Physical Properties and Mineralogy of Selected Samples of the Sediments From the Vicinity of the Brookhaven National Laboratory, Long Island, New York

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By GEORGE T. FAUST

STUDIES OF SITES FOR NUCLEAR ENERGY FACILITIES—
BROOKHAVEN NATIONAL LABORATORY

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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ABSTRACT

Twelve samples of unconsolidated sediments were collected from portions of cores obtained from seven wells near Brookhaven National Laboratory, Long Island, New York These samples were analyzed by mechanical, mineralogical, and cation-exchange methods. The results of the mechanical analyses are interpreted by means of camparison with the standard compilations in the literature and by using the methods of D. J. Doeglas. The mineralogic methods used in the identification and semiquantitative estimation of the phases include optical, X-ray diffraction, differential thermal analysis, electron microscopy, and radioactive measurements. The cation-exchange capacities are explained in terms of the mineralogic compositions of the specimens.

The results of the various techniques used in this investigation were critically evaluated to determine the petrographic significance of the data on the heavy, micaceous. and clay minerals. These and other pertinent data from the literature are interpreted in terms of work done in the Atlantic Coastal plain by Lincoln and Clarissa Dryden, by J. J. Groot and H. D. Glass, and by J. P. Owens.

INTRODUCTION

In 1951 the U.S. Geological Survey examined 12 samples of unconsolidated sediments collected from seven wells near the Brookhaven National Laboratory, Long Island, N.Y., to assess their properties when in contact with ground water. These samples were examined using mineralogic, petrologic, and chemical methods. The investigation was undertaken on behalf of the Division of Reactor Development, U.S. Atomic Energy Commission. The author supervised the investigations, except for the part dealing with the radioactive measurements, and correlated the various analytical data. The detailed studies are now available to scientists interested in the sedimentary petrography of the Atlantic Coastal Plain.

The study of the sediments described in this report was suggested by Wallace de Laguna, formerly with the U.S. Geological Survey, and now with Oak Ridge National Laboratory, who collected the samples and described their occurrence. His studies on the geology of an area in the vicinity of the Brookhaven National Laboratory (de Laguna, 1963) should be consulted for further details.

The mechanical analyses and optical mineralogic studies were made by Theodore Woodward and Joseph R. Houston; the X-ray-diffraction identifications were made by Marie L. Lindberg; the cation exchange capacities were determined by Margaret D. Foster; and the electron microscope photographs were prepared and interpreted by Edward J. Dwornik and Malcolm Ross, all of the U.S. Geological Survey. James P. Owens, U.S. Geological Survey, determined the monazite content of some beach sands collected by Wallace de Laguna near the area where the wells were drilled; and the radioactive constituents in the samples were studied by the Instrumentation and Health Physics Department of the Brookhaven National Laboratory.

DESCRIPTION AND LOCATION OF SAMPLES

The samples were all obtained from cores taken from test wells. The following descriptions of the samples were made by Wallace de Laguna, U.S. Geological Survey.

Typical samples of the upper, relatively clean, glacial outwash, upper Pleistocene, and probably from the Ronkonkoma Moraine.

Sample 1, well S6457, from a depth of 83–86 ft. Sand, fine to coarse, tan, containing some gravel, fine to medium.

Sample 2, well S6460, from depth of 71–74 ft. Sand, fine to coarse, tan, containing fine to coarse gravel scattered throughout.

Sample 3, well S6458, from depth of 73–76 ft. Sand, fine to coarse, light yellowish, tan, with some fine to coarse gravel.

Typical sample of the finer glacial outwash, upper Pleistocene.

Sample 4, well S6458, from depth of 109–112 ft. Sand, light-brown, chiefly fine grained, micaceous. Some medium and coarse grains, few medium gravel pebbles.

Typical sample of the unit in the lower part of the glacial outwash, unidentified unit at the base of the upper Pleistocene.

Sample 5, well S6456, from depth of 183–186 ft. Sand, fine to medium, clayey, dark greenish-gray, micaceous.

Samples from the Gardiners Clay. Sample 6 is typical of the silty clay zone and sample 7 is typical of the sandy parts.

Sample 6, well S6456, from depth of 202–205 ft. Clay, silty and fine sandy, greenish, gray when wet, dries to gray.

Sample 7, well S6460, from depth of 184–186 ft. Clay, greenish-gray, contains much coarse, angular sand and "grits", also some coarse, well rounded gravel.

Typical samples of the Magothy(?) Formation.

Sample 8, well S6459, from depth of 155–158 ft. Sand, medium to coarse, clayey (muddy), dark gray, few coarse, well rounded gravel pebbles.

Sample 9, well S6409, from depth of 607–616 ft. Sand, fine, clayey, light gray, with very thin streaks of lignite.

Typical sample of the clay member of the Raritan Formation.

Sample 10, well S6434, from depth of 1,141–1,151 ft. Clay, tough, gray, thin dark gray, solid clay bands alternating with slightly thicker, light gray, silty clay bands.

Typical samples of the relatively clean Lloyds Sand Member of the Raritan Formation.

Sample 11, well S6434, from depth of 1,467–1,476 ft. Sand, coarse, and fine to medium gravel, slightly clayey, purplish-pink color.

Sample 12, well S6409, from depth of 1,390–1,402 ft. Sand, coarse, white, clayey, with fine to coarse gravel.

Weiss (1954) gives a map of the area where these wells are located and describes the stratigraphy of the parts of the wells that he studied; de Laguna (1963) describes the geology in detail and gives more information on the location of the cores reported here.

MECHANICAL ANALYSIS

The mechanical analyses were made on quartered samples obtained after a careful mixing of the original samples. The samples were wet sieved by hand through Tyler sieves; grain diameters are shown in table 1. The material passing the 250-mesh sieve (0.0625 mm) was separated into silt (0.0625–0.00391 mm) and clay ($<$0.00391 mm) by sedimentation in water. For samples 11 and 12, a dispersing agent was used to separate the silt from the clay fractions, and 50 cc of a mixture consisting of 37.70 g of sodium hexametaphosphate and 7.94 g of Na_2CO_3 dissolved in 1000 ml of water was used to disperse them. The clay fractions were then centrifuged to remove the sodium hexametaphosphate.

The samples were selected from cores of several test wells and are believed to be typical of the formations from which they were taken. Such small sampling, however, is not necessarily representative.

TABLE 1.—*Size analyses of 12 unconsolidated sediments*

[For description of the samples see Introduction. All samples from Long Island, N.Y. Mechanical analyses on the basis of the Wentworth scale by Theodore Woodward, U.S. Geol. Survey]

Sample	Pebble (4–64 mm)	Granule (2–4 mm)	Very coarse sand (1–2 mm)	Coarse sand (0.5–1 mm)	Medium sand (0.25–0.5 mm)	Fine sand (0.125–0.25 mm)	Very fine sand (0.0625–0.125 mm)	Silt (0.00391–0.0625)	Clay ($<$0.00391)	Total
1		0.48	6.21	33.53	50.28	7.03	0.46	2.01		100.00
2		6.95	12.98	23.80	53.28	2.70	.23	.06		100.00
3		1.97	4.40	20.23	59.18	7.10	2.98	4.14		100.00
4		.94	2.42	5.91	53.84	30.11	4.50	2.28		100.00
5			.07	.74	51.65	31.72	4.52	8.76	2.54	100.00
6				.64	13.10	7.44	4.62	36.88	37.32	100.00
7			10.92	15.79	11.37	4.24	1.46	13.99	42.23	100.00
8		1.40	5.56	18.38	47.08	9.04	2.75	9.50	6.29	100.00
9			.04	1.62	71.98	6.49	3.81	9.06	7.00	100.00
10			.02	.01	.27	1.44	4.08	51.41	42.77	100.00
11	1.59	8.26	20.45	14.06	17.31	7.43	3.83	26.96	.11	100.00
12		9.94	35.85	9.36	10.64	5.02	2.65	16.56	9.98	100.00

The results of the mechanical analyses are given in table 1 and are plotted on a triangular sand-silt-clay diagram in figure 1 by using the nomenclature of Shepard (1954). In plotting, the small amounts of granules were added to the sand fraction. The Pleistocene sediments—samples 1, 2, 3, 4, and 5—are all sands which contain some granules; samples 6 and 7 from the Gardiners Clay are a silt-clay sand and a clayey sand, respectively; samples 8 and 9 from the Magothy(?) Formation are sands; the clay member of the Raritan Formation (sample 10) is a clayey silt; and the two samples (Nos. 11 and 12) of the Lloyd Sand Member of the Raritan Formation are silty sands.

The size compositions of these sediments are also plotted as cumulative curves in figures 2 to 5. The cumulative curves for the sands of Pleistocene age, chiefly medium sands, are shown in figure 2.

The Gardiners Clay of Pleistocene age is represented by samples 6 and 7 (fig. 3). Sample 6 is an almost uniform mixture of sand,
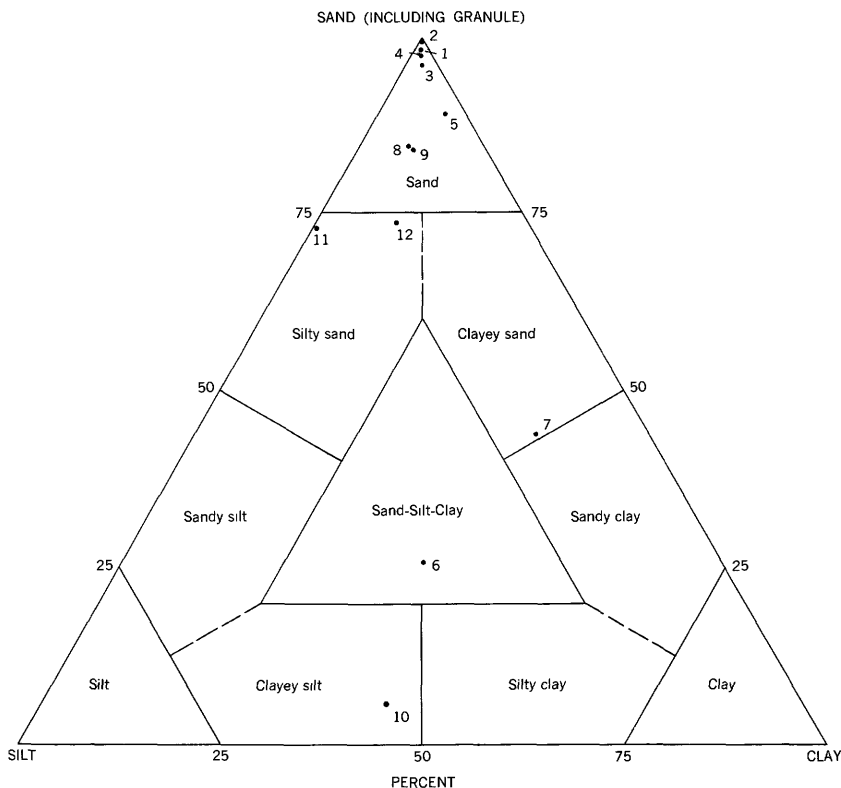
FIGURE 1.—Graphical representation of the size analyses of the twelve samples from Long Island, N.Y. The small amounts of granule-size fraction are added to the sand fraction. The nomenclature is after Shepard (1954).
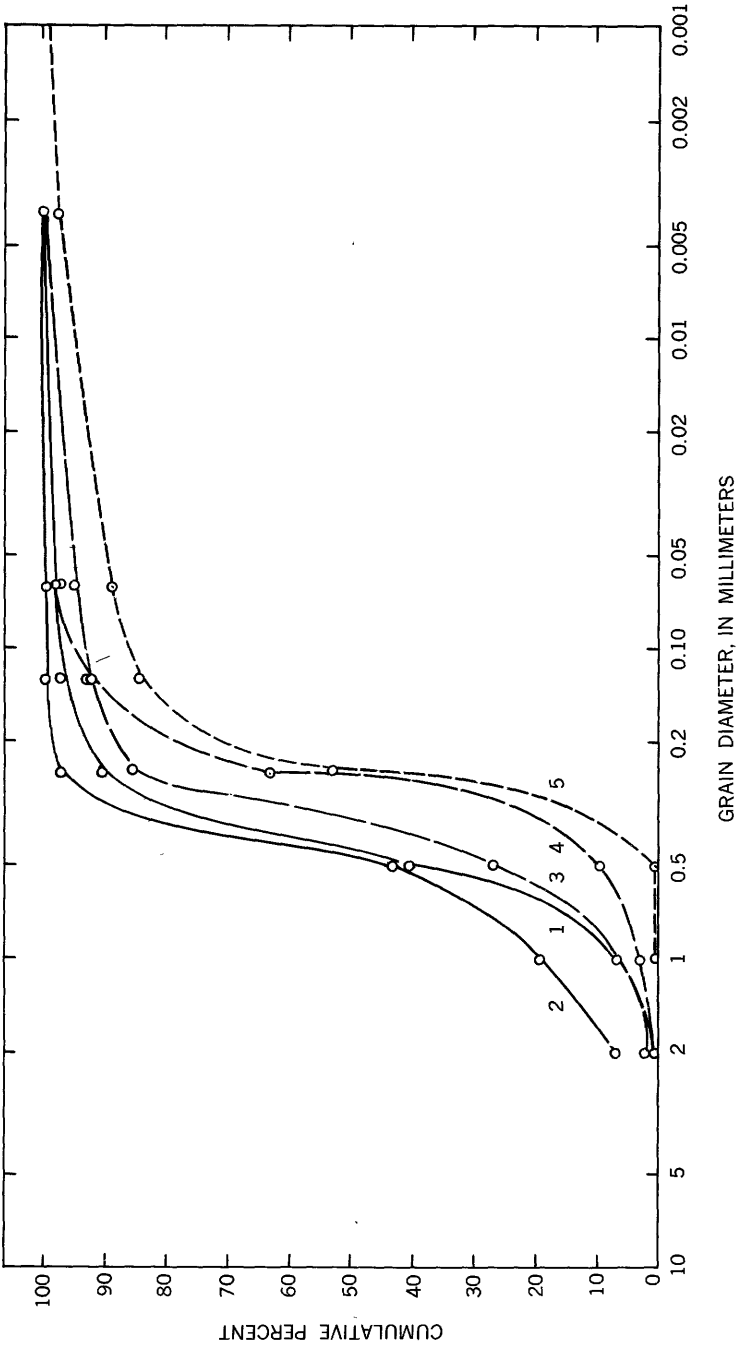
FIGURE 2.—Cumulative curves of the particle-size distribution in five Pleistocene sediments (samples 1–5) from Long Island, N.Y.
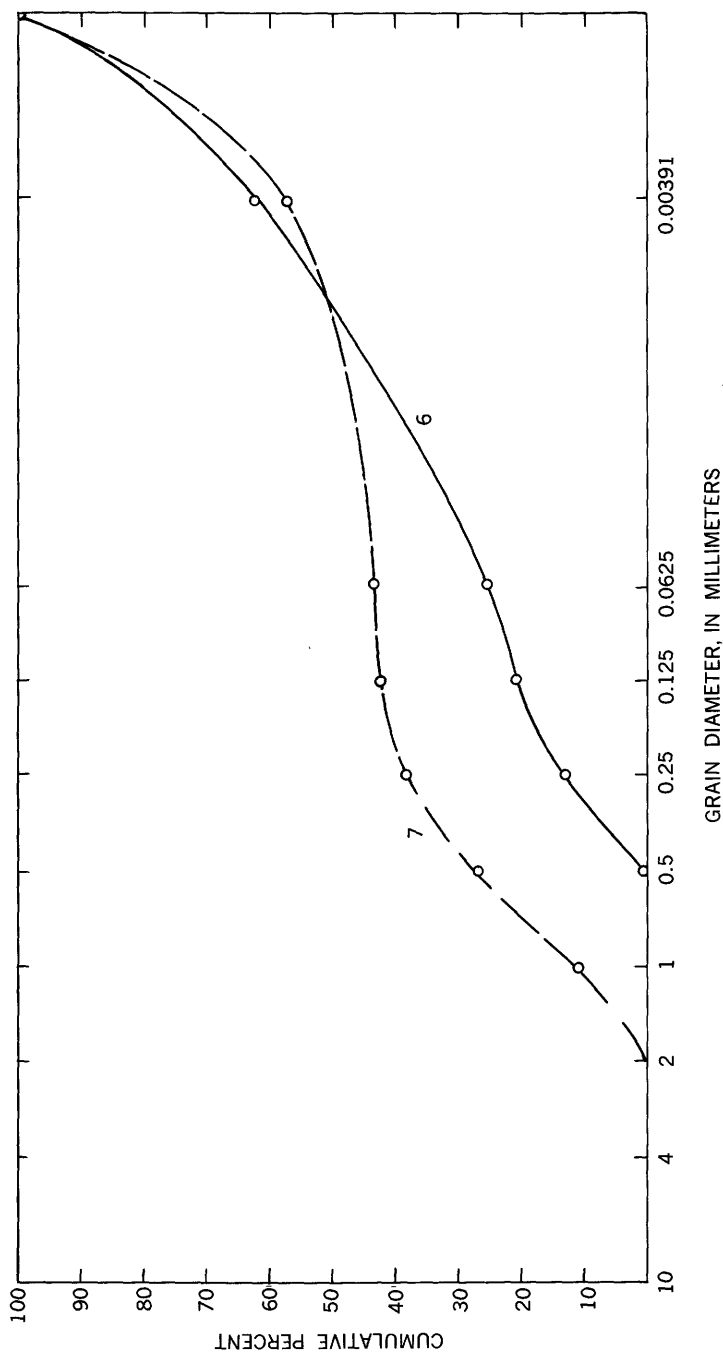
FIGURE 3.—Cumulative curves of the particle-size distribution in two samples from the Gardiners Clay of Pleistocene age from Long Island, N.Y.

silt, and clay particles, whereas sample 7 shows distinctly more of the sand and less of the silt particles.

The cumulative curves of the particle sizes of two medium sands from the Magothy(?) Formation of Late Cretaceous age are shown in figure 4.

Mechanical analyses of samples 11 and 12 of the Lloyd Sand Member of the Raritan Formation, and of sample 10, a clay of the same formation, are shown as cumulative plots in figure 5. The Lloyd Sand contains a significant amount of the very coarse sand and a small amount of granule-sized particles. The clay member of the Raritan Formation, sample 10, shows an unusual curve similar in shape (being concave downward) to that of the glacial clay from Hasketon, Suffolk, England, included in the collection of mechanical analyses of sediments by Boswell (1918) and to two river terrace soils in the Middle River of Virginia described by Carroll (1959). Doeglas (1946) shows that such curves result from the selective removal of the coarser fractions of a more heterogeneous sediment. Examination of the extensive collections of data and curves of mechanical analyses of sediments of Udden (1914), Lugn (1927), Wentworth (1932), and Doeglas (1946, 1950) shows that similar curves are characteristic of material that has been separated from the coarser fractions of the parent sediment, carried in suspension, and later deposited by settling.

MINERALOGIC COMPOSITION

For such complex assemblages of minerals as make up these sediments, a variety of mineralogic techniques—optical, X-ray diffraction, differential thermal analysis, and electron microscopy—are needed to determine their identity and relative abundance. The sized fractions from the mechanical analyses provided an effective concentration of some of the minerals and made a more accurate analysis possible.

OPTICAL STUDIES

After determining the identity of the various minerals present in the samples, quantitative measurements were made. The usual counting methods were used and the number of grains counted ranged from 400 to 1,240 in each size fraction, except for a few grains of coarser size. In the size fractions designated pebble, granule, very coarse sand, coarse sand, medium sand and fine sand, the grains were counted under a binocular microscope. Grains of the very fine sand, silt, and clay sizes were counted with a mechanical stage on a petrographic microscope. For samples 5 to 12, grain counts were not determined by optical methods for the silt and clay fractions. The results of these microscopic studies are given in table 2.

J. R. Houston measured the optical constants for nine minerals occurring in the sediment from a glacial outwash plain (sample 1) and his data are given in table 3. They illustrate the variable chemical character of some of the mineral species.

FIGURE 4.—Cumulative curves of the particle sizes of two samples from the Magothy(?) Formation of Late Cretaceous age from Long Island, N.Y.
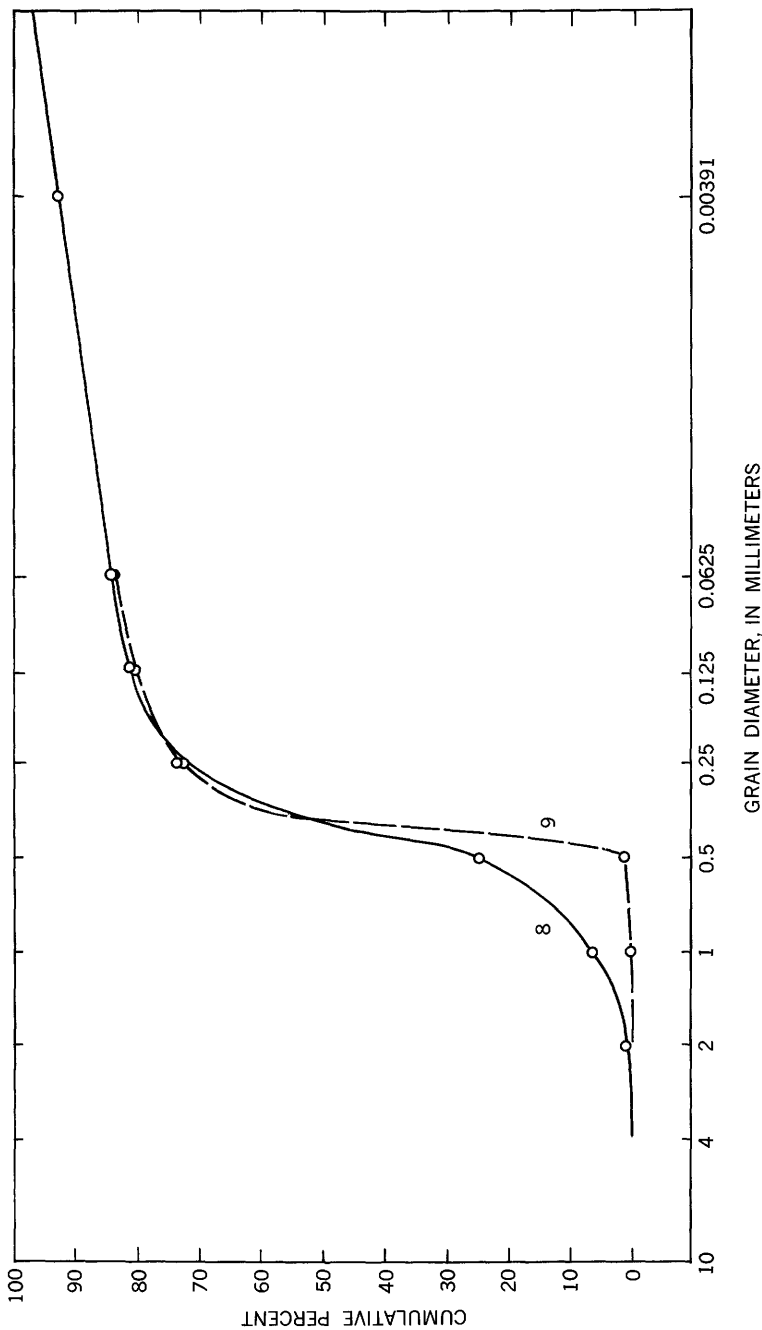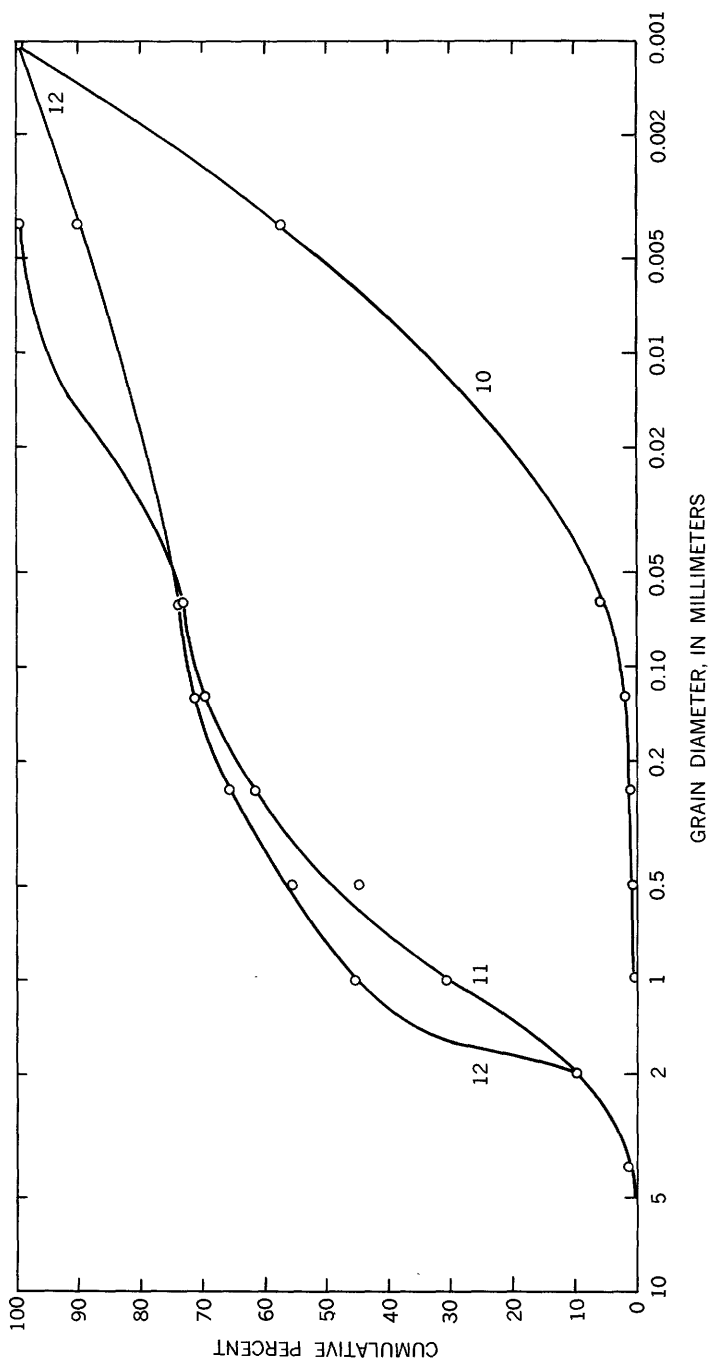
FIGURE 5.—Cumulative curves of the particle sizes of two samples from the Lloyd Sand Member of the Raritan Formation (samples 11 and 12) and of one sample from a clay member (sample 10), all of Late Cretaceous age. These samples are from Long Island, N.Y.

TABLE 2.—*Minerals identified in the*

[Determinations for samples 1–6 and 8 made by Joseph R. Houston and for samples 7 and 9–12 by Theodore

Size fraction	Light minerals								Micaceous minerals					
	Quartz	Alkali feldspar	Rock fragment [2]	Altered feldspar	Plagioclase	Lignite	Nonmagnetic opaque [3]	Total light minerals in size fraction (percent)	Chlorite (may include green biotite)	Muscovite	Biotite	Hydromica (?) [4]	Glauconite	Total micaceous minerals in size fraction (percent)
Sample														
Granule	77		23					100						0
Very coarse sand	89	4	7					100						0
Coarse sand	90(−)	7	3				T	100(−)		T				T
Medium sand	91(−)	6	3				T	100(−)	T	T	T			T
Fine sand	75(−)	12	4		T		1	92(−)	3	T	T			3(+)
Very fine sand	80(−)	10	4		T		1	95(−)	1	T	T			1(+)
Silt and clay	74(−)	7					2	83(−)	7		7	2		16(+)
Sample														
Granule	96		4					100						0
Very coarse sand	93(−)	2	5					100(−)		T	T			T
Coarse sand	92(−)	4	2				T	98(−)		1	1			2
Medium sand	92(−)	6	1				T	99(−)		1	T	T		T
Fine sand	79(−)	8	2				4	93(−)	1	T	T	T		1(+)
Very fine sand [6]	75(−)	13	2				5	95(−)		T	T			T
Silt and clay	75(−)	15					3	93(−)				3		3
Sample														
Granule	94		6					100						0
Very coarse sand	97(−)	2	1					100(−)		T	T			T
Coarse sand	99(−)	1	T					100(−)		T	T			T
Medium sand	98(−)	2	T					100(−)	T	T	T			T
Fine sand	93(−)	5	T		T		T	98(−)	T	T	T			T
Very fine sand	89(−)	8	T				T	97(−)	T					T
Silt and clay [7]	83(−)	9	T				2	94(−)	T		T	2		2(+)
Sample														
Granule	91		9					100						
Very coarse sand	94(−)	3	3					100(−)		T	T			T
Coarse sand	91	3	2					96		3	1			4
Medium sand	90(−)	7	2				1	100(−)	T	T	1			T
Fine sand	85(−)	8	1		T		1	95(−)			T			T
Very fine sand	71(−)	10					1	82(−)			T			T
Silt and clay	66(−)	12			T			78(−)			(8)			5
Sample														
Very coarse sand	59(−)					35		94(−)		6		T		6(+)
Coarse sand [9]	30(+)	T				14		44(+)	1	22		27(−)		50(−)
Medium sand	89(−)	4				3		96(−)	1	T				1(+)
Fine sand	82(−)	7				4		93(−)	T	T				T
Very fine sand	77(−)	6				5		88(−)	1	T				1(+)
Sample														
Coarse sand	85(−)	1						86(−)					14	14
Medium sand	61(−)	1		38				100(−)						
Fine sand	18	1		80				99	1					1
Very fine sand	25	1		72				98	2					2

Footnotes at end of table.

sediments, in percent by grain count

Woodward.   Explanation of symbols: T, trace; or <0.5 percent; T?, uncertainty as to abundance]

| | | | | | Heavy minerals arranged in the order of the "full suite" of Dryden and Dryden (1956) [1] | | | | | | | | | | | | | |
Zircon	Tourmaline	Staurolite	Garnet	Epidote	Zoisite or clinozoisite	Kyanite	Sillimanite	Hornblende	Amphibole-chlorite	Rutile	Andalusite	Hypersthene	Pyroxene	Apatite	Pyrite (marcasite)	Magnetic opaque	Total percent of heavy minerals in size fraction less the micas	Percentage weight of size fraction
1																		
																	0	0.48
																	0	6.21
	T	T	T									[5] T				T	T	33.53
		T	T						T			T				T	T	50.28
			1	1					2							1	5(+)	7.03
T	T	1	1	1	T?	T			1	T		T				1	4(+)	.46
1		T	T			T			T	T?	T?	T?		T			1(+)	2.01
2																		
																	0	6.95
																	T	12.98
					T	T										T	T	23.80
	T?	1	1						T			T?				T	1(+)	53.28
T		1	1	1	T?	T			2							2	6(+)	2.70
1	T	1	1						2							T	5(+)	.23
T			T						2			1		1			4(+)	.06
3																		
																	0	1.97
																	0	4.40
																	0	20.23
																T	T	59.18
T	T?	T	T	1	T				1			T?				T	2(+)	7.10
T		T	1	1		1	T					T	T?				3(+)	2.98
T		1	1	1					2			T	T	T			4(+)	4.14
4																		
																		0.94
																		2.42
																		5.91
																T	T	53.84
T		T	1	1	T	T			2		T?			T?		1	5(+)	30.11
1	T	T?	1	3	T		1(?)	1(?)	8		T	T	1	1		4	18(+)	4.50
1	T	T	2	1					5	T	T	T	1			4	17(+)	2.28
5																		
															T		T	0.07
															6		6	.74
T		T							2						1		3(+)	51.65
1	T	T	T						6							T	7(+)	31.72
1	T	T	1	T					9								11(+)	4.52
6																		
		T							T								T	0.64
		T							T								T	13.10
																	0	7.44
																	0	4.62

TABLE 2.—*Minerals identified in the sediments,*

[Determinations for samples 1–6 and 8 made by Joseph R. Houston and for samples 7 and 9–12 by Theodore

Size fraction	Light minerals								Micaceous minerals					
	Quartz	Alkali feldspar	Rock fragment [2]	Altered feldspar	Plagioclase	Lignite	Nonmagnetic opaque [3]	Total light minerals in size fraction (percent)	Chlorite (may include green biotite)	Muscovite	Biotite	Hydromica (?) [4]	Glauconite	Total micaceous minerals in size fraction (percent)
Sample														
Very coarse sand	93(−)	4	3	----	----	----	T	100(−)	----	T	---			T
Coarse sand	98(−)	2	T	----	----	----	T	100(−)	----	T	T			T
Medium sand	42(−)	1	5	----	----	----	1	49(−)	----	----	----			0
Fine sand	31(+)	T	----	15	----	----		46(+)	----	T	----			T
Very fine sand	19	T	----	28	----	----	1	48	----	T	----			T
Sample														
Granule	100(−)	----	----	----	----	----	T	100(−)	----	----	----			0
Very coarse sand	97(−)	----	3	----	----	----	T	100(−)	----	----	----			0
Coarse sand	96(−)	----	2	T	----	----	T	98(−)	T	T	T			T
Medium sand	98(−)	T	----	2	----	----	T	100(−)	----	T	----			T
Fine sand	93(−)	T	T	6	----	----	----	99(−)	T	T	----			T
Very fine sand	96(−)	----	----	4	----	----	T	100(−)	----	T	----			T
Sample														
Medium sand	82(−)	----	----	T	----	----	1	83(−)	T	17	----			17(+)
Fine sand	17	----	----	8	----	----	T	25(+)	T	73(−)	----			73(−)
Very fine sand	9	----	----	13	----	----	T	22(+)	1	74(−)	----			75(−)
Sample														
Fine sand	11	----	----	23	----	----	T	34(+)	6	50(−)	T			56(−)
Very fine sand	3	----	----	5	----	----	----	8(+)	10	79(−)	----			89(−)
Sample														
Pebble	100	----	----	----	----	----	----	100	----	----	----			0
Granule	98	----	2	----	----	----	----	100	----	----	----			0
Very coarse sand	99(−)	----	T	----	----	----	----	99(−)	----	1	----			1
Coarse sand	99(−)	----	T	----	----	----	T	99(−)	----	T	----			T
Medium sand	94(−)	----	----	----	----	----	----	94(−)	----	6	----			6
Fine sand	100(−)	----	----	----	----	----	T	100(−)	T	T	----			T
Very fine sand	96(−)	----	----	1	----	----	----	97(−)	----	3	----			3
Sample														
Granule	100(−)	----	----	----	----	----	----	100(−)	----	T	----			T
Very coarse sand	100	----	----	----	----	----	----	100	----	----	----			0
Coarse sand	100(−)	----	----	----	----	----	T	100(−)	----	T	----			T
Medium sand	97(−)	----	----	----	----	----	T	97(−)	----	3	----			3
Fine sand	98(−)	----	1	----	----	----	----	99(−)	----	T	T			T
Very fine sand	97(−)	----	----	----	----	----	T	97(−)	1	1	----			2

[1] Monazite has been omitted from the listing because none was observed.   See pages 25 and 26.
[2] Rock fragments are mostly greenschists with chlorite.
[3] Opaques nonmagnetic—chiefly organic matter, in part lignite.
[4] Yellowish-brown micaceous mineral cementing quartz.
[5] Exhibits schiller phenomenon.
[6] The quartz grains are dirty.   Most of the quartz is in small grains cemented by hydromica(?).

in percent by grain count—Continued

Woodward. Explanation of symbols: T. trace; or <0.5 percent; T?, uncertainty as to abundance]

Heavy minerals arranged in the order of the "full suite" of Dryden and Dryden (1956) [1]

Sample	Zircon	Tourmaline	Staurolite	Garnet	Epidote	Zoisite or clinozoisite	Kyanite	Sillimanite	Hornblende	Amphibole-chlorite	Rutile	Andalusite	Hypersthene	Pyroxene	Apatite	Pyrite (marcasite)	Magnetic opaque	Total percent of heavy minerals in size fraction less the micas	Percentage weight of size fraction
7				T														T	10.92
				T														T	15.79
		T	T	T				1		50								51(+)	11.37
		T	T	T						54(−)							T	54(−)	4.24
		T		T						52(−)					T			52(−)	1.46
8		T							T							T		T	1.40
																		T	5.56
	T?			2													T	2(+)	18.38
		T															T	T	47.08
	1			T														1(+)	9.04
				T			T?	T?						T				T	2.75
9	T?								T								T	T	71.98
			T										T?			2	T	2(+)	6.49
							T?						T?			3	T	3(+)	3.81
10							T?	T?			T			T		10	T	10(+)	1.44
		T			T			T		T?						3		3(+)	4.08
11																		0	1.59
																		0	8.26
				T														T	20.45
				T		T?												1(+)	14.06
				T						1			T					T	17.31
										T					T			T	7.43
	T	T?		T?	T					T?					T		T	T	3.83
12																		0	9.94
																		0	35.85
				T														T	9.36
			T?	1					T									T	10.64
									T						T?			1(+)	5.02
	1																T	1(+)	2.65

[7] In the silt and clay fraction there is a trace of an unidentified mineral.

[8] Sample 4 contains 5 percent (by grain count) of red-brown platy micaceous minerals in silt and clay fraction.

[9] The value of 27(−) for glauconite refers to nodules of quartz, chlorite, and mica grains all cemented together with grayish-green glauconite. There is a trace of cordierite in the fine-sand fraction of this sample.

TABLE 3.—*Mineralogic data for selected minerals in sample 1—a sediment from glacial outwash*

[Data measured by Joseph R. Houston, U.S. Geol. Survey]

Mineral	Indices of Refraction				2V	Extinction	Pleochroism	Remarks
	α / ϵ	β / n	γ / ω	Variability [1]				
Microcline	1.519±0.002	1.523±0.002	1.528±0.002		(+)85°	On {001}= 3.5–4.5°		Fine twin lamellae.
Albite		1.535±0.002	1.540±0.002		(+)85°			
Muscovite		1.608±0.002. n mean=1.635± 0.003.	1.612±0.002	⊓	(−)30°			Birefringence=0.001 to 0.003; plates in schist fragments.
Chlorite				⊓	(−)0°–5°		Green to dark green	
Garnet		n=1.795±0.003	ω=1.660	⊓				n varies ±0.01, a few grains above 1.800, probably almandite.
Tourmaline			ω=1.660				ω=dark greenish black; ϵ=dirty olive green.	ω varies considerably, ±0.020, color black.
Hornblende	1.683±0.005		1.700±0.005	⊓	(−)30°–40°	$Z\wedge c$=14°	Moderate; X=dirty yellow-brown; Y=smoky-bluish to olive green.	n varies ±0.03; pleochroism variable from grain to grain, several sources (?).
Hypersthene	1.690±0.003		1.700±0.003	⊓			Strong; X=brownish-pink; Z=pale green.	Shows schiller effect due to oriented augite(?) inclusions.
Staurolite	1.738±0.003–1.715	1.744±0.003–1.720	1.750±0.003–1.725		(+)85°–90°		Strong; dark brown to light brown.	$r>v$ distinct; indices vary widely, apparently with iron content.

[1] The variability from values given in the table is designated ⊔ for lower indices of refraction and ⊓ for higher. The combined symbol ⊓ indicates variation in both senses. See "Remarks" for details.

X-RAY DIFFRACTION STUDIES

X-ray powder-diffraction patterns were made by using nickel-filtered copper radiation. Unoriented samples in spindles, both un-treated and treated with ethylene glycol, were examined. No expansion was detected.

The use of the terms major and minor constituents depends upon the relative intensity of the X-ray powder-diffraction patterns of the various minerals present. For example, a well-crystallized mineral, such as quartz, may yield a better powder-diffraction pattern than other constituents which are poorly crystallized and present in equal proportions. These terms are, therefore, only semiquantitative.

The results of the X-ray studies are summarized in table 4.

DIFFERENTIAL THERMAL ANALYSIS

The differential thermal analyses (DTA) were made in the Hendricks-Nelson-Alexander (1939) form of apparatus, which records the data as a continuous curve on photographic paper. The resist-ance in series with the galvanometer for all the curves was 600 ohms. The samples were heated at the rate of 12°C per minute. Faust (1948, 1950) describes the techniques used in this study.

The association of lignite and pyrite, especially in some of the Cretaceous clays of New Jersey, has long been known (Ries and Kümmel, 1904) and their presence in the clays studied here makes it desirable to comment on their behavior when heated in differential thermal analyses.

Pyrolysis of carbonaceous matter admixed with clays takes place over a span of temperatures from 300° to 600°C, with a maximum near 400°C. In the temperature range of about 450° to 500°C, pyrite decomposes with the appearance of either a single or a double peak. The double peak is an expression of the inequilibrium accompanying the decomposition.

The results of the DTA study of the samples from Long Island, N.Y., are given in tables 5 and 6. In comparing the data in table 5 with the optical data in table 2 and the X-ray data in table 4, correlations must be made with caution, because these three methods use greatly different amounts of sample and therefore have different sensitivities. The DTA is designed especially for phases that undergo a reaction, such as a change of phase, inversion, dissociation, recrystal-lization, and the like, when they are heated. For such phases the method is specific, may be unique, and is generally at least semi-quantitative. Thermally inert phases behave as diluents and they produce no recognizable effect in the temperature range of the experi-ments and therefore are not recognized.

TABLE 4.—*Mineralogy of the silt and clay size fractions as determined by X-ray powder diffraction studies*

[Determinations by Marie L. Lindberg, U.S. Geol. Survey]

Sample	Size fraction	Kaolinite	Muscovite	Chlorite	Mixed layer mineral	Quartz	Pyrite	Alkali feldspar
1	Silt plus clay	?	Very minor [1]	Very minor		Major		Minor, [2]
2	do		Very weak if present at all			do		Do. [2]
3	do	Very weak if present at all	do	Very weak if present at all		do		Do. [3]
4	do		do [1]			do		Do. [3]
5	Silt	Very minor	Minor			do	Very minor	Very minor.
	Clay	do	do	Very minor		do	do	Do.
6	Fine sand	Very minor if present at all	do			do	Minor	Minor.
7	Silt	do	do	do		do	do	Do.
	Clay	Major	do	do		do	do	Do.
8	Silt	Minor	do [5]	Minor	Major [4]	Minor		
	Clay	Major [4]	do [5]		do [4]	Major		
9	Silt	Very minor	do	Very minor		do		
	Clay	Major [6]	do			do		
10	Silt	Very minor	do	Minor		Minor		
	Clay	Major	do			Major		
11	Silt	Very minor	do	Very minor		do		
	Clay	Major	do			do		
12	Silt	Very minor	do	Minor		do		
	Clay	Major	do			do		

[1] The muscovite has a broad basal reflection suggesting some alteration to hydromica.

[2] Minor constituent; picture too weak to measure the line at 6.44 A, which was usually used to distinguish feldspar from a mixture containing quartz, muscovite, and kaolinite.

[3] Either kaolinite or chlorite must be present to account for the line at 7.08 A: either muscovite or kaolinite must be present to account for the line at 4.44 A; the 7.08 A line is too weak to find the 4.73-line of chlorite.

[4] This material is either mica or hydromica with a mixed-layer relationship suggesting mica-vermiculite. The mixed-layer relationship is more pronounced in the clay fraction. Ethylene glycol treatment of these size fractions did not measurably change the positions of the basal reflections indicating the absence or nondetectable presence of montmorillonite.

[5] A broad inner band suggests the possibility of hydromica or montmorillonite.

[6] This sample gave the best X-ray powder pattern for kaolinite in the group, and the identification of kaolinite, where the pattern was weaker, was partly justified by the good pattern obtained here.

TABLE 5.—*Mineralogy of some of the silt and clay size fractions as shown by differential thermal analysis*

[Determinations by George T. Faust, U.S. Geol. Survey]

Sample	Record	Size fraction	Kaolinite (percent)	Lignite	Glauconite	Mixed-layer mineral	Quartz	Pyrite
3	C-664	Silt and clay	------	------	------	------	Major	------
4	663	Silt and clay	64	------	------	------	------	------
5	657	Clay	(1)	Present	Present	------	Present	Present.
6	659	----do	13	----do	----do	------	----do	Do.
7	662	----do	25	----do	----do	Present	------	Do.
8	660	----do	37	----do	------	------	------	Do.
9	656	----do	67	----do	------	------	------	Do.
10	658	----do	47	----do	------	------	------	Do.
11	661	----do	83	------	------	------	------	------

1 Not measured.

TABLE 6.—*Observations on the thermal analysis curves of the silt and clay fractions of some sediments from the vicinity of the Brookhaven National Laboratory, Long Island, N.Y.*

[These curves were all made with a resistance of 600 ohms in the galvanometer circuit. M = major peak or trough]

Sample	Record	Size fraction	Low temperature		Intermediate temperature		High temperature		Weight of sample used (grams)
			Endotherm	Exotherm	Exotherm	Endotherm	Endotherm	Exotherm	
3	C-664	Silt and clay	--------	--------	--------	--------	573	--------	--------	0.4800
4	663	----do	--------	--------	--------	--------	594(M)	--------	959(M)	.3011
5	657	Clay	123	--------	395(M)	483(M)	573	930	--------	.3499
6	659	----do	130	289(M)	376	425(M)	561	929	--------	.2750
7	662	----do	135(M)	--------	--------	--------	564(M)	748	--------	.3548
8	660	----do	--------	--------	--------	429(M)	582(M)	--------	961(M)	.2732
9	656	----do	--------	--------	404(M)	507	597(M)	--------	967(M)	.2572
10	658	----do	--------	--------	416	--------	591(M)	--------	940(M)	.3257
11	661	----do	--------	--------	341	--------	597(M)	--------	969(M)	.2799

To facilitate their interpretation, these DTA curves are grouped together on the basis of their geologic age. Three clays from glacial outwash plains of Pleistocene age—samples 3, 4, and 5—yielded DTA curves C–664, C–663, and C–657, respectively (fig. 6). The silt-clay fraction of sample 3 shows the DTA curve of quartz; the silt-clay fraction of sample 4 (curve C–663) shows an excellent kaolinite pattern, but no sign of the quartz inversion appears as an inflexion on the endotherm of kaolinite. The clay fraction of sample 5 is more complex and shows, in addition to the quartz inversion, exothermic peaks caused by the pyrolysis of organic matter and by the decomposition of pyrite and two endothermic troughs—one at a low temperature and the other at a high temperature—caused by glauconite.

Samples 6 and 7 from the Gardiners Clay yielded curves C–659 and C–662 (fig. 6). These rather complex patterns are made up of the
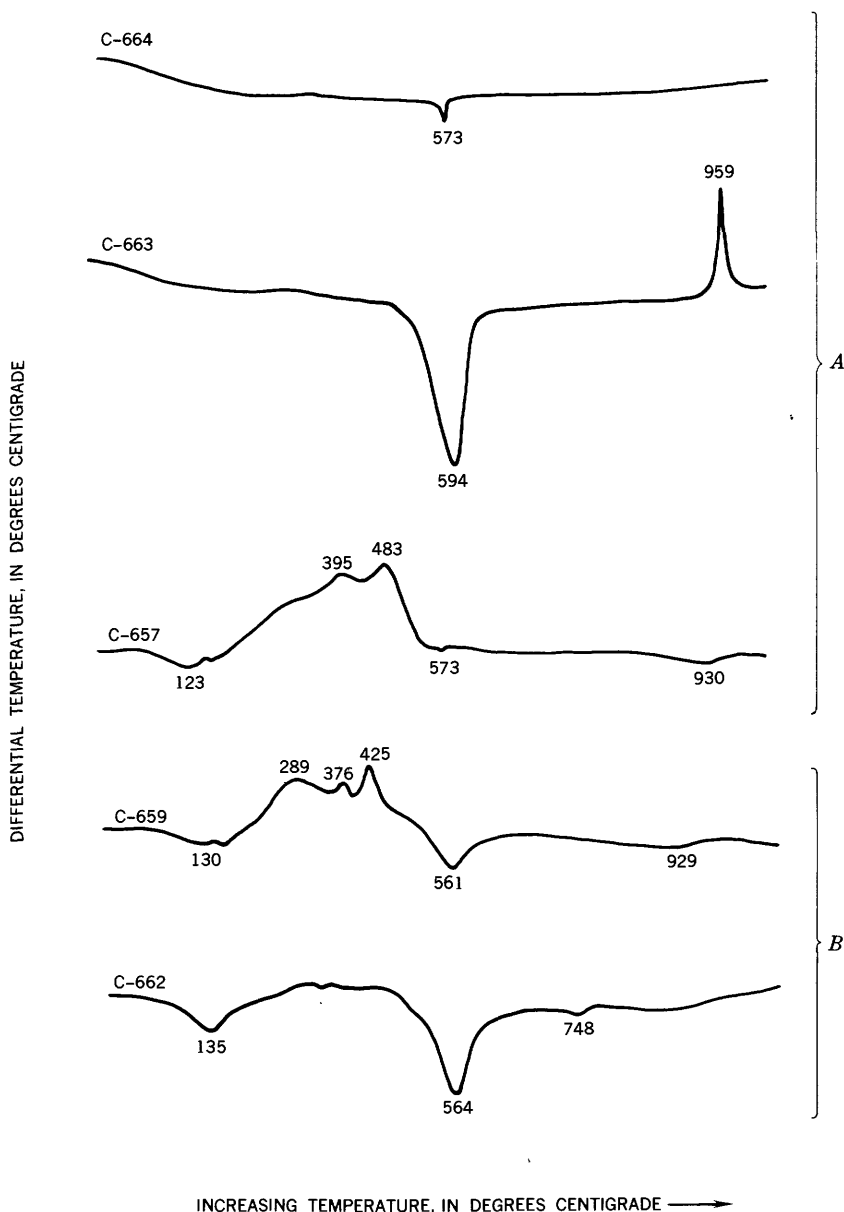
FIGURE 6.—Differential thermal analyses curves of samples of Pleistocene age from the vicinity of the Brookhaven National Laboratory, Long Island, N.Y. A, Three clays from glacial outwash plains (curve C–664, samples 3; curve C–663, sample 4; curve C–657, sample 5). B, Samples from the Gardiners Clay (curve C–659, sample 6; curve C–662, sample 7). All curves were obtained with a resistance of 600 ohms in the galvanometer circuit.

combined curves of kaolinite, pyrite, organic matter, and a small amount of constituents yielding a low- and a high-temperature endotherm; for sample 6, the endothermic trough is due to the presence of glauconite and for sample 7, to the presence of a mixed-layer mineral.

Samples 8 and 9 from the Magothy(?) Formation yielded curves C–660 and C–656, respectively (fig. 7), which show excellent patterns typical of kaolinite and exothermic peaks due to the pyrolysis of organic matter and the decomposition of pyrite.

Sample 10 of the clay member of the Raritan Formation (curve C–658, fig. 7) shows a well-developed kaolinite pattern together with a small endotherm that is characteristic of organic matter. The clay fraction of the Lloyd Sand Member of the Raritan Formation (sample 11, curve C–661) shows an excellent kaolinite pattern.

DTA studies on related clay samples from New Jersey have been made by Cuthbert (1951) and, although there is no direct stratigraphic correlation between these samples, some of the results of his study are of interest here. Cuthbert studied a sample from a clay lens in the Magothy Formation from Cheesequake State Park in eastern Middlesex County and found the clay mineral to be "largely kaolinite." He also observed a large effect on the DTA patterns arising from the pyrolysis of organic matter. This observation agrees with our findings. Cuthbert studied twelve clays from the Raritan Formation. He found eleven of these clays to be typical kaolinites; some were pure but others contained a little organic matter and—in some of the clays—also pyrite. Only one clay showed—in addition to the DTA pattern from the major constituent, kaolinite—a high-temperature endothermic trough at about 900° C, which Cuthbert believed might be due to the presence of "illite" (hydromica). The samples studied in this investigation agree in their thermal behavior with his eleven typical samples.

ELECTRON MICROSCOPY

The electron microscope studies were made using an RCA model EM 2b instrument. The technique used in the studies is described by Dwornik and Ross (1955). Briefly, their procedure is as follows: The material is disaggregated in distilled water in a Waring blender for 2–3 minutes. A droplet of the cloudy suspension is then placed on a 200-mesh stainless-steel grid, previously covered with a thin collodion substrate film, and the water is allowed to evaporate. The sample is then examined. In addition, mounts of each sample are placed in a metal evaporation unit and shadowed with chromium at an angle of approximately 23°. This technique permits a rough determination of the thickness of particles and enhances contrast in the image.
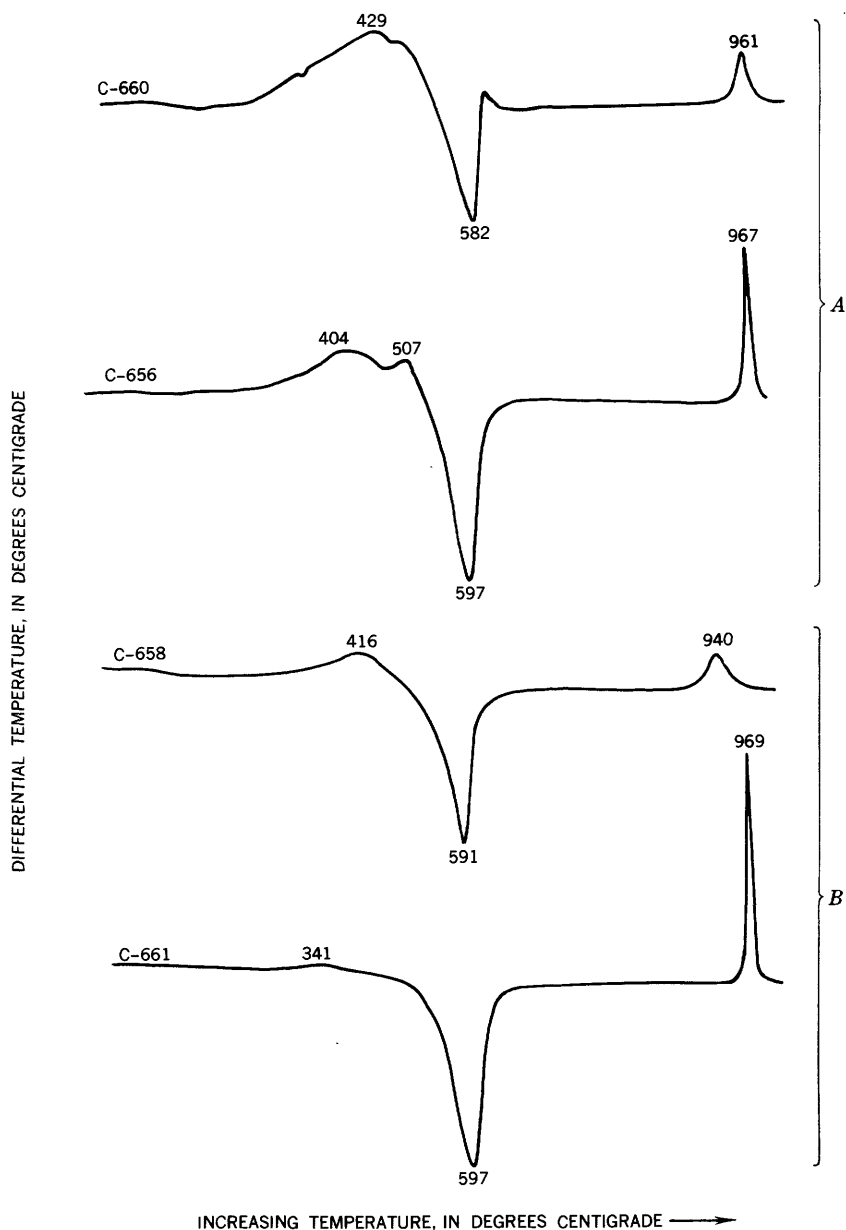
FIGURE 7.—Differential thermal analyses curves of samples from the vicinity of the Brook-
haven National Laboratory, Long Island, N.Y. *A*, Samples from the Magothy(?) For-
mation of Late Cretaceous age (curve C–660, sample 8; curve C–656, sample 9). *B*,
Samples from the Raritan Formation of Late Cretaceous age (curve C–658, sample 10,
clay member; curve C–661, sample 11, the clay fraction of the Lloyd Sand Member of
Raritan Formation). All curves were obtained with a resistance of 600 ohms in the
galvanometer circuit.

The micrographs selected for illustration are typical of the fields observed in the microscope, but they may not be representative of the entire sample. Because of the preparation of the sample as a suspension in water, a settling out of heavier and larger mineral particles was difficult to avoid. Accordingly, the clay content may appear to be greater and the quartz content and the content of other minerals of higher specific gravity may appear to be less than the concentrations that are actually present. The results of these studies are summarized in table 7, and selected electron micrographs of the clay fractions are given in figures 8 to 10.

TABLE 7.—*Electron microscope studies of the clay-size fractions*

[Letter symbols used in figs. 8-10. Determinations by Edward J. Dwornik and Malcom Ross, U.S. Geol. Survey]

Sample	Kaolinite (K)	Opaque material, irregularly shaped particles (X) (includes lignite)	Platy mineral (S) or mica(?)	Diatoms (D)	Quartz (Q)	Montmorillo-nite(M)+ hydromica
5	A large aggregate is present.	Present	A fragment of (S) is perched on (K).			
6	Present	do.[1]	Present	Present	Present	
7	do		do			Large fluffy particles.[2]
8	do	Present				
9	do	do	A large plate is present.			
10	do	do				
11	Predominant				Random grains.	
12	Large aggregates are present.	Present	Present			

[1] A "feathery" substance (F) which radiates from (X) suggests recrystallization of a water-soluble compound.
[2] The "fluffs" of (M) and a finely divided background suggest a mixed aggregate of montmorillonite and hydromica.

RADIOACTIVE MINERALS IN THE ENVIRONMENT

Monitoring equipment for recording the radioactivity of airborne dust was operated by the staff of the Instrumentation and Health Physics Department of the Brookhaven National Laboratory in the area from which the samples studied here were taken. They detected daughter products of thoron and, to a lesser extent, of radon. This detection was particularly noticed after periods of atmospheric temperature inversion. These inversions tend to trap near the ground any gases released to the atmosphere by the soil. These scientists estimated that the amount of thorium in the soil at the Brookhaven National Laboratory was of the order of 1 part thorium in 2×10^8 parts of soil. At such low concentrations of thorium it is therefore not surprising that Houston and Woodward did not report the presence of any thorium-bearing mineral in their study of these samples. (See table 2.)
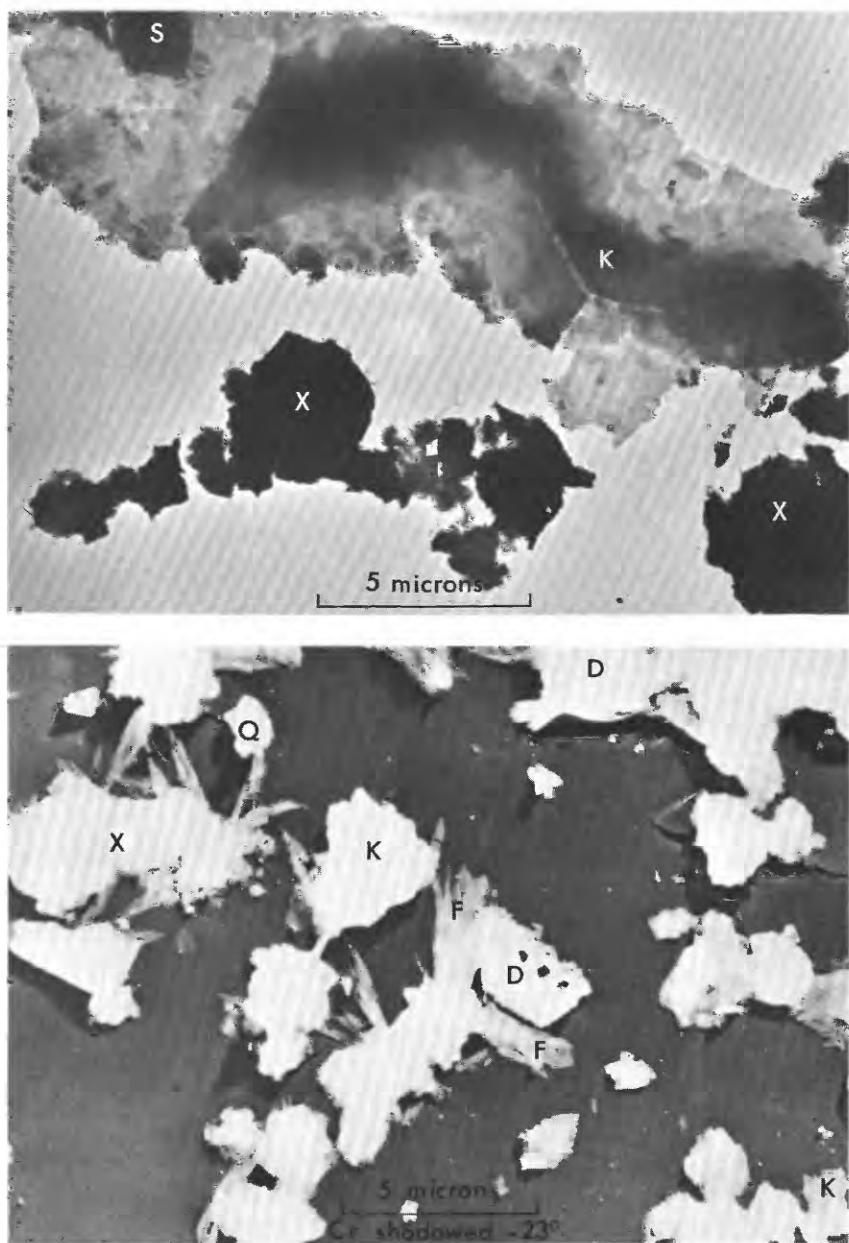
FIGURE 8.—Electron micrographs of selected fields observed under the electron micro-
scope. *A* (upper), Sample 5, from glacial outwash plain of Pleistocene age. *B*
(lower), Sample 6, silty clay zone of the Gardiners Clay, of Pleistocene age, chrominum
shadowed mount (23°).

NOTE.—Explanation for symbols on figures 8, 9, and 10. K=kaolinite, X=opaque min-
erals, S=plates of mica, F=recrystallization product. Q=quartz, M=montmorillonite and
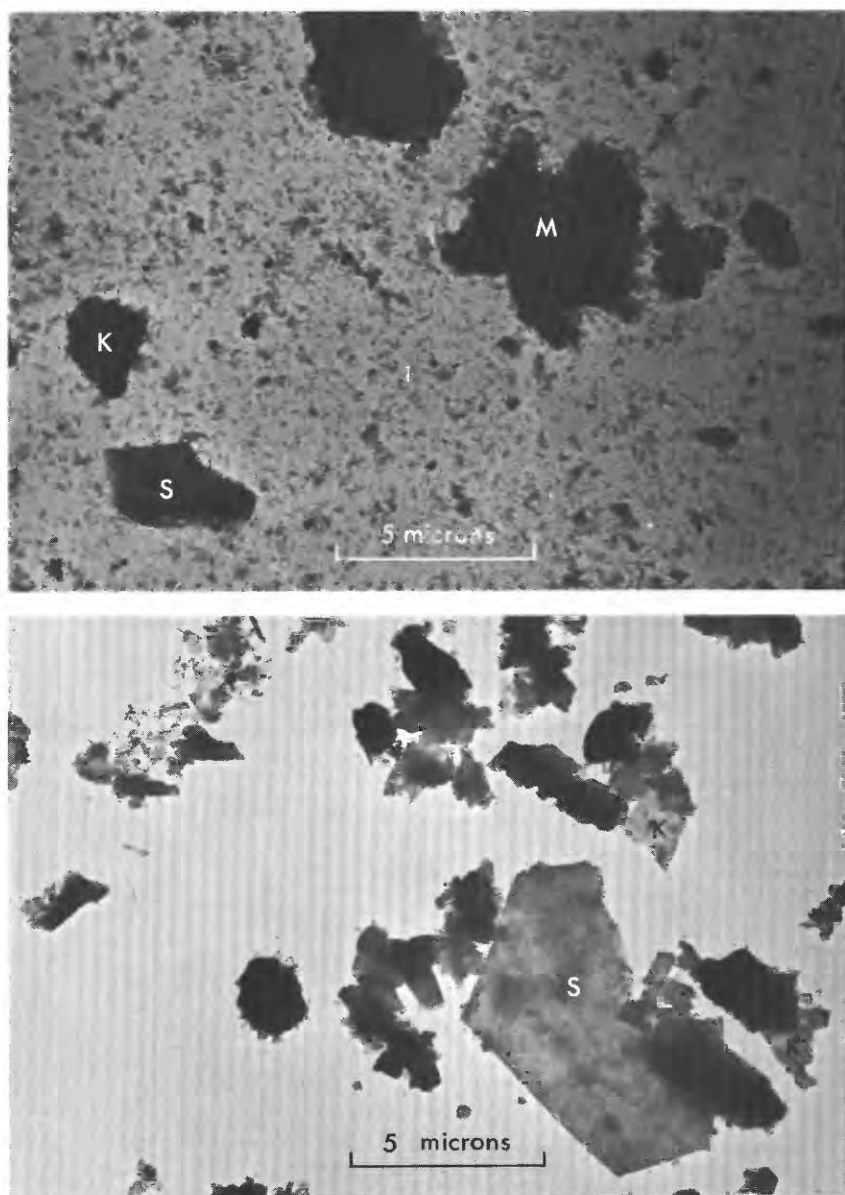hydromica(?), D=diatoms, I=finely divided background material.

FIGURE 9.—Electron micrographs of selected fields observed under the electron 'microscope. *A* (upper), Sample 7, clay fraction from the sandy part of the Gardiners Clay of Pleistocene age. *B* (lower), Sample 9, typical Magothy(?) Formation (clayey sand) of Late Cretaceous age.
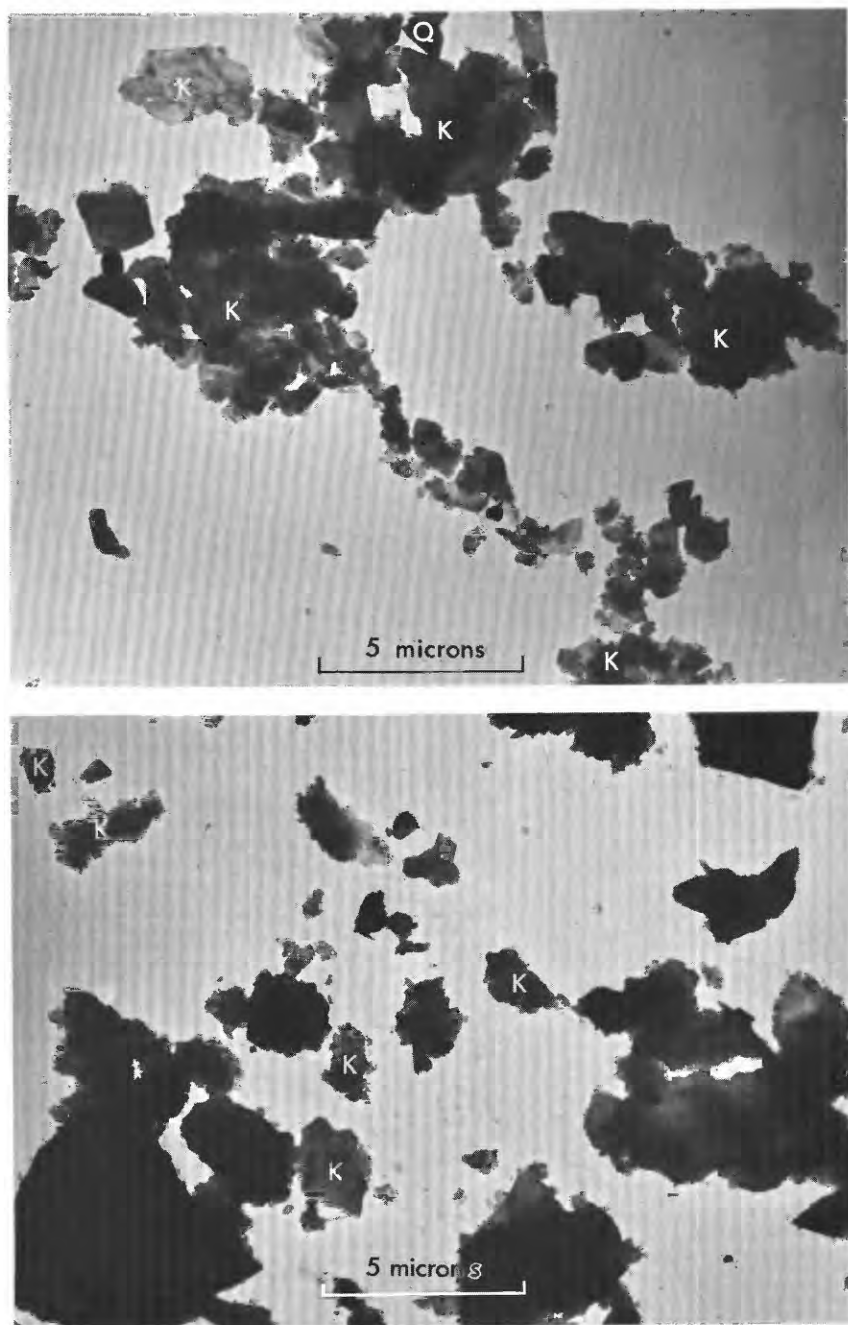
FIGURE 10.—Electron micrographs of selected fields observed under the electron microscope. A (upper), Sample 10, clay member of the Raritan Formation, of Late Cretaceous age. B (lower), Sample 11, clay fraction of typical Lloyd Sand Member of the Raritan Formation of Late Cretaceous age.

To investigate the occurrence of small amounts of thorium-bearing minerals in the beach sands along the shores of Long Island Sound and the Atlantic Ocean, Wallace de Laguna searched for natural concentrates of heavy minerals in places where the abundance of heavy minerals was greatly exaggerated by wave action. Samples were collected from a locality just west of Baiting Hollow, about 9 miles northeast of the center of the Brookhaven National Laboratory. These samples were mixed to give a composite sample. This sample was analyzed by James P. Owens, U.S. Geological Survey, who found 77 percent of ilmenite, 8 percent of garnet, 5 percent of magnetite, 4 percent zircon, 3 percent of monazite, 2 percent of quartz, and 1 percent of a mixture of staurolite, rutile, and hornblende.

The equivalent uranium content of the composite "black sand" sample was determined to be 0.032 percent from the beta-gamma count, which represents the total radioactivity of the sample (under the experimental conditions) based on the assumption that all the radioactivity is caused by the 0.032 percent uranium in equilibrium. If this amount of radioactivity represents thorium, the thorium content would be about 0.12 percent.

A Geiger-Müller survey meter gave a reading of 200 to 250 counts per minute (cpm) for the beach sands in place. The background count of this meter is 30 cpm. A brief survey of some of the more accessible beaches along Long Island Sound and the Atlantic Ocean showed that the dark streaks in the sand, representing natural concentrates of heavy minerals, commonly yielded counts of 50 to 100 cpm. No other natural concentrates as active as the sand at Baiting Hollow were found.

Small aliquots of several sand and mineral samples were counted by the staff of the Instrumentation and Health Physics Department of the Brookhaven National Laboratory to determine their relative radioactivities; no attempt at absolute measurement was made. These data are given in table 8. These data indicate that by far the greater part of the natural activity in the sand samples is in the monazite and that the zircon probably contains small amounts of uranium.

The fact that 3 percent of monazite occurs in a natural heavy-mineral concentrate of a beach sand along this part of the Atlantic Coast in association with 77 percent ilmenite is a matter of interest. Dr. R. W. Stoenner of the Brookhaven National Laboratory found that the ilmenite fraction contains only 8.12 percent titanium, 13.54 percent TiO_2 (average of four determinations ranging from 8.20 to 8.05 percent titanium, 13.68 to 13.43 percent TiO_2) ; these concentrations suggest possible intergrowths with other minerals. Owens, Minard, Wiesnet, and Markewicz (1960) showed through X-ray analysis that Ilmenite from the Miocene and Post-Miocene forma-

tions near Trenton, N.J., is a mixture of ilmenite and ferric and titanium oxides.

This natural concentrate from Baiting Hollow is not necessarily representative of the heavy minerals in the beach sand of Long Island. The heavy-mineral content of the sands that lie in the area between low and high tide along the Atlantic Coast beach of Long Island was determined by Taney (1961). He found that the heavy-mineral content for the area between East Hampton and West Hampton ranges from 8 down to 2 percent; no data were obtained between West Hampton and Fire Island, where the Brookhaven National Laboratory is located, but at Fire Island the heavy-mineral content of the sands is about 15 percent. At Montauk Point and Point Lookout, exceptionally large percentages were observed. Magnetite appears in the heavy-mineral fraction at Southampton and increases eastward to a maximum of about 25 percent of the entire sample at Montauk Point.

The monazite concentrate from the Baiting Hollow beach sand was chemically analyzed by Maryse Delevaux, Harry Levine, and Benjamin A. McCall, all of the U.S. Geological Survey, who reported as follows: 0.16 percent uranium, 2.0 percent equivalent uranium, and 8.48 percent thorium oxide (ThO_2). The zircon concentrate from Baiting Hollow was analyzed by R. W. Stoenner and M. Slavin, both of the Brookhaven National Laboratory, who found that it contained 0.031 percent uranium but no thorium. This confirmed the tentative conclusion reached from the counting measurements that the greater part of the local activity is due to the monazite.

TABLE 8.—*Relative radioactivity of some sands and concentrates from beaches on Long Island, N.Y.*

[Measurements by the staff of the Instrumentation and Health Physics Department, Brookhaven National Laboratory]

Sample	Locality	Relative radioactivity (curies per gram)	
		Alpha	Beta
Sand	Baiting Hollow, Suffolk County (Beach on Long Island Sound).	$1.2\text{-}2.2\times10^{-11}$	$1.5\text{-}2.9\times10^{-10}$.
Sand	Westhampton beach, Suffolk County (Beach on the Atlantic Ocean).	$0.05\text{-}0.1\times10^{-11}$	$3.2\text{-}6\times10^{-11}$.
Zircon concentrate	Baiting Hollow	2.7×10^{-11}	2.6×10^{-11}.
Monazite concentrate	Baiting Hollow	7.1×10^{-10}	1.3×10^{-8}.

CATION-EXCHANGE CAPACITIES OF THE SEDIMENTS

The cation-exchange capacity of 5-g samples of the original unsized sediments was determined by a standard method using ammonium