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SOME OBSERVATIONS ON THE SEDIMENTS OF THE DELAWARE RIVER SOUTH OF WILMINGTON

By

Robert R. lordan

and

l ohan I. Groot

Newark, Delaware
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Robert R. Jordan
Geologist, Delaware Geological Survey

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Johan I. Groot
State Geologist

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Abstract

A series of cores was obtained from a boring in the sediments of the Delaware River near the Delaware Memorial Bridge. The mineralogy, texture and palynology of these samples have been studied. The sedimentary and palynological records suggest that the Delaware River, while swollen with Wisconsin meltwaters, deepened its channel and that subsequent flooding of the mouth of the stream by rising sea waters initiated the deposition of estuarine silts in post-Wisconsin time.

Introduction

A set of cores taken from a test boring for a proposed bridge adjacent to the present Delaware Memorial Bridge between New Castle County, Delaware and Salem County, New Jersey, provided an opportunity to study the sediments accumulating in that portion of the Delaware River estuary. The nature of these sediments is significant as a study of a depositional environment, as an inquiry into the geologically recent history of the Delaware River and also because of the economic effects which these sediments may have on the maintenance of navigation channels, the shell fisheries, and the quality of ground water drawn from wells along the shores of the Delaware. The present study must be considered as a preliminary investigation for it deals only with a single point. Areal studies of much greater magnitude will be necessary to achieve a more complete understanding of these sediments.

The boring from which the cores were taken is located 200 feet north of the centerline of the existing bridge and adjacent to its west tower (fig. 1). This point is approximately 2340 feet from the Delaware shore and 1050 feet west of the center of the navigation channel. The total depth of this boring was 222 feet (sea level datum). Only the upper 85 feet are considered here for this interval includes the relatively uncompacted river silts and the immediately subjacent materials. An abbreviated log of the boring, showing the positions of the 9 cores studied, is shown in figure 2.

At present the Delaware River is brackish and tidal at the Delaware Memorial Bridge. The chloride ion concentration of the water at this point ranges from less than 50 ppm to more than 2000 ppm with fluctuations in runoff, tide and wind (City of Philadelphia and U. S. Geological Survey, 1958). Surface currents average 2.4 knots during the ebb tide and 1.9 knots during the flood tide (U. S. Coast and Geodetic Survey, 1961).

The writers gratefully acknowledge the help of Mr. John R. Lewis, Resident Engineer of the Delaware Memorial Bridge, in procuring the samples; Dr. John K. Adams, University of Delaware, interpreted the X-ray diffraction data, and Mr. Thomas C. Gray prepared and made a preliminary study of the pollen contained in the sediments.

Description of Samples

Each sample has been examined megascopically and under the stereographic microscope, analyzed to determine mechanical composition and heavy mineral content and studied by X-ray diffraction to identify the clay minerals.

MEGASCOPIC DESCRIPTIONS

Samples 20908 through 20914 (fig. 2) are identical in megascopic appearance. They are dark gray, slightly micaceous and organic, relatively uncompacted silts. Thin lamellar concentrations of very fine sand are irregularly distributed through the finer material. The water content of the undisturbed cores was high, particularly in the upper samples. The driller recorded little resistance to his tools which generally sank through these sediments under their own weight. These are the sediments of primary interest to this study for they are the most recent sediments transported and deposited by the Delaware.

Below the gray silt is a thin brown silt from which no cores are available. Below this is a yellow, fine, quartz sand 8 feet thick. It is represented by sample 20915. Some small pebbles were reported from this sand by the driller.

Sample 20916 is a dense and compact light gray clay with some streaks of red. It is the uppermost part of a thick sequence of variegated and gray clays and fine-grained sands.

MICROSCOPIC DESCRIPTIONS

Apart from the clay minerals quartz is the dominant component of the sediments. In the gray silt the quartz is mainly subangular but ranges from angular to rounded. These samples, 20908 through through 20914, also contain organic debris and small amounts of mica, chert and glauconite. Very few lithic fragments were found.

Sample 20915 is a "clean" sand containing quartz and a little chert. The quartz is angular.

The sand size fraction of sample 20916 consists almost entirely of very angular quartz. The only other minerals noted were heavy minerals which are comparatively rare.

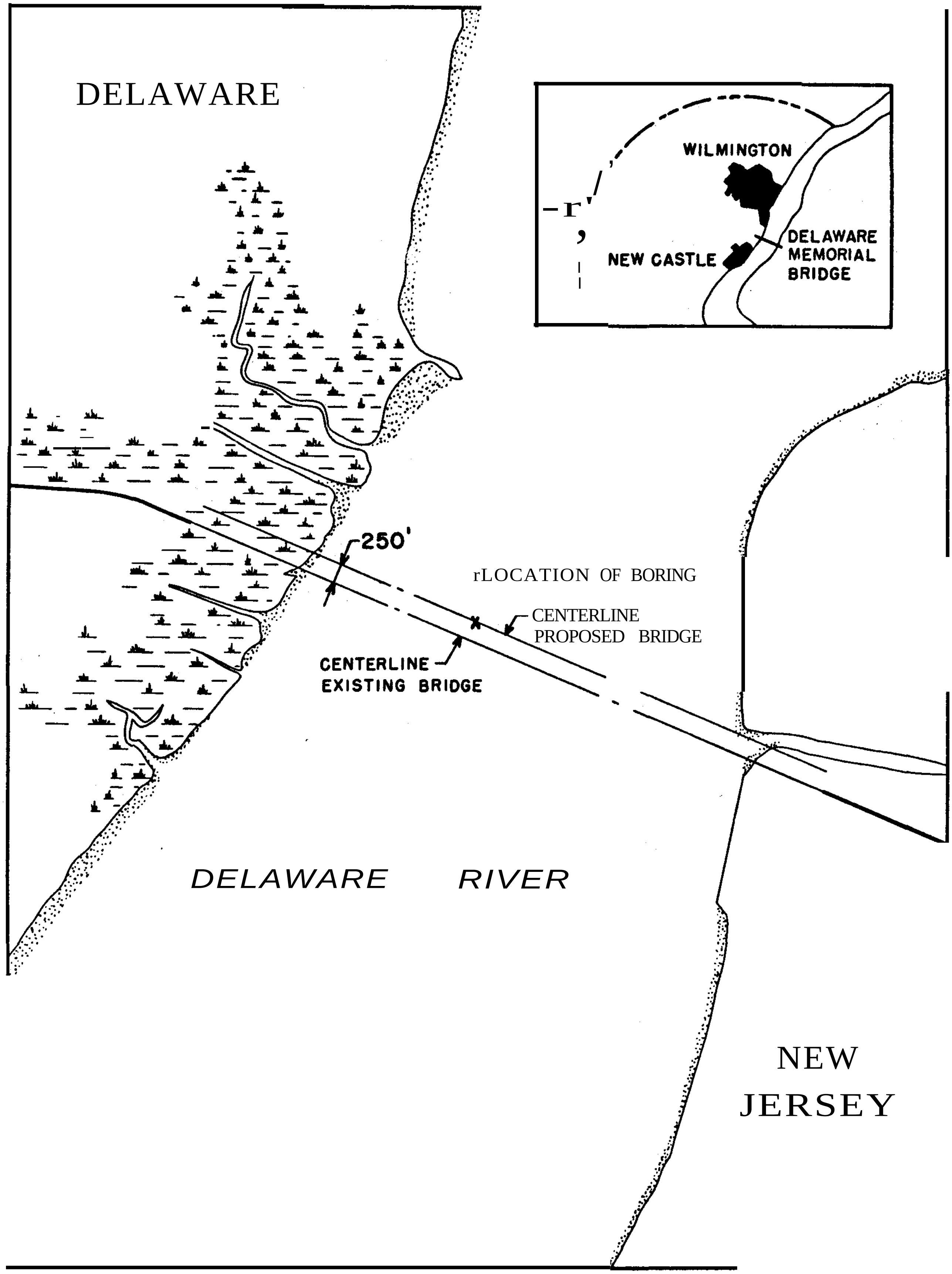

Figure l. Location of boring studied in this report

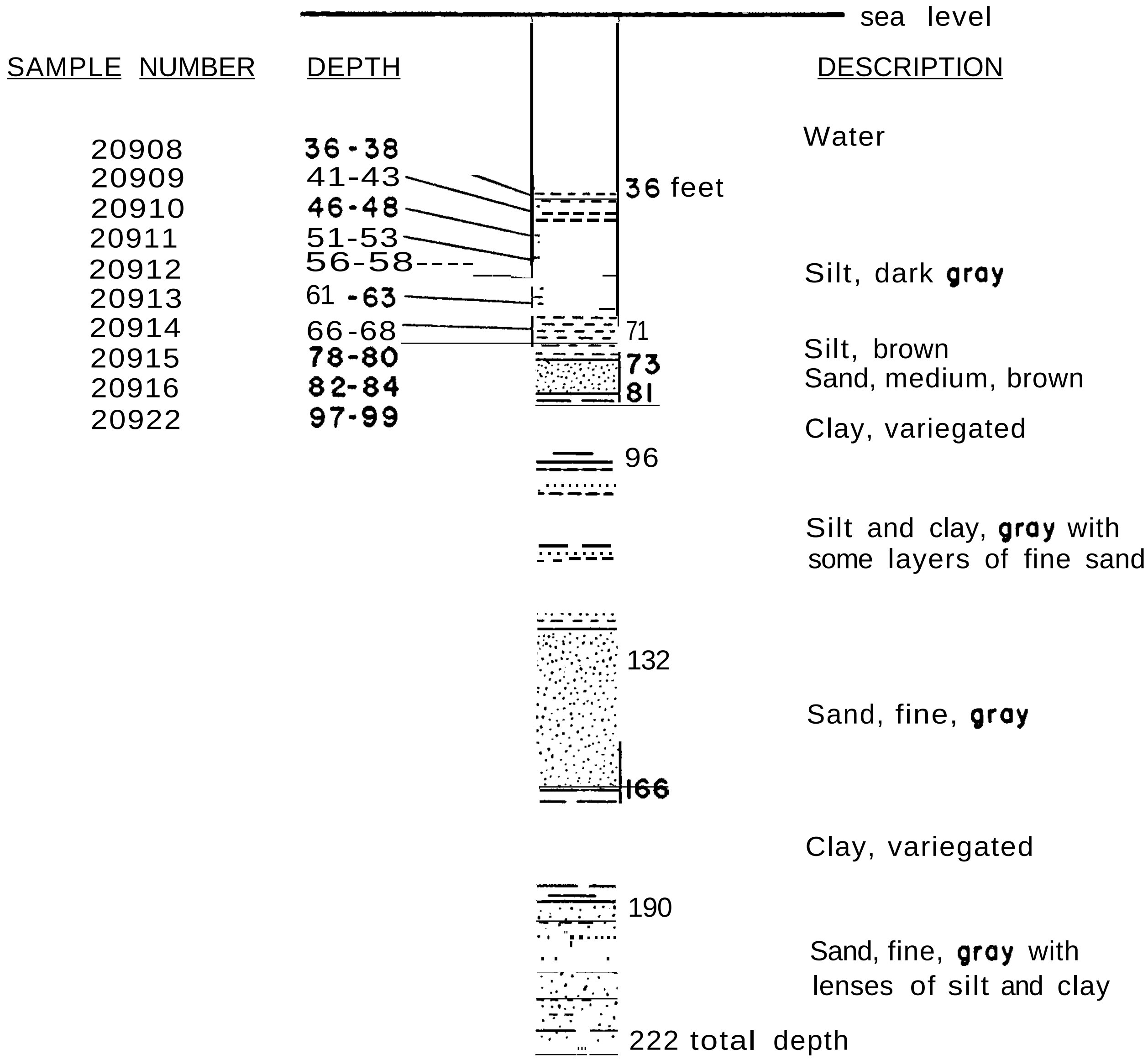

Figure 2. Log of boring showing locations of samples

MECHANICAL ANALYSES

Mechanical analyses of all samples were made using U. S. standard sieves for the sand sizes and hydrometer methods for the finer sizes. The results were plotted as cumulative grain size distribution curves which are shown in figure 3. The grain size is measured in phi (ϕ) units (Knimbein, 1934). Values are recorded from the curves at the 50th percentile fot the median grain size (Mdϕ) and at the 84th (ϕ84) and 16th (ϕ16) percentiles one standard deviation eicher side of the mean. Measures of the sorting ($\sigma\phi$) and skewness ($\alpha\phi$) were calculaced using the formulae of Inman (1952):

$$\sigma\phi \quad 1/2\,(\phi 84 - \phi 16)$$

$$\alpha\phi \quad \frac{M\phi - Md\phi}{\sigma\phi}$$

where $\quad 1/2\,(\phi 16 + \phi 84)$

The statistical parameters for each sample are given in table 1. Because of the very fine texture of the sediments ϕ84 did not fall within the limits of the cumulative *fceq* ueoey curves in all cases. Values listed as estimated are based on extended curves. Calculations of $\sigma\phi$ and $\alpha\phi$ based on these estimates are, of course, also approximate. The errors introduced in this manner are thought to be insignificant for the purpose of this investigation.

Sample 20916 is a clay with a median grain size of 8.41¢. The overlying quartz sand (sample 20915) is a fine sand with a median grain size of 2.38ϕ. The uncompacted materials above are all silts except for the deepest sample, 20914, which is a clay (Mdϕ = 8.23). With the exception of sample 20910, the median grain size decreases with increasing depth through the silt.

The sorting coefficients, $\sigma\phi$, show a tendency to increase (indicating poorer sorting) with decreasing grain size. Skewness values for all samples but 20914 are small and positive. Sample *20914* is negatively skewed.

HEAVY MINERAL ANALYSES

The size grades of very fine, fine and medium sand (62μ - 500μ) from the mechanical analyses were used for the heavy mineral separations. The samples were boiled 10 minutes in dilute hydrochloric acid and then in dilute nitric acid to remove coatings on the grains. The heavy fraction was separated by centrifuging the samples in tetrabromoethane (S.G. 2.92) then freezing the lower portion of the centrifuge tubes and decanting the light fraction. The method of separation is essentially that described by Fessenden (1959). Between 100 and 150 non-opaque grains were identified for each sample using the line count method (Doeglas, *1940).*

The heavy mineral suites from the deep clay, the sand and the upper silts are somewhat different. The heavy mineral content of each sample is given in table 2. The clay has a restricted suite with a very high staurolite coment and relatively large amounts of tourmaline and zircon. The sand has a much more varied suite including hornblende, gamet, kyanite, fibrolite, hypersthene, tourmaline, staurolite, sillimanite and zircon in order of decreasing abundance. The heavy mineral suites from each of the samples of silt (20908 through 20914) are very similar. All are dominated by hornblende, which exceeds 50 percent of the non-opaque minerals in each case. Lesser amounts of tourmaline, zircon, gamet, sillimanite and fibrolite as well as other relatively scarce minerals are present.

Some of the features of tourmaline, zircon, hornblende and garnet have been noted. About one-fourth of the tourmaline grains in the silt and clay are rounded. Tourmaline found in the sand was almost entirely angular. Nearly all of the tourmaline examined was pleochroic ((to ω) brown or reddish-brown to black or yellow to brown. Grains pleochroic green to dark green, blue to green and gray to blue occur very rarely. In the deeper clay the brown to black grains are dominant over yellow to brown grains and in the 51lts and sand they are roughly evenly divided. In each sample about half of the zircons are rounded and half are angular. Rounded zircon cannot be considered as an index of transpoceation because it is known from fresh crystalline rocks of the Piedmont. Pink zircons occur very rarely throughout the section studied. One-third of the garnets in the silts are essentially colorless. Approximately 70 percent of the hornblende, which is so abundant in the silts, is green. The remaining hornblende is brown or pleochroic from blue to green with the former case more common.

It should be noted that hypersthene, which is a relatively unstable mineral not usually found in the sediments of the Coastal Plain, has survived weathering in the source area and transportation to the site of deposition. All samples except 20916 contaiO the full heavy mineral suite defined by Dryden and Dryden (196?).

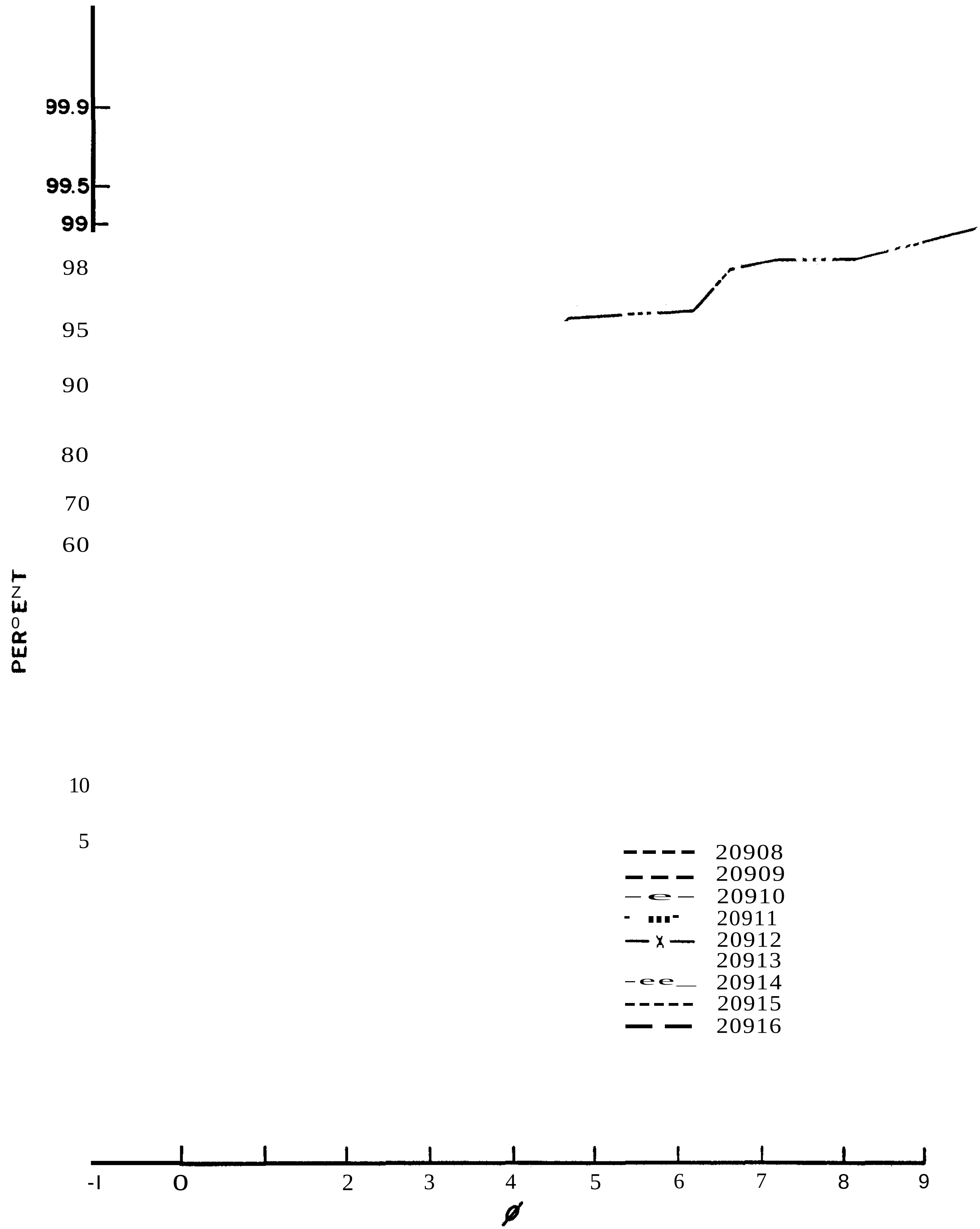

Figure 3. Cumulative curves of samples 20908- 20916

CLAY MINERALOGY

The clay mineralogy was investigated by the X-ray diffraction technique. Sample 20916 contained kaolinite with subsidiary amounts of illite. All of the other samples contain illite, chlorite and lesser amounts of kaolinite.

PLANT MICROFOSSILS

Pollen were recovered from samples 20908 to 20911 (inclusive) and from samples 20913. 20914 and 20922. At least 150 tree pollen from each sample were determined except from sample 20914, in which only 104 atborial pollen were encountered and from sample 20922 which is of Cretaceous age. The results of the pollen count are presented in table 3 and in figure 4.

The vegetation represenced by a significant number of arborial pollen consists of *Pinus* (pine), *Tsuga* (hemlock), *Carya* (hickory) and *Quercus* (oak). The viltual absence of *Picea* (spruce) and *Abies* (fir) should be noted.

Apart from the somewhat anomalous sample 20910, a general inctease in the petcentages of *Quercus* and *Tsuga* pollen occurs from the bottom to the top of the Recent sedimems; this is accompanied by a general decrease in the percentage of *Carya* pollen.

Among the non-arborial pollen the families Gramineae, Compositae and Chenopodiaceae are represented, as well as spores of the genera *Sphagnum*, *Lycopodium*, and *Osmundo*, and the family *Polypodiaceae*. The percentages of non-arhorial pollen are rather low, suggesting a well-developed forest vegetation.

Oiscussion

It is possible to characterize the age relationships of the samples studied. On the basis of gross lithology sample 20916 and the section of clays, silts and fine sands below it may be correlated with the nonmarine Cretaceous deposits referred to the Potomac Group. The high staurolite heavy mineral suite of this sample is the same as that which Groot (1955) called the "Patuxent zone" of the nonmarine Cretaceous sediments. Pollen and spores identified from sample 20922 (97 - 99 fr.) include the following genera: *Appendicisporites*. *Cicatricosisporites*, *Gleicheniidites*, *Lycopodiumsporites*, *Deltoidoospora*, *Concavisporites*, *Cingulatisporites*, *Eucommiidites* and *Abietineaepollenites*. A few grains of *Tricolpopollenites micromunus* and pOSSibly *T. reti{onnis* were found, but fern spores and gymnosperm pollen far exceed the angiosperm pollen both in number of species and number of speClmens. ThIS sporomorph assemblage suggests an Albian age. The palynology, lithology, heavy mineral suite, stratigraphic and geographic posicion leave little doubt regarding the correlation of this unit.

Sample 20915 resembles, lithologically, known Pleistocene sands in Delaware and the heavy mineral suite differs from the suites of those sands only in that it contains more hypersthene and less epi. dote. These criteria and the use of a single sample cannot yield definitive results but it may be said that the sand does not resemble known pre-Pleistocene deposits and is probably Quaternary.

The silts are considered as the depositional products of the latest phase in the development of the Delaware River and Bay.

The borings at the Delaware Memorial Bridge site indicate that the soft silts are 30 to 40 feet thick throughout a valley essentially coincident with the present course of the Delaware. Beyond the margins of this valley the silt thins rapidly landward and sometimes changes to peat. The borings nearest the center of the valley were made in about 37 feet of water; therefore, at the start of the deposition of of these silts the channel of the Delaware was approximately 70 feet below present sea level. One other locality known to the writers confirms this situation. Borings made where U.S. Route 13 crosses Drawyer's Creek, which flows into Delaware Bay 16 miles south of the Memorial Bridge, revealed that soft silts containing organic matter extend to more than 60 feet below present sea level.

The most recent sediments at the Delaware Memorial Bridge site are remarkably uniform in mineralogy and do not vary greatly in texture (see fig. 4). It may be said that conditions at this point, and in the Delaware River generally, have been fairly stable since the start of the deposition of the silts.

On the basis of these few samples little can be said regarding the provenance of the silts. .The full suite of heavy minerals with many fresh minerals of metamorphic and igneous origin seems to indicate a major contribution from rhe Piedrnonc. The glauconite grains found in th.e silts. are almost certainly not authigenic for this environment is quite different from that in which glauconite is known to form (Cloud, 1955). The glauconite represents a contribution from screams flowing into the lower part of the Delaware River from the New Jersey Coastal Plain.

These young sediments are fine grained enough, especially near the bottom, to act as an ,impermeable barrier against brackish water enteClng aqUlfers crossing under the Delaware River. However, the

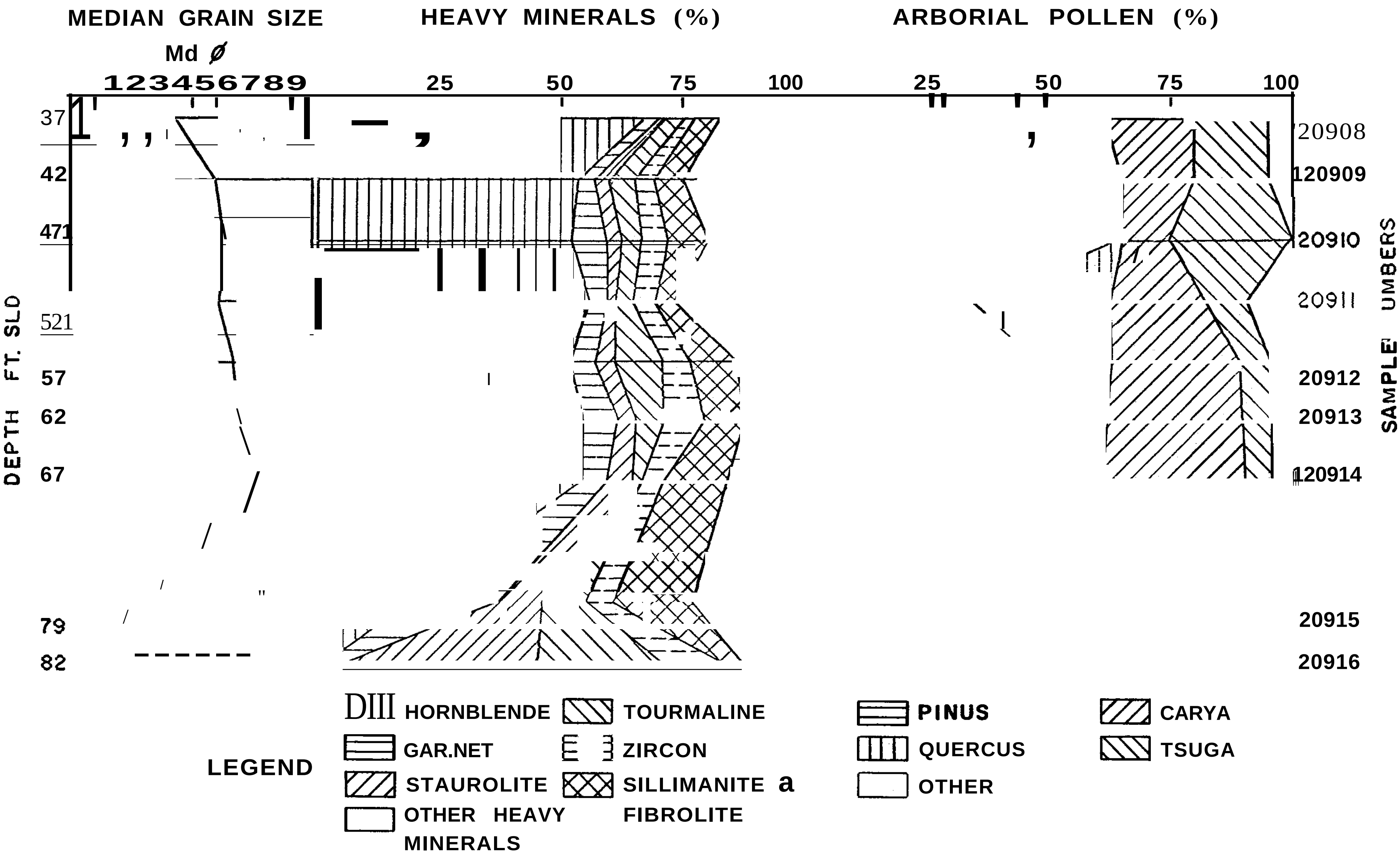

Figure 4. Median 9rain size, heavy minerals and arborial pollen

lateral extent of the silts is not known nor are the effects of dredging. Also, in their present saturated, relatively uncompacted condition the ions contained in the brackish water might possibly diffuse through the silts.

Interpretation of the pollen record should be done with extreme caution, because only a few, rather widely separated samples are involved, and also because the pollen do not necessarily reflect the vegetation in the immediate vicinity of the site of deposition. Owing to transportation by the water of the Delaware River, some of the pollen may have travelled a considerabl.e distance; the rather poor state of preservation of *Pinus* and *Tsuga*, the former often with its air bladders removed, suggests a transportational history at least of these twO genera.

The prevalence of *Carya*, *Quercus* and *Pinus*, and the absence of *Picea* and *Abies*, even in sample 20914, strongly suggests that deposition of the silts in the Delaware River in nonhern Delaware did not begin immediately after the last phase of Wisconsin glaciation. Rather, it started after climatic conditions had ameliorated to such an extent that a broad leaf forest had established itself.

Considering the well known fact that *Pinus* is a profuse pollen producer and is often over-represented in pollen diagrams, the rather high percentages of *Carya* in samples 20914 and 20913 may be particularly significant. These high percentages suggest correlation with the C_2 zone of pollen diagrams of eastern North America (Deevey, 1949). It is evident that the 8-zone, or the zone with a high percentage of *Pinus*, is not present. Considering that the *Pinus* maximum occurred 9000 to 6000 years ago, depending on latitude (Flint and Deevey, 1951), we can state with reasonable certainty that deposition of the silt did not begin until 8000 years ago, and perhaps more recemly. Such a rathet recent beginning of deposition would not be surprising if it is remembered that sea level had to rise considerably since the end of Wisconsin time in order to initiate estuarine deposition at this site.

A post-Wisconsin age is also required by the depositional history of the sediments. During the period of lowered sea level accompanying the greatest extent of Wisconsin glaciation the melrwaters from the ice front flushed the Delaware River channel of any previous accumulation of river sediments which may have been present. At this time the channel in the Cretaceous sediments was CUt to its present depth of about 70 feet below present sea level. The sand of sample 20915 may represent a part of the detritus deposited by the stream during the waning phase of the Wisconsin. With the melting of the continental glaciers the rising sea drowned the lower channel of the Delaware and now serves to check the velocity of the stream and cause deposition of the finer detritus (probably including flocculation of the clay) carried by the somewhat shrunken stream.

The interpretation offered above is tentative, because only few data are available at present. However, a systematic investigation of the sediments of the Delaware River and Bay could undoubtedly contribute greatly to a fuller understanding of the late Quaternary history of the area.

Table 1.• Mechanical composition: statistical parameters

Sample Number	Depth (SLD; feet)	$\phi 16$	$\phi 84$	$Md\phi$	$\sigma\phi$	$\alpha\phi$
20908	36-38	2.98	7.65	4.44	2.34	0.371
20909·	41-43	3.14	9.0	5.95	2.93	0.040
20910	46-48	4.41	9.6 (est.)	6.40	2.60	0.234
20911	51-53	3.75	8.90	6.18	2.58	0.054
20912	56-58	4.73	10.0 (est.)	6.75	2.64	0.231
20913	61-63	4.90	10.5 (est.)	6.95	2.80	0.267
20914	66-68	4.92	11.0 (est.)	8.23	3.04	-0.088
20915	78-80	1.30	3.59	2.38	1.15	0.060
20916	82-84	4.95	13.0 (est.)	8.41	4.03	0.138

Table 2 • Percentages of heavy minerals

Sample Number	Depth (SLD; feet)	Actinolite	Andalusite	Augite	Brookite	Chloritoid	Enstatite	Epidote	Garnet	Hornblende	Hypersthene	Kyanite	Rutile	Sillimanite	Fibrolite	Staurolite	Tourmaline	Tremolite	Zircon	Zoisite	Opaque (% of total)
20908	36-38		1				1	10	3	67	4	1		4	1	1	4	1	2	1	24.5
20909	41·43	4	1			3		8	4	53	5		1	6	1	3	5	2	4	1	17.6
20910	46-48	4				2	1	7	7	52	2		3	4	5	3	4	1	5	1	27.7
20911	51-53	2	4	1		3		9	3	56	4	2		2	2	2	3		4	1	28.4
20912	56-58	1	1			3		1	5	52	3	1	1	5	5	4	10	1	6		47.8
20913	61-63		1			1		5	8	54	3	1	1	4	4	4	6		8	1	54.6
20914	66-68	2	2	1		1	1	4	5	54	4	1	1	6	7	6	2		4		48.1
20915	78-80		2	1			1	3	18	19	8	10		7	9	8	8		6		33.7
20916	82-84				2	2		3	4	1		4	2		4	41	26		12		95.1

(Figures given to nearest per cent)

Table 3. - Percentages of arborial pollen

Sample No. and Depth		Picea	Pinus	Tsuga	Alnus	Betulaceae	Quercus	Ulmus	Tilia	Castanea	Carya	Jugland	Liquidambar	Nyssa	Ilex	NAP (in % of arborial pollen)
20908	37'		40	14	1	1	23		1		18		1		1	33
20909	42'	1	45	15	1	2	20				15		1	P		33
20910	47'	P	64	25	P	P	P				10		1			26
20911	52'		34	9	3	4	28	P	P	P	20	P	1			18
20913	62'		47	7	P	1	16	P		P	26	P	P			24
20914	67'		50	6	2	1	11				29		1			64

P - Present, less than 1%.

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