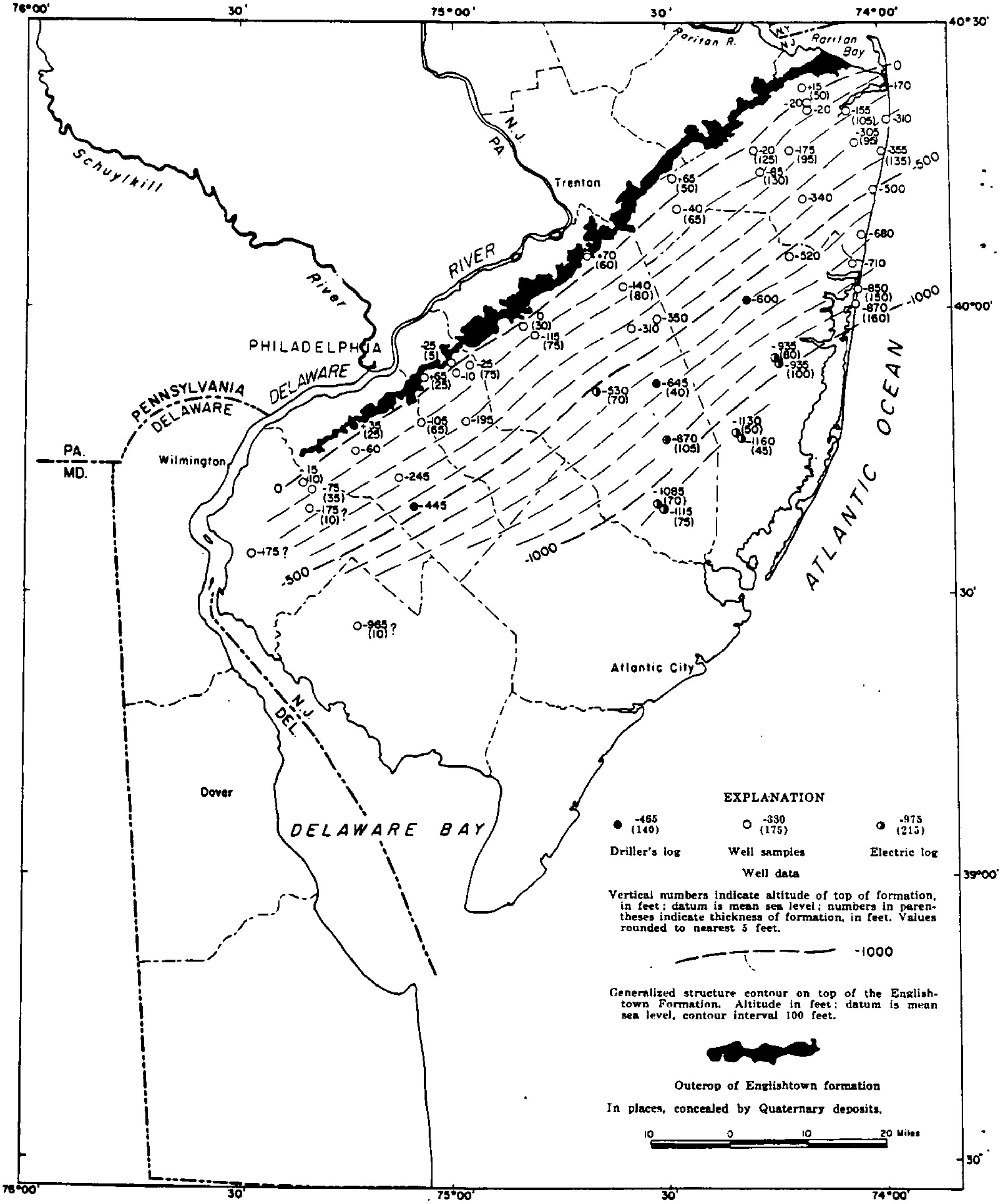

FIGURE 5.—MAP OF ENGLISHTOWN FORMATION SHOWING ITS EXTENT AND SUBSURFACE CONFIGURATION IN NEW JERSEY

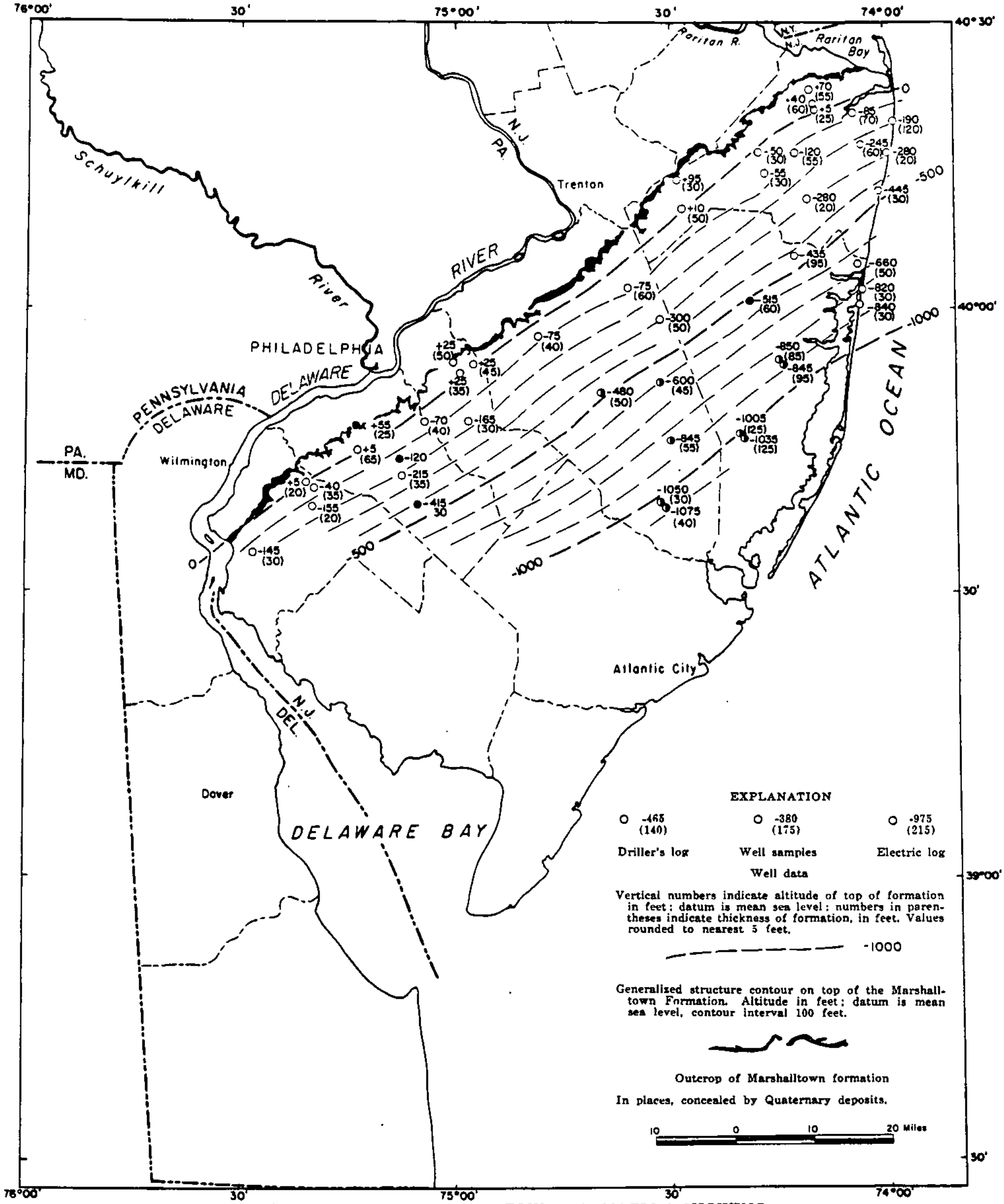

FIGURE 6.—MAP OF MARSHALLTOWN FORMATION SHOWING ITS EXTENT AND SUBSURFACE CONFIGURATION IN NEW JERSEY

WENONAH FORMATION AND MOUNT LAUREL SAND

The Wenonah Formation and the overlying Mount Laurel Sand are difficult to differentiate without detailed lithologic or paleontologic study and are combined on the geologic map of New Jersey (Lewis and Kümmel, 1910-12).

The boundary between the Matawan and Monmouth groups is considered to be the contact of the Wenonah and Mount Laurel Formations (Table 1), even though the two formations are not mapped separately. The fossils of the Mount Laurel sand are very similar to those of the overlying Navesink formation and very different from those of the underlying Wenonah formation.

The Wenonah conformably overlies the Marshalltown Formation, and in several places the contact appears to be gradational. The Wenonah, which was first described by Knapp (in Salisbury, 1899, p. 35-36) for exposures in the vicinity of Wenonah, in Gloucester County, N. J., generally consists of very fine- to coarse-grained quartz sand of various colors, but is usually light colored in the outcrop. It is not very glauconitic, but is locally micaceous. In New Jersey the Wenonah becomes fine-grained and silty downdip and is, in general, finer grained than the Mount Laurel, but in northern Delaware the Wenonah is the coarser of the two. There the Wenonah consists of rustbrown and gray, well-stratified, fine-grained micaceous quartz sand which reaches a thickness of 12 feet along the Chesapeake and Delaware Canal.

At several places the Wenonah is characterized by tubes named *Halymenites major* Lesquereux, a fossil of uncertain affinity.

The Mount Laurel Sand, originally named by Clark (Clark, Bagg, and Shattuck, 1898, p. 315, 333), from Mount Laurel in Burlington County, N. J., is a fine- to medium-grained quartz sand having a variable content of glauconite and a salt-and-pepper appearance. It becomes finer grained toward the south and southwest and in Delaware contains considerable clay. In New Jersey, the Mount Laurel usually can be distinguished from the Wenonah by the abundance of glauconite, a generally coarser grain, and by a distinctive fauna.

At most places in New Jersey, the thickness of the combined Wenonah and Mount Laurel ranges from 60 to 100 feet. The top of the Mount Laurel dips 33 to 42 feet per mile toward the southeast, but steepens to 62 feet per mile near Atlantic City (fig. 7).

Work now in progress by Ruhle shows no consistency in the relative proportions of heavy minerals to aid in the differentiation of the Mount Laurel from the Wenonah. The glauconite increases considerably downdip.

NAVESINK FORMATION

The Navesink Formation, which was named by Clark (1894, p. 336, 337) for typical exposures in the Navesink Highlands of Monmouth County, N. J., consists of glauconitic sand, silt, and clay. The lower part of the formation is rich in glauconite and is distinc-

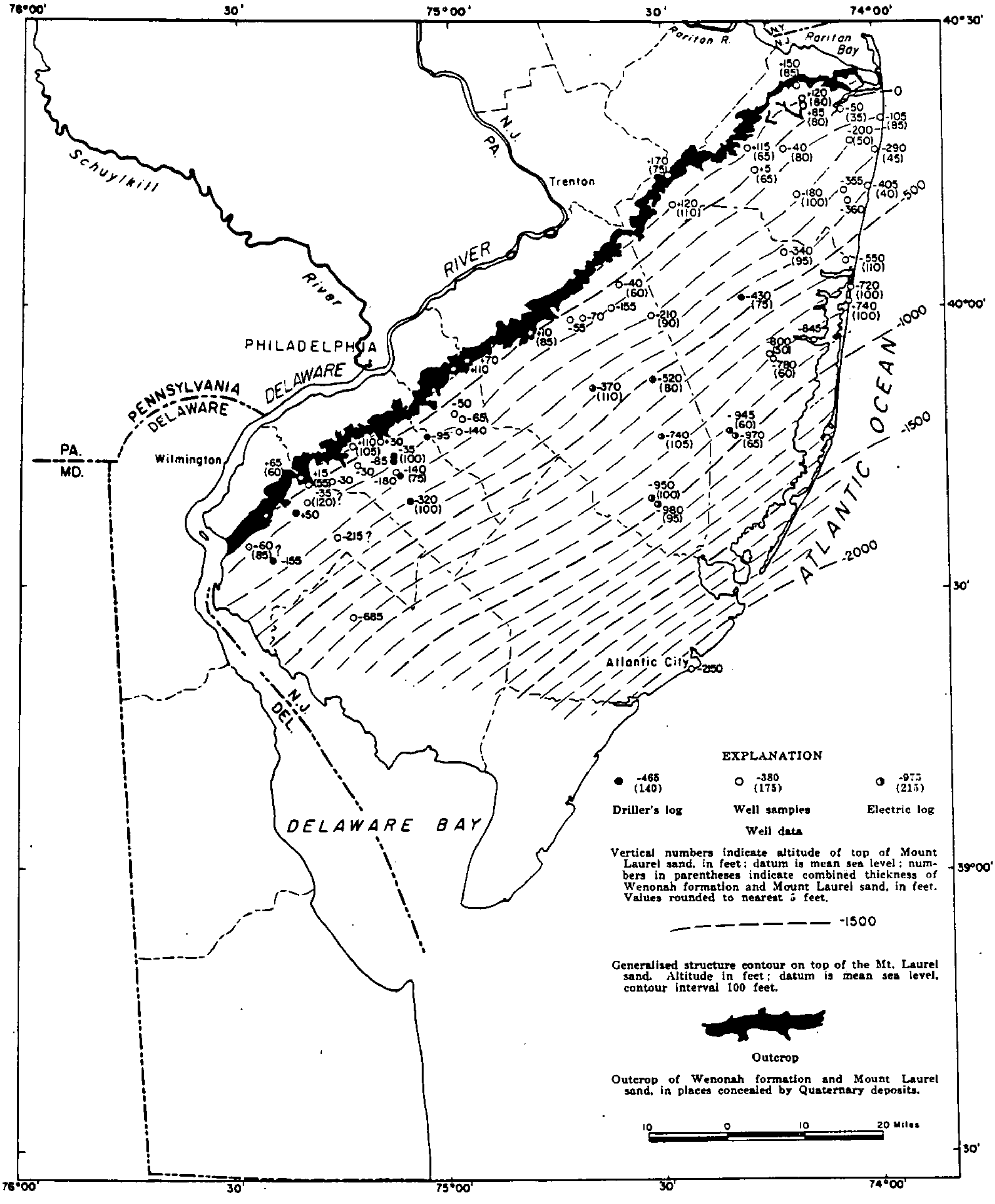

FIGURE 7.—MAP OF WENONAH FORMATION AND MOUNT LAUREL SAND SHOWING THEIR EXTENT AND SUBSURFACE CONFIGURATIONS IN NEW JERSEY

tively dark green, whereas the upper part is less glauconitic and more clayey. The base at many places is marked by a conspicuous shell bed containing *Exogyra costata* (Say), *Belemnitella americana,* (Morton), and other fossils.

In Monmouth County, and southward to the vicinity of Sykesville, Burlington County, N. J., the Navesink grades upward into the Red Bank Sand. The Red Bank is missing in the southern part of New Jersey, and the Navesink is separated from the overlying Hornerstown Sand (Paleocene) by a disconformity. The Navesink commonly is mistaken for the Hornerstown in the southern part of the State, so that it has been difficult to determine the top of the Navesink in many well logs. For this reason the accompanying map (fig. 8) is based on relatively little control.

In New Jersey, the thickness of the Navesink generally ranges from about 20 to 45 feet and does not have any apparent systematic areal variation. In Delaware, the contact of the Wenonah and Mount Laurel is very sharp, whereas the Mount Laurel and Navesink are so similar that they are regarded as a single unit by Groot, Organist, and Richards (1954).

RED BANK SAND

The Red Bank Sand was named by Clark (1894, p. 337) from typical exposures in Monmouth County, N. J., where it is most conspicuous and attains a thickness of 140 feet. It gradationally overlies the Navesink, and the contact is difficult to determine precisely in some places. It has, however, been recognized in wells farther south, for example, at Fort Dix, and in several of the test wells in Burlington and Ocean Counties of the Transcontinental Gas Pipeline Co. (fig. 9). Miller (1956) suggested that it occurs as far south as Sewell, Gloucester County, but its presence there has not been verified on paleontologic grounds. A probable equivalent of the Red Bank Sand occurs along the Chesapeake and Delaware Canal in Delaware (Groot, Organist, and Richards, 1954).

The Red Bank Sand is typically coarse-grained and in outcrop is yellow or reddish brown, owing to oxidation of the ferriferous minerals. In the subsurface, below the zone of intensive weathering, the beds are commonly dark gray. Beds of clay and sandy clay containing glauconite occur in the lower part.

Olsson (1960, p. 4) has suggested the division of the Red Bank Sand into an upper Shrewsbury Member consisting of "quartz sand, slightly glauconitic" and a lower Sandy Hook Member of "glauconitic sand, clayey, light gray, some quartz in basal beds."

Tinton Sand Member.—The Tinton Sand Member of the Red Bank Sand (considered a separate formation by the New Jersey Geological Survey) was named by Weller (1905, p. 155) for exposures near Tinton Falls in Monmouth County, N. J. It consists of 10 to 20 feet of a semi-indurated, glauconitic, clayey sand and sandy clay. It has not been identified outside of Monmouth County.

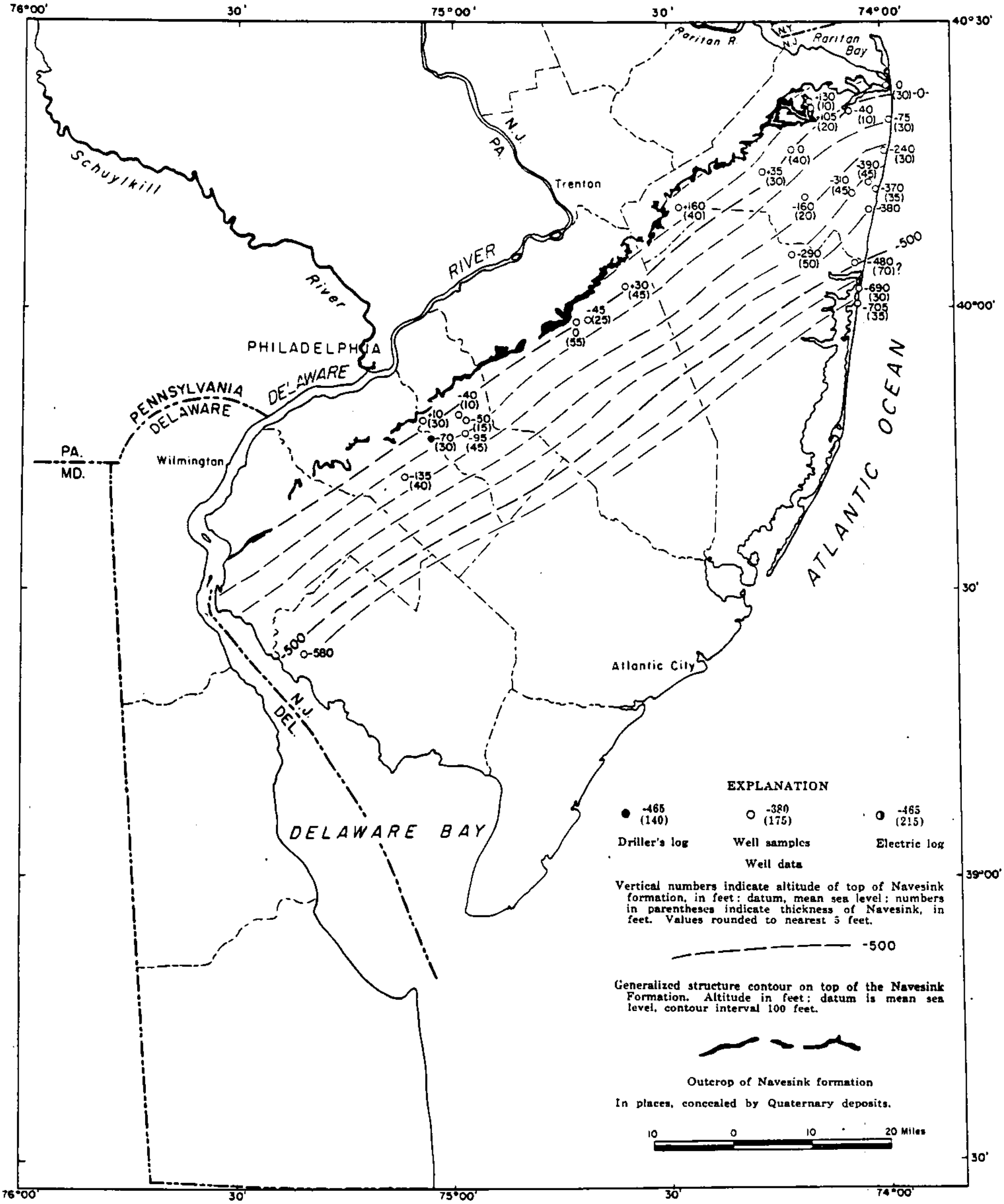

FIGURE 8.—MAP OF NAVESINK FORMATION SHOWING ITS EXTENT AND SUBSURFACE CONFIGURATION IN NEW JERSEY

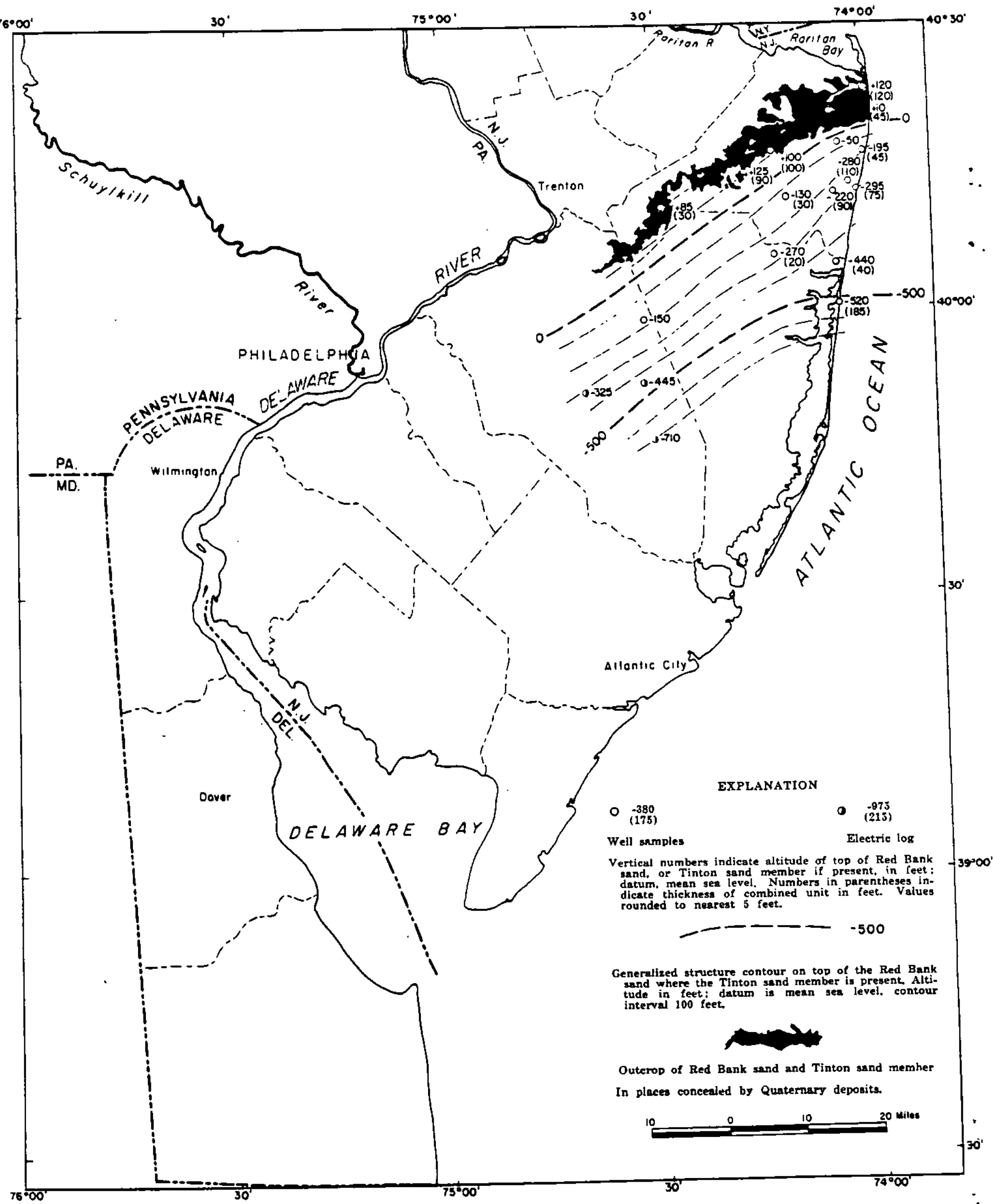

FIGURE 9.—MAP OF RED BANK SAND AND TINTON SAND MEMBER SHOWING THEIR EXTENT AND SUBSURFACE CONFIGURATIONS IN NEW JERSEY

HORNERSTOWN SAND

The term Hornerstown, named from exposures near the town of that name in Monmouth County, was first used in print by Clark (1907, p. 3), although it had previously been used in an unpublished manuscript by Knapp. It is the lowest formation of the Rancocas group.

Like the Navesink, little of the Hornerstown is a true marl. The Hornerstown is glauconitic sand (greensand) mixed with some glauconitic silt and clay and quartz sand. The proportion of glauconite decreases toward the southwest, where it becomes difficult to distinguish the Hornerstown from the overlying Vincentown Formation. Though the Hornerstown is sometimes confused with the Navesink on lithologic grounds, the fauna of the Hornerstown is of Paleocene age rather than Cretaceous. Moreover, the Hornerstown is commonly lighter green in color than the Navesink and contains less clay. Its average thickness is 30 feet.

The Hornerstown appears to overlap the Red Bank Sand of Cretaceous age. Dorf and Fox (1957, p. 8-9) believe that the contacts of the Hornerstown, the Red Bank, and possibly the Navesink are unconformabale. At least a disconformable relationship between the Hornerstown and Navesink has been observed in southern New Jersey.

The Hornerstown was originally regarded as Cretaceous, but is now assigned to the Paleocene.

Glauconitic sand resembling that of the Hornerstown has been noted at Drawers and Noxontown Pond in Delaware. However, at the present time, the Delaware Geological Survey does not recognize the Hornerstown Sand and the Vincentown Formation as distinct units of the Paleocene, accordingly figure 10 shows only the extent of the Hornerstown in New Jersey. However, the Brightseat Formation is recognized in the subsurface; it is probably equivalent to the lower part of the Hornerstown. (See Table 1).

VINCENTOWN FORMATION

The Vincentown Formation of the Rancocas group (table 1) was originally named by Clark (Clark, Bagg, and Shattuck, 1898, p. 316-338) from Vincentown in Burlington County, N. J., who regarded it as Cretaceous. Its Tertiary age was first pointed out by Cooke and Stephenson (1928). It was regarded as early Eocene by some (Fox and Olsson, 1955; Miller, 1956; Dorf and Fox 1957) and as Paleocene by others (McLean, 1952, 1953; Hofker, 1955). Paleontological evidence favors assignment to the Paleocene. The contact of the Vincentown and the underlying Hornerstown is gradational. According to Loeblich and Tappan (1957), the Vincentown contains planktonic foraminifera similar to those in the upper part of the Hornerstown.

In and near the outcrop, the Vincentown consists of two facies: (1) a calcareous or limesand facies, locally semiconsolidated and highly fossiliferous, and (2) a quartz sand facies of variable glauconite content.

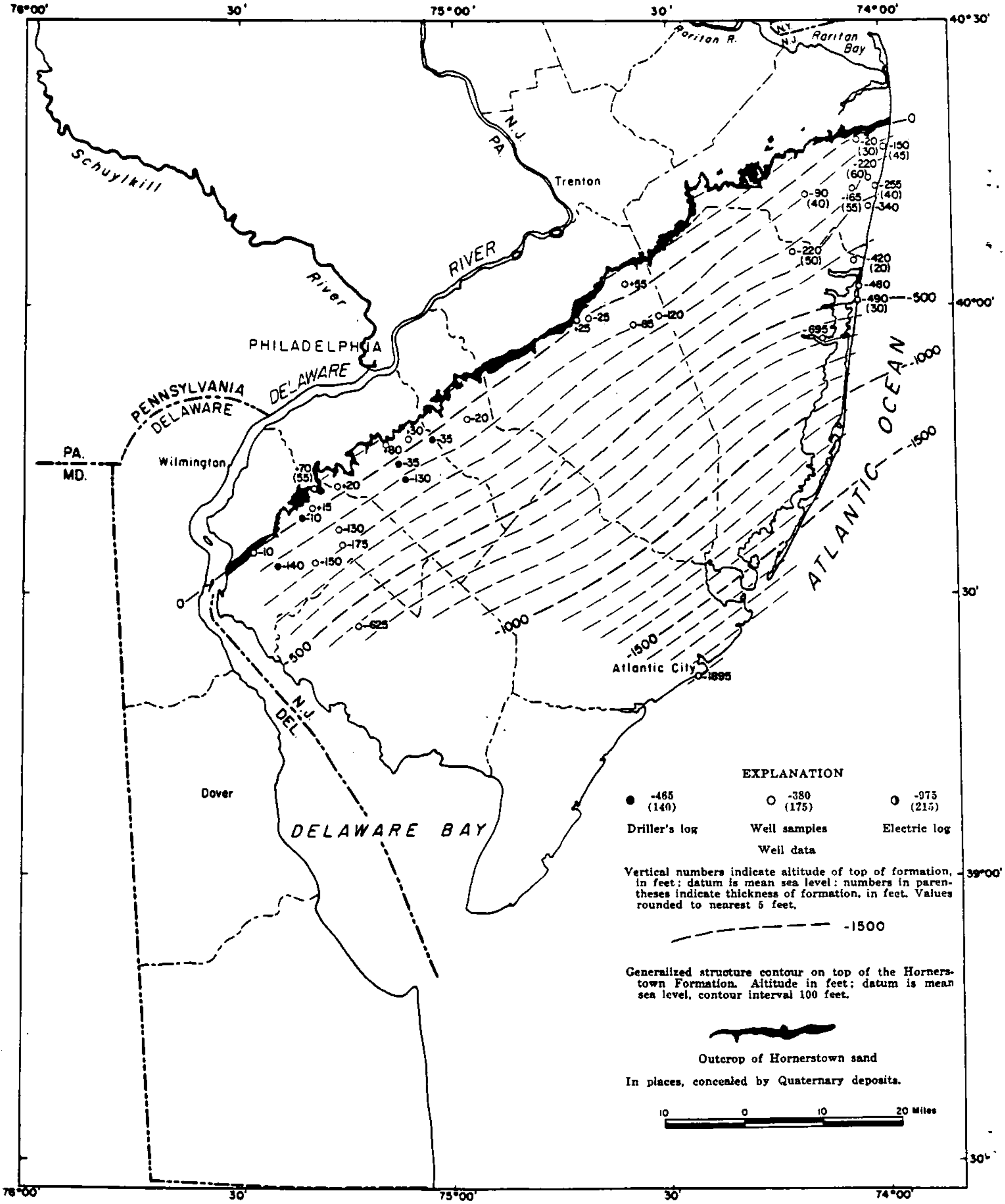

FIGURE 10.—MAP OF HORNERSTOWN SAND SHOWING ITS EXTENT AND SUBSURFACE CONFIGURATION IN NEW JERSEY

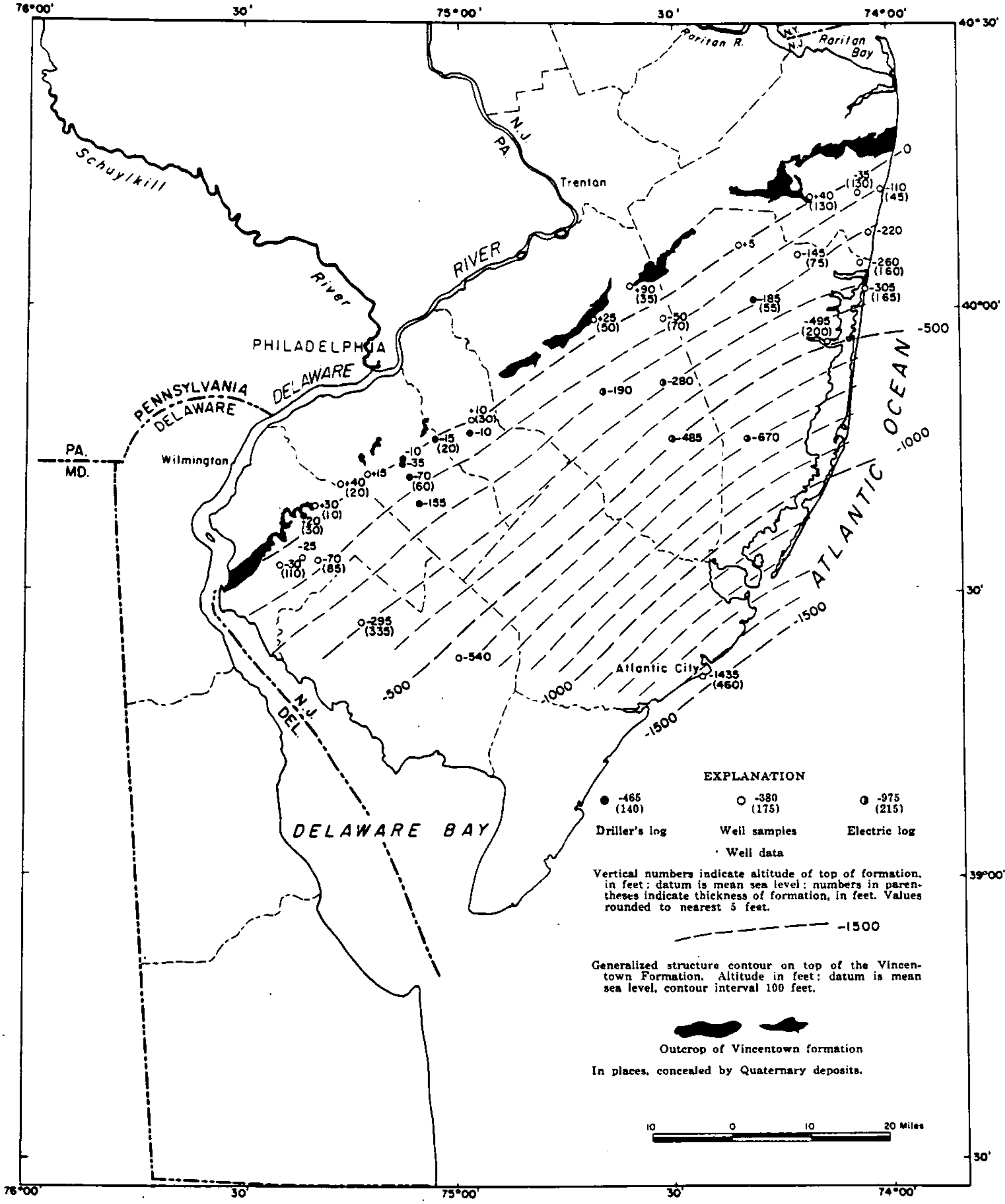

FIGURE 11.—MAP OF VINCENTOWN FORMATION SHOWING ITS EXTENT AND SUBSURFACE CONFIGURATION IN NEW JERSEY

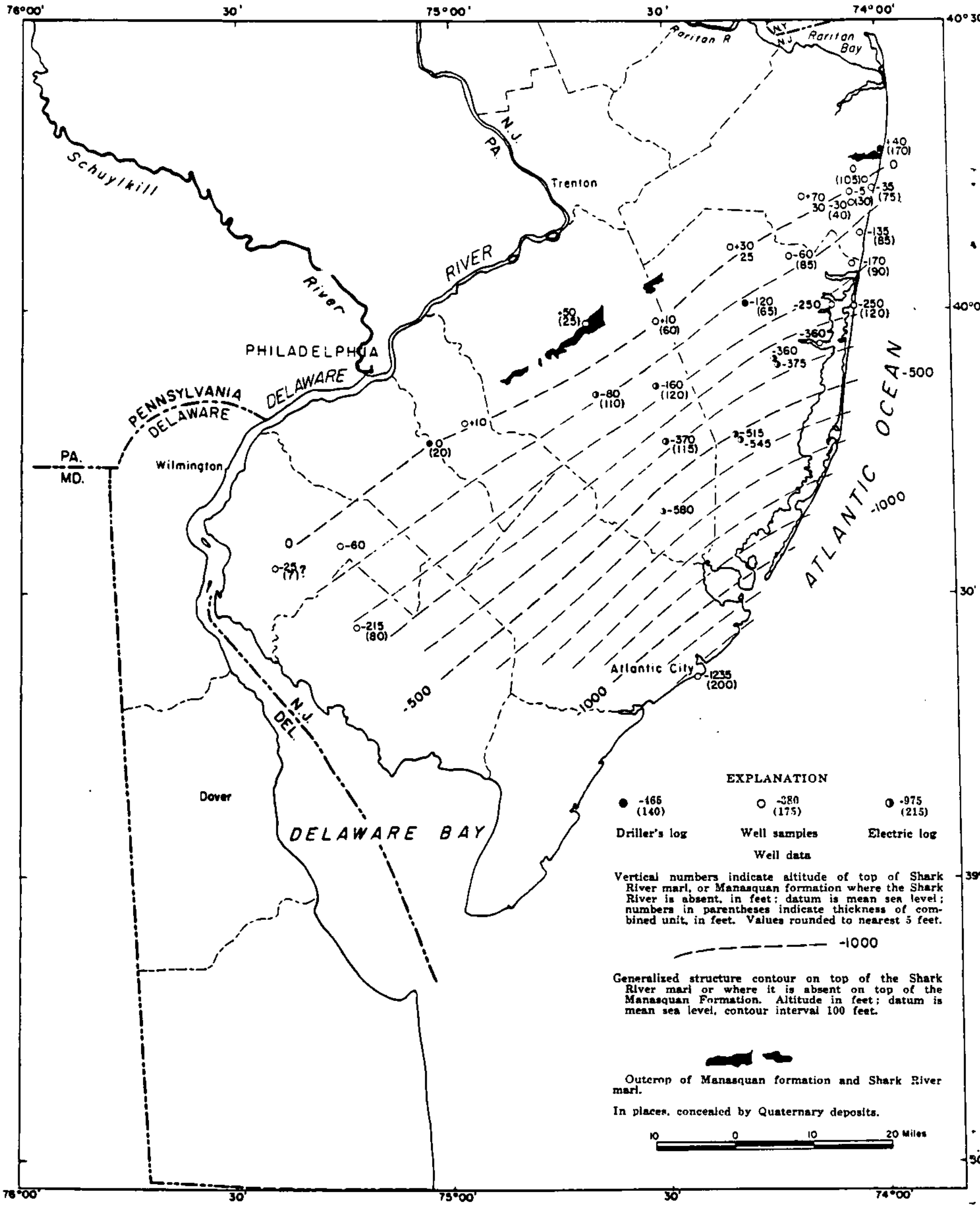

FIGURE 12.—MAP OF MANASQUAN FORMATION AND SHARK RIVER MARL SHOWING THEIR EXTENT AND SUBSURFACE CONFIGURATIONS IN NEW JERSEY

Downdip the sandy beds are cemented or are represented by beds richer in clay and glauconite. The formation thickens from 10 to 130 feet in outcrop to as much as 460 feet downdip at Atlantic City, N. J. (fig. 11). The top of the formation dips 15 to 35 feet per mile until a depth of about 200 feet below sea level is reached; below that depth the dip steepens and exceeds 40 feet per mile near Atlantic City (fig. 11). Ewing, Woollard, and Vine (1939, 1940) interpreted the V-zone of their seismic surveys as the top of the Vincentown. It is believed that this indurated zone is not necessarily the top of the formation and may represent different horizons. Consequently, the V-zone has not been considered in preparing figure 11 which shows the extent and subsurface configuration of the Vincentown in New Jersey.

MANASQUAN FORMATION AND SHARK RIVER MARL

Although faunally distinct, the Manasquan and Shark River probably form a single lithologic unit; they are so considered in this report. The Manasquan Formation, named by Clark (1893, p. 205, 206) from typical exposures near Manasquan, in coastal Monmouth County, N. J., consists of glauconite (greensand) in the lower part, and of a fine-grained sand mixed with greenish-white clay in the upper part. The term Shark River was first used by Conrad (1865), but the unit was defined more completely by Clark (1893, p. 208-210). It consists of a fossiliferous glauconitic clay and silt and is known only from Monmouth County, N. J. However, the two formations are very difficult to separate. The fauna of the Manasquan is correlated with the Wilcox Group (lower Eocene) of the Gulf Coast, whereas that of the Shark River has affinities with the Claiborne Group (middle Eocene). (Dorf and Fox, 1957).

In outcrop, the maximum combined thickness of the Manasquan and Shark River is about 40 feet, but in the subsurface the combined unit thickens to about 200 feet at Atlantic City, N. J. (fig. 12).

PINEY POINT FORMATION

Marine sediments of late Eocene age that are correlative with the Jackson group of the Gulf Coast have been recognized in the subsurface of Delaware (Marine and Rasmussen, 1955) and southern New Jersey (Richards, 1956, p. 84). Otton (1955, p. 85) named the "glauconitic sands and interspersed shell beds of Jackson age" of southern Maryland the Piney Point Formation from the location of a well at Piney Point, St. Mary's County, Md. On the basis of lithology, microfossils, and discontinuous tracing using well logs, the name was extended by Rasmussen and others (1957, p. 61-67) to a similar unit on the Eastern Shore of Maryland, and by Rasmussen, Groot, and Depman (1958) to fossiliferous, glauconitic sand and clay penetrated in a test well at Dover Air Force Base, Del. (no. 164, Table 2). Rasmussen (written communication, 1957) gave the name Piney Point Formation to the sediments of Jackson age penetrated by a deep well at Atlantic City, N. J.; Parker and others (in press) follow this usage in their report on the water resources of the Delaware River basin and adjacent coastal New Jersey. The Piney Point Formation, as defined herein, thus comprises all the sediments of late Eocene (Jackson) age in New Jersey and Delaware. Insofar as is known, the Piney Point does not crop out in either New Jersey or Delaware; all lithological and paleontological data are from well samples.

The Piney Point Formation consists of fine- to coarse-grained glauconitic, "salt-and-pepper" sand and greenish-gray clay. Clay and silt dominate at Atlantic City, N. J. (well no. 137, Table 2), and south of Bridgeville, Del. (well no. 166) (Rasmussen, Groot, and Depman, 1958, p. 29), but in central Delaware the formation is more sandy. In southern New Jersey, the Piney Point has only been identified in four wells (nos. 137, 154, 156 and 157, Table 2), so that its extent and character there are largely unknown. Although its maximum known thickness is 290 feet at Atlantic City, the Piney Point has not been recognized in deep wells farther north, hence it probably pinches out or is overlapped by the Kirkwood Formation of middle Miocene age in that direction. The distribution of the Piney Point Formation in Delaware as shown in figure 13 must be regarded as tentative pending the completion of work on well samples now in progress at the Delaware Geological Survey.

FORMATIONS OF LATE TERTIARY AND QUATERNARY AGE

Unconformably overlying the formations of Cretaceous, Paleocene, and Eocene age is a sequence of deposits ranging in age from middle Miocene to Recent. Because of the lack of reliable subsurface information, structural contour maps of these formations are omitted.

Kirkwood Formation.—The lower of these units is the Kirkwood formation, which is of middle Miocene age and equivalent to the Calvert, Choptank, and St. Mary's formations of the Chesapeake Group of Maryland. The Kirkwood Formation, which was named by Knapp (1904, p. 81, 82) from deposits near Kirkwood in Camden County, consists of fine-grained, micaceous, quartzose sand, and beds of silt and clay of variable thickness. The Shiloh marl member, a highly fossiliferous clayey or silty sand, marks the top of the Kirkwood in parts of southern New Jersey.

The Kirkwood is largely of marine origin, as contrasted with the younger formations, which are mostly nonmarine. It lies on a buried surface of low relief eroded on formations ranging from the Piney Point Formation to the Navesink Formation. In thickness the Kirkwood ranges from less than 100 feet in much of the outcrop to possibly more than 700 feet beneath the mouth of Delaware Bay.

Cohansey Sand.—The Cohansey Sand (Miocene?), named by Kümmel and Knapp (1904, p. 132) from deposits along the Cohansey River in Cumberland County, N. J., consists chiefly of light-colored quartzose, somewhat micaceous sand, and lenses of silt and clay. The deposits are thought to be mostly nonmarine. The age of the Cohansey is uncertain owing to the almost complete lack of fossils. The apparent absence of a significant unconformity at the base, and the difficulty of identifying the contact of the Cohansey and the underlying Kirkwood suggest that the Cohansey is probably of late Miocene age and that it may be nonmarine equivalent of the marine Yorktown Formation of Virginia.

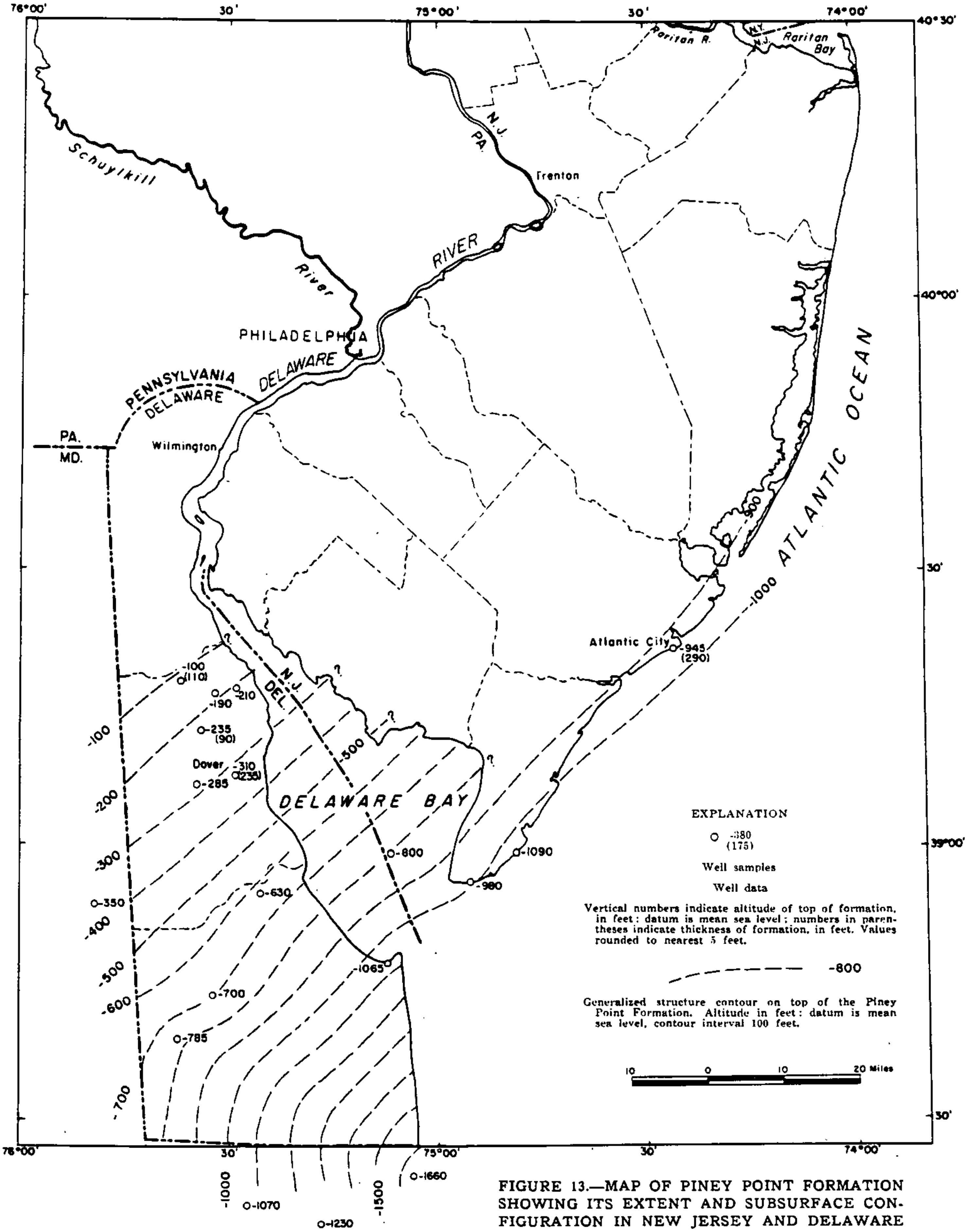

FIGURE 13.—MAP OF PINEY POINT FORMATION SHOWING ITS EXTENT AND SUBSURFACE CONFIGURATION IN NEW JERSEY AND DELAWARE

Except where covered by a veneer of Pleistocene deposits, the Cohansey is exposed in much of the outer Coastal Plain of New Jersey. In Delaware the Pleistocene deposits entirely conceal the Cohansey so that its extent and character are not as well known there. Its maximum known thickness is about 265 feet, at Atlantic City, N. J.

Deposits of Pliocene (?) and Pleistocene age.—Pleistocene sands and gravel generally form a veneer on the older formations throughout much of the Coastal Plain; deposits of Pliocene (?) age, known as the Beacon Hill Gravel occur only as thin, isolated remnants capping hills in Ocean, Monmouth, and Burlington Counties and possibly elsewhere in New Jersey. The Bryn Mawr Gravel of northern Delaware may be the equivalent of the Beacon Hill.

In New Jersey, the deposits of Pleistocene age are divided into the Bridgeton, Pensauken, and Cape May formations, but in places there are unnamed deposits whose correlation is uncertain. The Bridgeton and Pensauken formations are nonmarine, whereas the Cape May Formation is partly marine near the coast. At most places the Pleistocene deposits are less than 50 feet thick, though their aggregate thickness may exceed 175 feet in parts of Cape May County and elsewhere in coastal New Jersey.

Recent deposits.—Deposits of Recent age include thin alluvial deposits along present streams, fresh-water and tidal-marsh deposits, beach sands, and dune sands. Such deposits rarely are more than a few tens of feet thick.

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