PAPERS IN PHYSICAL OCEANOGRAPHY AND METEOROLOGY

PUBLISHED BY

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

AND

WOODS HOLE OCEANOGRAPHIC INSTITUTION

VOL. XI, No. 2

THE SEDIMENTS AND STRATIGRAPHY OF THE EAST COAST CONTINENTAL MARGIN; GEORGES BANK TO NORFOLK CANYON

BY

HENRY C. STETSON

CAMBRIDGE AND WOODS HOLE, MASSACHUSETTS

AUGUST, 1949

PAPERS IN PHYSICAL OCEANOGRAPHY AND METEOROLOGY

(In continuation of Meteorological Papers)

Meteorological Papers

Vol. I,	No. 1.	H. C. Willett: Synoptic Studies in Fog, 1930.	Out of Print
	No. 2.	Horace R. Byers: Characteristic Weather Phenomena of California, 1931.	1.00*
	No. 3.	C.-G. Rossby: Thermodynamics Applied to Air Mass Analysis, 1932.	1.00*
	No. 4.	C.-G. Rossby: A Generalization of the Theory of the Mixing Length with Applications to Atmospheric and Oceanic Turbulence, 1932.	Out of Print

Papers in Physical Oceanography and Meteorology

Vol. II,	No. 1.	H. U. Sverdrup and F. M. Soule: Scientific Results of the "Nautilus" Expedition, 1931, Parts I to III, 1933.	1.00†
	No. 2.	H. C. Willett: American Air Mass Properties, 1933.	1.00*
	No. 3.	B. Villinger and Henry C. Stetson: Scientific Results of the "Nautilus" Expedition, 1931, Parts IV and V, 1933.	1.00†
	No. 4.	Henry B. Bigelow: Studies of the Waters on the Continental Shelf, Cape Cod to Chesapeake Bay, I. The Cycle of Temperature, 1933.	1.00†
Vol. III,	No. 1.	H. R. Seiwell: The Distribution of Oxygen in the Western Basin of the North Atlantic, 1934.	1.00†
	No. 2.	K. O. Lange and C. S. Draper: The Meteorological Airplane Ascents of the Massachusetts Institute of Technology, 1934.	Out of Print
	No. 3.	C.-G. Rossby and R. B. Montgomery: The Layer of Frictional Influence in Wind and Ocean Currents, 1935.	Out of Print
	No. 4.	H. R. Seiwell: The Cycle of Phosphorus in the Western Basin of the North Atlantic, I. Phosphate Phosphorus, 1935.	1.00†
Vol. IV,	No. 1.	Henry B. Bigelow and Mary Sears: Studies of the Waters on the Continental Shelf, Cape Cod to Chespeake Bay, II. Salinity, 1935.	1.00†
	No. 2.	H. C. Willett: Discussion and Illustration of Problems Suggested by the Analysis of Atmospheric Cross-Sections, 1935.	Out of Print
	No. 3.	C.-G. Rossby and R. B. Montgomery: On the Momentum Transfer at the Sea Surface, 1936.	Out of Print
	No. 4.	C. O'D. Iselin: A Study of the Circulation of the Western North Atlantic, 1936.	1.00†
Vol. V,	No. 1.	C.-G. Rossby: Dynamics of Steady Ocean Currents in the Light of Experimental Fluid Mechanics, 1936.	1.00*
	No. 2.	H. R. Seiwell: Short Period Vertical Oscillations in the Western Basin of the North Atlantic, 1937.	0.75†
	No. 3.	H. R. Seiwell: The Minimum Oxygen Concentration in the Western Basin of the North Atlantic, 1937.	0.50†
	No. 4.	Henry C. Stetson: The Sediments of the Continental Shelf off the Eastern Coast of the United States, 1938.	Out of Print

(*Continued on inside back cover*)

* Requests for this number should be addressed to Meteorological Department, Massachusetts Institute of Technology, Cambridge, Massachusetts.

† Requests for this number should be addressed to Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

PAPERS IN PHYSICAL OCEANOGRAPHY AND METEOROLOGY

PUBLISHED BY

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

AND

WOODS HOLE OCEANOGRAPHIC INSTITUTION

VOL. XI, NO. 2

THE SEDIMENTS AND STRATIGRAPHY OF THE EAST COAST CONTINENTAL MARGIN; GEORGES BANK TO NORFOLK CANYON

BY

HENRY C. STETSON

Contribution No. 487 from the Woods Hole Oceanographic Institution

CAMBRIDGE AND WOODS HOLE, MASSACHUSETTS

AUGUST, 1949

CONTENTS

Introduction 5

Sampling Apparatus 7

The Formations of the Continental Shelf 8
- Upper Cretaceous 8
- Eocene 11
- Miocene 11
- Pliocene 12
- Late Pliocene or Pleistocene 13
- Consolidated Sediments of Unknown Age 13

Late Pleistocene and Recent Deposition in the Canyons and on the Slope 14
- Introduction 14
- General Statement 15
- Deposition in the Canyons 15
- Deposition on the Continental Slope 20
- Traverses 21

Structure of Continental Shelves and Slopes 22
- General Considerations 22
- Transgressive and Regressive Overlap 23

Origin of Atlantic Continental Shelf and Slope 25

The Canyon Problem 29

Summary and Conclusions 32

Table 1 — Cretaceous and Tertiary Formations 33

Table 2 — Tows and Cores from the Canyons 35

Table 3 — Cores from the Continental Slope 47

Table 4 — Traverses 52

Appendix A — by Fred B Phleger 53

Bibliography 58

INTRODUCTION

The continental shelf off the northeastern coast of the United States was the first of our offshore coastal areas to be charted in detail by the Coast and Geodetic Survey, starting on Georges Bank in 1930. The techniques responsible for this increased accuracy in offshore waters were first described by Rudé (1938) and have been constantly improved. From these soundings Veatch and Smith (1939) compiled their set of contour charts aided by a grant from the Penrose Bequest of the Geological Society of America. These soundings reopened the submarine canyon problem first commented upon by Dana (1863), which had gradually lapsed into obscurity from insufficient data. The reader is, of course, well aware of the major controversy, with all its far reaching implications, which has been precipitated since the 1930 surveys of Georges Bank were brought to the attention of geologists by Shepard (1933).

As more of the new surveys were completed, data from the field sheets were kindly furnished by the U. S. Coast and Geodetic Survey to the Woods Hole Oceanographic Institution for use in dredging and coring operations. This field work, first reported in 1936, was continued from time to time until 1941 as new soundings became available. Rock dredging and coring has been carried out in every major canyon on the slope from Corsair Canyon at the tip of Georges Bank to Norfolk Canyon off the entrance to the Chesapeake (Fig. 1). Numerous cores have also been taken from the areas in between; and while the whole slope from Georges to the Chesapeake has not been covered, it is believed that no significant areas have been missed. In fact, cores from the slope taken during the summers of 1940 and 1941 have yielded results that are corroborative rather than new. In 1938 on a cruise from Hudson Gorge to Norfolk Canyon, cores were taken on the slope in areas which Veatch had considered to be the most important (personal communication).

In the following report the tows and cores will be described by areas from Georges Bank southwards, as the same region was revisited in successive years. The various samples, however, will be referred to by number followed by the year in which they were taken. The material is in storage in the Woods Hole Oceanographic Institution and in the Museum of Comparative Zoology at Harvard University.

The late Joseph A. Cushman was kind enough to identify the Foraminifera which have been obtained in tows from the canyon walls and in cores, except for those described in Appendix A which is contributed by Fred B Phleger, Jr. Most of the type material is in storage in the Museum of Comparative Zoology, although at the present writing some is in the Cushman Laboratory in Sharon, Massachusetts. I am indebted to Lloyd W. Stephenson for identifying a molluscan fauna from one of the canyons, and to W. C. Mansfield who has reported on another formation. Numerous discussions with Percy E. Raymond have, as usual, proved most helpful, and thanks are also due to Eugenia C. Lambert for performing the mechanical analyses and to Constance French for other laboratory assistance. Phleger (1939, 1942, 1946) has previously published on the Foraminifera from the slope and deep water cores. This material is, at present, at Scripps Institution of Oceanography.

The Cretaceous and Tertiary formations, their position and depths are listed in Table I. Some of these data have been published in previous reports. However, at the risk of some repetition, it seems worth while to assemble in one place all existing information bearing on the stratigraphy at the continental margin.

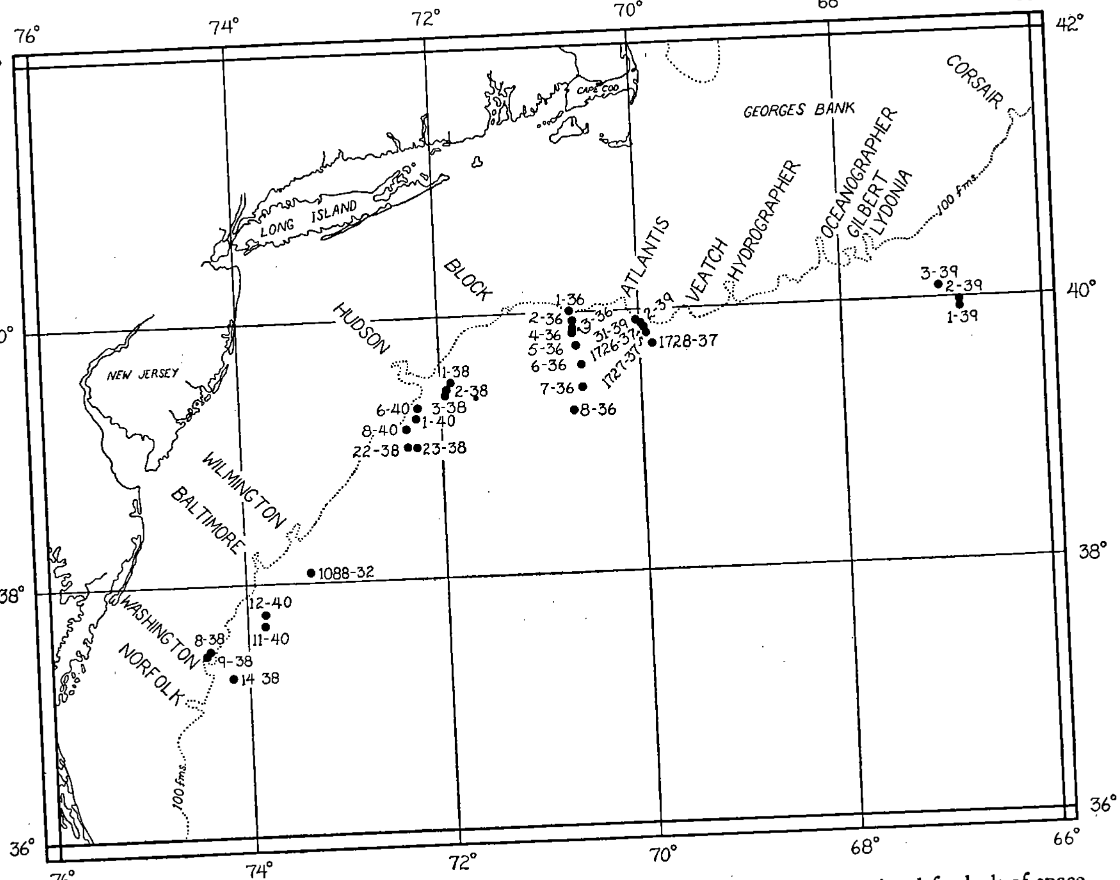

FIG. 1. Location chart giving positions of slope cores. Cores from the canyons were omitted for lack of space.

SAMPLING APPARATUS

The same dredges and methods were used in breaking off pieces of rock from outcrops in the canyon walls which were described in a previous report (Stetson, 1936). Fragments were not considered to have been obtained in place unless the tension on the trawl wire exceeded 5000–6000 lbs. (sometimes going as high as 14,000–15,000 lbs.) and the pieces showed freshly broken faces. Talus fragments were easily recognized by their rounded and weathered appearance, and by the fact that when the dredge was scooping through this loose material the tension on the wire never went over 2000–3000 lbs. The same low tensions were noted when dredging in glacial material. Tows were always made uphill, except in two or three cases where a mistake in position was made and, therefore, it was possible to record only the lower and upper limits of many of the tows, as the dredge was often as much as a mile behind the ship. As the dredge was dragged up the canyon wall and encountered an outcrop the tension would build up rapidly until a fragment of the ledge was broken off. This might happen two or three times in the course of the tow, and it was impossible to record the exact depth at which each outcrop was hooked after the break occurred. Occasionally, however, the dredge hooked so solidly that vessel's headway was stopped. It was necessary to take in the wire until it was straight up and down bringing the ship directly over the formation, and in this position the exact depth could be recorded. The vessel would then slowly circle, maintaining as much tension on the wire as safety would allow until either the rock broke or the dredge pulled loose.

Traverses of surface samples were also taken across three of the Georges Bank canyons, from wall to wall, with the sampler (Stetson, 1938) which had previously been used on the continental shelf. Such traverses give a clear picture of the transition between the material which covers the surface of the Bank, and the Recent sediment which is filling the canyons.

All cores were taken either with the Piggot gun (Piggot, 1936) or with the Free-Fall coring tube (Hvorslev and Stetson, 1946).

THE FORMATIONS OF THE CONTINENTAL SHELF

Nine sedimentary formations older than Recent have been found in the walls of some of the major canyons and in adjacent smaller gullies; and of these, eight can be dated exactly by the fossils which they contain. Upon these fossils rest the age estimates for the time of canyon cutting. Therefore, it is essential to distinguish between fragments broken from outcrops, and talus. This procedure was outlined under the section describing the methods of dredging.

It was expected that these faunal assemblages would resemble those of similar age from the Atlantic Coastal Plain, as the continental shelf can be regarded as the seaward extension of this feature; and in some instances this proved to be the case. Most unexpected, however, was the strong faunal similarity to formations of the Mississippi embayment and the Gulf Coast found in some of the other sediments. This Gulf fauna may have been characteristic of the continental slope throughout its length with no intervening faunas of the Atlantic type, but data are lacking on this point, because it has not been possible to dredge any fossiliferous samples from the slope south of the latitude of northern New Jersey. For the statistics Table 1 should be referred to during the following discussion.

Upper Cretaceous

The oldest formations that have been found in place and which can be accurately dated are from the Upper Cretaceous. Rocks of Matawan age outcrop in two places in Oceanographer Canyon, appearing in Tow 5–34 and in Tow 10–36. Stephenson (1936) has previously described the fauna from Tow 5. He also examined the fossils from Tow 10 which are found in a coarse-grained, friable, brownish sandstone and reports as follows (personal communication): "The rock appears to be identical with that from which the fossils described in the Bulletin of the Geological Society of America, vol. 47, pp. 367–384, 1936 were obtained. The species marked with an asterisk are the same as species described in the report cited. The evidence tends to show the Matawan rather than the lower Monmouth age of the rock. In the earlier report I was undecided as to whether it was of upper Matawan or lower Monmouth age." The list of fossils is as follows:

Porifera:
- *Cliona* sp.

Coelenterata:
- *Micrabacia* ? sp. (an imperfect fragment)

Mollusca:
- Pelecypoda:
  - *Idonearca woodburyensis* Weller
  - **Glycymeris subcrenata* Wade
  - **Postligata schalki* Stephenson
  - *Ostrea* sp. (young individuals)
  - *Trigonia* sp. (imprints of fragments)

Lima n. sp.? (aff. *L. reticulata* Forbes)
?**Liopistha* aff. *L. protexta* (Conrad)
Astarte? sp.
**Crassatella roodensis* Stephenson
**Cardium* (*Trachycardium*) *nixicollis* Stephenson?
(= *C.* (*T.*) *vaughani* Stephenson; not *C.* (*Protocardia*) *vaughani* Shattuck)
**Cardium* (*Trachycardium*) *longstreeti* Weller?
Cardium (*Trachycardium*) sp.
Cardium (*Granocardium*) *atlanticanum* Stephenson
Tellina sp.
Cymbophora sp.
Unidentified pelecypods

Scaphopoda:
Cadulus sp.
Dentalium sp.

Gastropoda:
Polinices? sp.
Gyrodes petrosus (Morton)?
Turritella (2 species)
Paladmete? sp.
Unidentified gastropods

The sandstone fragments from which the fossils in Tow 10–36 were obtained were probably all talus. However, as Tow 5–34 covered practically the same vertical range and brought up fragments broken from outcrops as well as talus, it is probable that either the outcrop in the path of the 1936 tow was buried or that the dredge passed over it without catching. Both tows are on the east side of Oceanographer Canyon.

Large slabs of a finer-grained, friable sandstone, which had every indication of having been broken off in place, were also found in Tow 10–36 but they, unfortunately, proved unfossiliferous, as did pieces of a coarse-grained, glauconitic sandstone, almost a conglomerate, which were obviously talus.

Sediments of Navarro age were dredged three times, twice in Gilbert Canyon and once in Oceanographer. The first occurrence, Tow 6–34, from the east side of Gilbert Canyon, consisted of a coarse, friable greensand with a considerable admixture of quartz. According to Cushman (1936) this greensand contains a large fauna of about 85 species of Foraminifera and is to be correlated with faunas of Upper Cretaceous age (Navarro) from the general Gulf Coast region. Little is known of the Cretaceous Foraminifera of the Atlantic Coastal Plain, "so that correlations with that area cannot definitely be made."

The second formation of Navarro age, from the east side of Gilbert Canyon, Tow 14–36, is a fine-grained, micaceous sandstone, heavily stained with limonite. The dredge brought up fragments of this formation in a rather curious way, which proved definitely that it had broken pieces from an outcrop. When the dredge came to the surface of the water, a large slab of sandstone was seen hanging on the trawl wire by a deep slot which had been cut in one edge (Fig. 2). This slab was the topmost stratum of the ledge as the top surface was covered with worm tubes and algal growths and the bottom showed a clean break along a parting plane. The bag of the dredge was full of slabs of the same material. The dredge had evidently come up to a steep cliff and because of the long scope used in these tows (about a mile of wire to 758 meters of water in this case) the towing

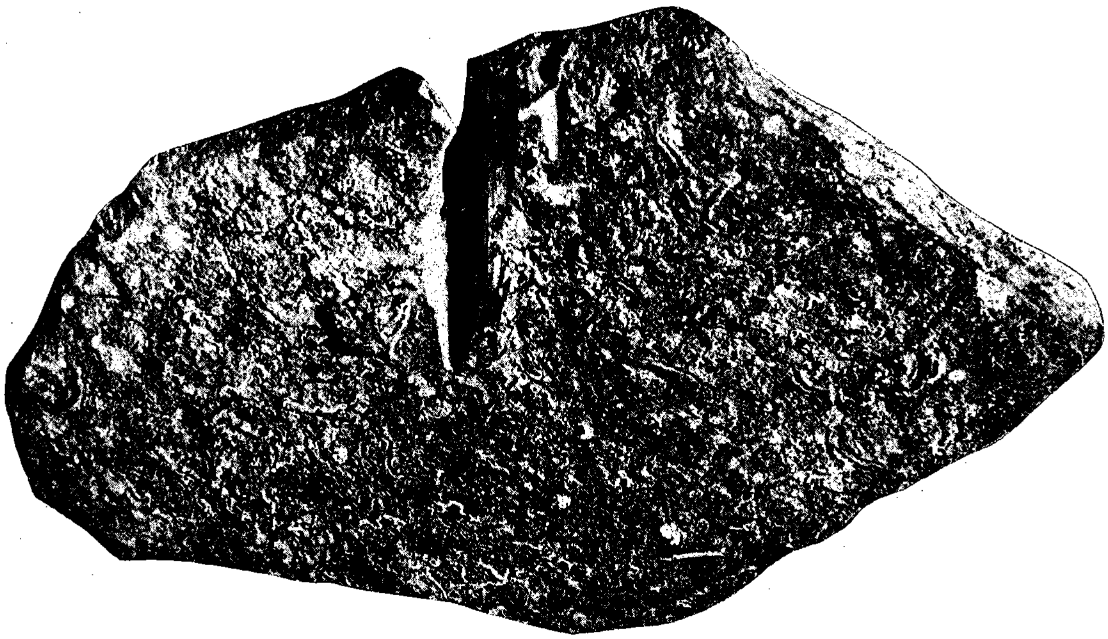

FIG. 2. Tow 14–36. A slab of Navarro sandstone broken from a cliff in Gilbert Canyon. Note the cut made by the dredge wire and the worm tubes encrusting the upper surface. The lower surface shows a fresh break along a parting plane. Maximum dimensions 29 x 19 inches.

wire made a sharp angle over the edge of the cliff while the dredge was travelling up its face. As the ship moved ahead the wire sawed into the topmost layer, which must have been flat lying, or nearly so, cutting a deep slot. The clips holding the thimble in the end of the towing wire, to which the arms of the dredge are shackled, were much larger than the diameter of the wire, and as they could not pass through this slot, the slab was ripped off. Although the sandstone was fairly hard, enough was disintegrated to obtain a few Foraminifera. It is a much smaller assemblage than that from the greensand reported above, probably because the rock cannot be broken down so easily, but enough material was obtained to establish its age definitely. The diagnostic forms as determined by Cushman are as follows: *Gümbelina globulosa* (Ehrenberg), *Loxostoma plaitum* (Carsey), *Planulina correcta* (Carsey), *Dorothia bulletta* (Carsey) (personal communication).

The third formation of Navarro age, Tow 2–39, outcrops on the east side of Oceanographer Canyon, and contains a fauna which, according to Cushman (personal communication), is the equivalent of the Kemp Clay. It is a dark colored, silty clay containing a large amount of mica and is partly indurated. On reimmersing in water, after complete desiccation, this clay breaks down completely because the process of drying and rapid reabsorption of water disturbs the packing of its constituent particles and causes the original sedimentary structure to collapse. The diagnostic forms are as follows: *Arenobulimina americana* (Cushman), *Gümbelitria cretacea* (Cushman), *Ventilabrella carseyae* (Plummer), *Pseudouvigerina plummerae* (Cushman), *Loxostoma plaitum* (Carsey), *Planulina correcta* (Carsey).

Eocene

Sediments of Jackson age have been found in three cores. The first outcrop, core 12–36, is on the continental slope about 90 miles south of Marthas Vineyard in 880 meters of water. The formation is here a pure foraminiferal chalk, only slightly indurated, and is unconformably overlain by four inches of Recent green silt. According to the boat sheets of the U. S. Coast and Geodetic Survey, kindly furnished by Comdr. Paul A. Smith, this particular portion of the slope shows no pronounced gullying, and at the position of this core the slope contours are, in general, regular. The second outcrop, core 21–38, in 1565 meters of water, is in the bottom of the first large gully southwest of the Hudson Gorge. This gully A. C. Veatch called "Toms Canyon," from the New Jersey river of that name, on a chart which he sent to the author prior to the 1938 cruise, but the name never has been officially adopted. Here again, the formation is a pure foraminiferal chalk, and it is unconformably overlain by 122 cms of Recent green silt. Streaks of this chalk are found in the silt 66–68 cms below the top of the core. It does not occur in a regular band but has a smeared appearance, being thicker on one side of the core than on the other, with small patches lying apart from the main mass. This disturbance could not be due to the impact of the sampler on the sediment as the main deposit of the chalk lies twenty inches below the streak, and, furthermore, according to Hvorslev (1946), disturbances due to this cause are never of this particular type. It seems probable that the core was taken in material that had slumped, resulting in a certain amount of mixing. This point will be discussed later. Cushman (1939) has published on the fauna of these two cores. The most important diagnostic form is *Hantkenina alabamensis* (Cushman) which is common to both cores, and which correlates them with such widely separated areas as Cuba, Venezuela, Mexico, and California. As might be expected, both cores contain many undescribed species. The fauna of 12–36 is the richer of the two. The curious fact that the Navarro, Kemp and Jackson faunas are all typical Gulf Coast assemblages probably indicates that a warm current from the south, the forerunner of the present day Gulf Stream, was flowing up the westerly side of the Atlantic.

In 1947 what is probably this same marl was obtained by John Northrup in a short core taken in conjunction with an underwater photograph, from the slope south of Marthas Vineyard at Lat. 39° 43′ N., Long. 70° 48′ W. (position approximate) in about 1000 meters of water.

Miocene

A Miocene formation of Yorktown age has been found four times, once in place in Lydonia Canyon, twice as talus in Hydrographer, and once in Corsair (Tows 20–36, 1–36, 2–36, 23–36). It is a highly indurated, fine-grained, greenish sandstone and is by far the hardest formation that has been found (Fig. 3). The Foraminifera were all found by the laborious process of examining numerous small chips as the rock is too hard to break down by the usual methods of boiling in soda and prolonged agitation. Of the three commonest forms, *Robulus americanus*, var. *spinosus* (Cushman), *Cassidulina laevigata* (D'Orb.), and *Uvigerina* cf. *pigmea* (D'Orb.), *Robulus americanus*, var. *spinosus*, is the most diagnostic. The records for it are from the Miocene (Yorktown formation) of North Carolina, Miocene of Florida in three zones of the Choctawhatchee and three of the Shoal River, Miocene (well samples) of southern Louisiana, and Miocene of California." (Cushman, personal communication.)

FIG. 3. Tow 20–36. A block of indurated, fine-grained Yorktown sandstone broken from a cliff in Lydonia Canyon. Note the worm tubes and mollusk borings on the upper surface indicating exposure to the water, and the fresh breaks on the other faces. Maximum dimensions 28 x 17 x 15 inches.

From this sandstone also comes a specimen of *Phacoides* (*Lucinoma*) cf. *contractus* (Say) which was identified by Mansfield. Of the distribution of this species, Dall (1903) says that it is found in the "Miocene of Maryland at Calvert Cliffs, Plum Point, and Charles County; of the eastern shore of Maryland and at Suffolk, Virginia; of the Ashley River beds of South Carolina and of Florida at Alum Bluffs on the Chattahoochee River."

Pliocene

From Lydonia Canyon came a very friable greensand with a large admixture of quartz which contains a peculiar fauna (Tow 9–34). According to Cushman (1936, p. 414) most of the species are living but are confined to much warmer waters than those found over Georges Bank today. Other species show "relationships to those of the Pliocene of the western coast of the United States and even to the Pliocene of Japan." . . . It would seem to indicate that they were deposited in late Tertiary time, before the cooling of the waters by the accumulation of ice in the Pleistocene."

Late Pliocene or Pleistocene

A hard, green silt has been found once in Oceanographer Canyon, once in Gilbert, and twice in Lydonia Canyon (Tows 9–34, 6–34, 5–34, 11–34). Although not an indurated formation, the material came up in large, angular fragments, much harder than Recent silts of similar texture, and sufficiently compact to be practically dry inside when broken open immediately on reaching the deck. Furthermore, the sediment was compact enough, in spite of rough handling it had received in the dredge, to retain undistorted the burrows of worms and other bottom living organisms. Some of the Foraminifera show the same late Pliocene resemblances that were found in the greensand mentioned above, but the rest of the assemblage indicates a distinctly colder water environment, and, in addition, the proportion of living species is much greater. There are, however, striking differences between this assemblage and the one now found in the present day muds of the canyon bottoms as obtained from the tops of cores. One of the most striking is the complete lack of the genus *Plectofrondicularia* in the latter. In discussing both the greensand and the green silt formations Cushman (1936, p. 414) goes on to say, "With an almost entire absence of Pliocene foraminifera on the Atlantic Coast, especially faunas representing cooler waters, it is difficult to determine with any certainty the exact age of this material. The great predominance of living species would indicate that both the greensand and the silts are of very late Tertiary age, and indications seem to point to late Pliocene or earliest Pleistocene as the most probable age. The green sand represents a warmer water condition and is, therefore, probably older than the silts."

Consolidated Sediments of Unknown Age

In Washington Canyon, the dredge brought up many talus fragments of a coarse-grained, indurated sandstone as well as Recent silts and clays. The rock was unfossiliferous and the outcrop itself was never found.

Four different types of sedimentary rocks have been found in Norfolk Canyon but only one of them was in place and none can be dated. Fragments of a highly indurated fine-grained sandstone with a calcareous cement were obtained from ledges on the northeast side between 604–530 meters. The dredge was dragged over successive outcrops breaking off pieces on the way, which unfortunately proved to be unfossiliferous. The other three specimens are obviously talus fragments. In one, a very coarse-grained greensand containing considerable quartz, there were a few Foraminifera, but although Cushman (personal communication) says they are not Recent, they are not diagnostic enough to assign a definite age to the formation from which they came. The other two talus fragments are sandstones, one coarse and one fine, and both fairly hard, but of different texture from the one which was found in place. Both are unfossiliferous. If we may judge by the amount of induration exhibited by these sediments, it is most unlikely that any of them are Recent. Although their age is unknown they are important evidence that the continental shelf, at least this far south, does contain some hard formations. Except for these occurrences, the other well indurated formations all come from Georges Bank. Talus fragments from the southern canyons have more significance than those from canyons which lie within the limits of glaciation, as the factor of ice rafting is largely eliminated. Fragments of any size, in all probability, have fallen from the walls of the same valleys in which they were dredged up.

LATE PLEISTOCENE AND RECENT DEPOSITION IN THE CANYONS AND ON THE SLOPE

Introduction

In the sections which follow, a detailed description of late Pleistocene and present day sedimentation both on the continental slope and in the canyons will be given. Certain trends reflecting conditions of deposition are apparent, but it should be remembered that variations will be found which cannot, at present, be explained. Perhaps they may be due to the sampling error, or to a set of peculiar local conditions about which a single core or dredge sample gives no clue. But the fact that any sedimentary patterns at all can be recognized is the point to stress, and not that certain departures from these trends can be picked out because the large areas involved and the necessarily wide spacing of the samples must be taken into account.

Professor E. S. Larsen, from time to time, has had his students make heavy mineral studies of suites of samples from the continental shelf as part of the laboratory instruction in his courses. A certain amount of differentiation has been found but in the present state of our knowledge it is not interpretable. In the sediments of glacial origin, as might be expected, mineral species have been mixed to a considerable extent, and in the case of those samples taken beyond the limits of the ice sheets so little is known about the source rocks, and the resulting sediment has gone through so many cycles, that no definite results can be arrived at. It is probable, therefore, that a heavy mineral study of material lying even further offshore would be even more confusing, and only result in the accumulation of data which would not be usable in the immediate problem.

The combined sieve and pipette method of mechanical analysis, described by Krumbein (1932), was employed, and the data, plotted as cumulative curves on 4-cycle semi-logarithmic graph paper, were treated statistically using the median and the coefficient of sorting and skewness described by Trask (1932). For specific details of the procedure, their papers should be consulted. Briefly, the median diameter represents the mid-point of the size distribution and is the most important single constant. It, together with the sorting coefficient, is an indicator of texture. A perfectly sorted sample, which, of course, would never be found under natural conditions, would have a value of 1. For purposes of comparison, the analysis of many samples by the present author gives an average value of 1.45 as indicative of good sorting in the neritic zone, and 1.25 for beach sands. The coefficient of skewness measures the dissymmetry of the size distribution curve, and shows on which side of the median and how far from it the point of maximum sorting lies. For ease of interpretation, the logarithm of skewness is given. A log of 0.0 indicates the mode coincides with the median, a plus log that the mode is on the fine side of the median and a minus log the opposite. At the present time the measurement of skewness is difficult to interpret and, as Krumbein (1939) observes, "its exact geological significance is not fully understood." However, he goes on to say, "the full explanation is probably not simple, but in the writer's opinion skewness will be found to have a genetic significance in many sediments."

General Statement

Overlying the Cretaceous and Tertiary formations which outcrop on the sides of the canyons and the smaller gullies are the deposits of Pleistocene and Recent age. They cover the continental slope and extend out over the bottom of the ocean. The Recent sediments are usually silts of varying textures, but occasional clays are found. The Wisconsin deposits, on the whole, are finer textured than the Recent with clays and the finer grades of silt occurring more frequently. The two types of sediments can be distinguished by color as the Recent material is usually greenish and the late Wisconsin different shades of gray or pink. When thoroughly dry these color differences fade out. Everywhere that cores have been taken Recent deposits are always present and always overlie the Wisconsin, although the layer is of varying thickness depending on the topographic location. For instance, sedimentation will be thicker in the bottom of a gully than on an adjoining ridge.

The dating of the two sediments rests on the pelagic Foraminifera. Throughout the whole layer which is classed as Recent are found the dead tests of the same forms which are now settling out of the modern ocean, and they indicate that the upper layers of water today are somewhat warmer than they were during the last of the Wisconsin. The fauna which lies below this surface material also consists of pelagic Foraminifera which are still living, but not in the latitudes in which these cores were taken. They are, for the most part, northern forms which, according to the interpretation given here, were able to extend their range farther south when the surface layers of the sea were chilled during the last ice advance. The type of sediment which was laid down in the colder seas can, therefore, be distinguished from Recent deposition both by texture and by the contained fauna. In a great many instances the correlation between the two faunas and the type of sediment is exact, indicating that the change in conditions of deposition occurred abruptly.

During the hunt for the consolidated formations a good deal of unconsolidated Pleistocene and Recent sediment was brought up by the dredge. These tows are chiefly useful as indicating that in the area traversed the older rocks are completely mantled by younger deposits, because during the course of long tows much of this soft sediment must have been squeezed out through the iron meshes of the dredge bag.

Phleger (1939, 1942, 1946 and in Appendix A of this paper) has reported on the Foraminifera from the cores in detail and, therefore, only his general results as they apply to sedimentary conditions will be cited here. In the pages which follow, all the climatic data are based on the above references. They will not be cited in each individual instance. For the statistical data on the sediments of tows and cores, see Tables 2, 3, and 4.

Deposition in the Canyons

Corsair Canyon

Three tows were made on the east side of Corsair Canyon, none of which encountered anything older than the late Wisconsin. The dredge came up full of chunks of hard green silt which were smeared with softer green silt. Two of these tows, 22–36 and 23–36, from comparable depths were analyzed mechanically and proved to be very similar, with medians of .025 and .016 mm., poor sortings of 6.05 and 6.82 and fairly large skewnesses. From the table of size fractions it will be seen that the sand and silt divisions together average over 60%. The Foraminifera are the cold water type. It is impossible to determine the superposition of material brought up in the dredge, but on the basis of the cores taken in other canyons where such relationships can be established, the dredge evidently cut through the softer Recent deposits and reached the harder Wisconsin silt below. The former was not analyzed in this case because it had been badly mixed and presumably contaminated. No cores were taken in this canyon.

Lydonia Canyon

Four cores, 4–39, 5–39, 6–39, and 7–39, were taken down the length of this canyon in deepening water; the two inner ones in the middle and the two outer slightly to the west of the center. The two shallower cores did not penetrate the layer of Recent sediment; and, although one of them is 196 cm long, the Foraminifera are all warm water forms. There is nothing significant in the sequence of the medians, relatively fine material being found at the surface as well as some distance below it. The two deeper cores, however, penetrated the late Wisconsin, and in core 7–39 between sections 2 and 3, where the cold water fauna comes in, a progressive decrease in the median diameter also begins and continues to the bottom section. The trend is slight in this case, but it is there. However, as it has been found repeatedly in other cores, it can be said that the cold water faunas tend to be correlated with the finer textured sediments. The sorting is fair, which is normal for a fine textured, offshore sediment.

Unless a core was sampled continuously, which obviously can only be done occasionally when dealing with a large number, it is impossible to give exact figures for the thickness of the layer of Recent sediment. In this paper, therefore, except in one instance, only the order of magnitude is given for the depth at which the cold water fauna is first picked up and it is usually somewhat larger than the actual figure would be. However, in view of the changes in the length of the core due to the impact of the sampler which cannot at present be evaluated, and of the accidents of deposition which likewise cannot be explained in an offshore survey of this sort, such a laboratory sampling procedure is considered adequate.

Three tows, 17–36, 19–36, and 20–36 in addition to those recorded in Table 1, were made on the sides of this canyon at comparable depths with the two inner cores. Texturally they are similar to the hard green silts brought up in Corsair Canyon, and they have the same cold water fauna. They probably represent the same late Wisconsin deposition.

Gilbert Canyon

Three cores, 9–39, 10–39, and 11–39, were taken following the course of Gilbert Canyon outward to 2194 meters of water. The material is very similar to that found in Lydonia, as might be expected, although somewhat coarser. The shallowest core consists of Recent silt down to the section at 102 cm where the cold water Foraminifera first make their appearance. There is, however, no tendency to grow progressively finer with depth. In the two deeper cores the median diameter decreases downward in each case, and contains the cold water fauna indicating that late Wisconsin sediment has been reached at section 2 in 10–39 and section 3 in 11–39. Sorting values show no definite trends and are normal for offshore material. Four tows, 13–36, 14–36, 16a and 16b–36, and 25–36, in addition to those recorded in Table 1, were made all on the east side which yielded fairly compact clays and silts. The Foraminifera from the compact material are all cold water forms. There were smears of greenish clay and silt on all of these fragments, however, which were only analyzed in the case of tow 16b–36, and the Foraminifera from it proved to be of the warmer water type. This would indicate that the dredge had cut through the cover of the soft present day sediment and had scooped out pieces of the more consolidated material deposited during the late Wisconsin. The median diameter and sortings are comparable to those of sediments of the same age deeper down in this same canyon, and to those lying further offshore which have been brought up as cores.

A long core, 8–39, of 219 cm was taken in 1919 meters of water from a small gully between Lydonia and Gilbert Canyons. Here, the transition occurs between sections 2 and 3 as section 3 is definitely cold and 2 is transitional. With the advent of the cold water fauna, the sediment becomes very much finer with the median dropping from .199 to .004. The small values for the median are maintained to the bottom of the core. The sorting values are uniform but relatively poor.

Oceanographer Canyon

The cores, 12–39, 13–39, 14–39, 16–39, and 17–39, from Oceanographer Canyon are all shorter than usual because the sediment is more compact, but the texture has no apparent relation to compaction as silts and clays are equally hard. The median diameters are comparable to those from the other canyons on this part of the shelf. However, the sorting is noticeably better than in the samples from the other three canyons on Georges. These cores follow the course of the canyon and although only one is in the middle none is far from the deepest point in their respective cross sections. The shallowest one is Recent silt with the warm water fauna throughout its length. Cores 13–39 and 14–39 were not examined for Foraminifera. In the two deepest cores we find the transition from the warm to the cold fauna, occurring at 77–82 cms for 16–39 and at 66 cms for 17–39, and once again the change is accompanied by a corresponding reduction in the median diameter. Core 12–39 was Recent throughout.

Four tows, 26–36, 12–36, 7–36, and 27–36 in addition to those recorded in Table 1, were made in this canyon. The material consisted of hard green silts and clays corresponding in texture to the cold water green clays and silts brought up in the other canyons. The Foraminifera from one of them, tow 7–36, were examined and classified as a cold water fauna.

Hydrographer Canyon

Five tows, 1–36, 2–36, 3–36, 5–36 and 28–36 were made on the sides of this canyon, all of which yielded green silts and clays apparently identical to those from Oceanographer, and with the same cold water fauna. Nothing older than these formations was found.

Veatch Canyon

Two cores, 20–39 and 22–39 were taken in this small canyon in green silt. The former shows a tendency towards a cold water fauna in the bottom section, but the latter is warm water throughout.

Hudson Canyon

This canyon was sampled repeatedly, both by dredge and coring tube in an attempt to reach the formations into which it has been cut, but with no success. The blanket of late Pleistocene and Recent sedimentation is too thick to be penetrated at each place which was tried.

Four cores, 1–35, 1–40, 2–40, 2–35, were taken in the very head of the canyon in 344 to 417 meters of water which show no grade size trends of any sort in the length of the core. Most of the sections would be classed texturally as silts of various grain sizes with an occasional sand or clay. Core 2–40 which was sampled continuously gives a clear picture of these fluctuations in the grade size in this group. The 1935 cores were not examined for Foraminifera as were 1–40 and 2–40. These latter cores indicate that the late Wisconsin was reached at about 55 cm in one case and 40 cm in the other. However, there is no correlation with regard to grade size, and the sediment may be relatively coarse or fine regardless of age.

Three cores, 4–35, 4–40, and 5–40, were taken below the bend of the canyon in 664 to 815 meters of water, in or near the deepest part. On the whole, the textures of the different sections of these cores average finer than those from the head of the canyon, but there is no correlation between texture and the fauna. Core 4–40 becomes increasingly finer downwards, but the material is all Recent. Core 5–40 reaches the cold water fauna at about 120 cm, but there is no diminution in the median diameter. Core 4–35 was not analyzed for Foraminifera.

Four cores, 4–38, 5–38, 6–38, and 7–38, were taken across the canyon on a traverse about half way down the continental slope. It started on the northeast side in 1042 meters of water and ended on the opposite side in 1125 meters. A core was taken in the deepest part at 1710 meters. All the cores penetrate to the cold water deposits beneath a cover of warm water sediment varying from 55 to 144 cm thick, and they are all very similar in texture. This indicates that environmental conditions were uniform over the whole area, and that there was no differential deposition between valley walls and valley bottom. Silts of the finer grades and, to a lesser degree, clays predominate and apparently the depth of water had little effect on the distribution of the material. The tendency for the finer grade sizes to be associated with cold water fauna is well demonstrated here, which is rather surprising because the actual differences in the medians are relatively slight. For instance, in core 6–38 the medians become finer by less than .001 mm when the definite shift from the warmer to the colder fauna takes place, and in 5–38 it is but little more than .003 mm. In this core, furthermore, the bottom section at 142 to 147 cm is the coarsest of all, and the fauna which in sections 4, 5, and 6 had been the cold water type shifts to the warm type. This means that the coring tube penetrated into sediment laid down during part of yet another climatic cycle.

The Foraminifera of four tows, 4–35, 21–35, 22–35, and 23–35, were examined and they all proved to be cold water forms. The sediments for the most part can be classed as sandy silts. They were all taken from the walls in the section of the canyon just below the large bend and are similar to the cores which come from this same locality. The dredge had evidently plowed through the surface layer of Recent material into the late Wisconsin as was the case in the Georges Bank Canyons.

Large Gully West of Hudson "Delta"

Although not strictly a canyon, the cores, 9–40, 20–38, 21–38, and 10–40, taken from two gullies west of the Hudson Gorge may be considered here. The point to be noted is the uniformity of the sediment throughout the entire length of the cores with all the medians lying in the fine silt grades. The greatest difference between any of the medians is .003 mm. Two cores, 10–40 and 20–38, taken in 1197 and 1260 meters of water, respectively, reached the cold water sediment at 74 and 89 cm. Core 21–38, taken in slightly deeper water, shows 121 cm of Recent material lying over an Eocene marl (Jackson) which has been described above.

Wilmington Canyon

The canyons south of the Hudson Gorge are distinguished from the Hudson and those of Georges Bank by the uniform type of the sediments with which they are filled. Two cores, 14–35 and 13–35, were taken in the middle of Wilmington Canyon, one near the head in 457 meters of water and one near the mouth in 1124 meters. In both the median remains at about .01 mm and fluctuates very little. The sorting is fair and ranges about 3.00. Both of them would be classed as sandy silts.

Five tows, 18–35, 19–35, 20–35, 6–40, and 15–35, were made on the sides of this canyon, but nothing was found except silty clays all Recent in age and with a warm water fauna. Here again the median diameters and the coefficients of sorting indicate that the sedimentary veneer deposited on the walls of both sides is a uniform material.

Baltimore Canyon

Seven tows, 3–40, 4–40, 5–40, 10–35, 12–35, 13–35, and 14–35, were made in this canyon in an unsuccessful effort to find outcrops of the formations which make up the canyon walls. The samples are all clays and silts containing a warm water fauna Recent in age. This Recent deposition evidently blankets the older rocks as it is found at all depths throughout the length of the canyon.

The three cores, 10–35, 11–35, and 12–35, were taken in this canyon all between 500–600 meters. They are quite similar to those from the adjoining canyons. Only the Foraminifera from the top sections were examined and they proved to be a Recent warm water assemblage.

Washington Canyon

Like all the other southern canyons, the tows from this one yielded either clays or silts. Tows 5–35, 6–35, 7–35, and 8–35 indicate cold water deposition; the dredge having cut through the mantle of present day veneer. Tow 7–35 brought up only Recent green silt. Each core shows remarkable uniformity section by section with but little change in the median diameters and in the sorting coefficients throughout its length. The medians show only a slight tendency to become smaller with increasing depth of water proceeding down the canyon. For instance, core 10–38, taken from the middle of the canyon in 512 meters of water, while it is still within the confines of the shelf, has a median diameter of .009 mm for the top section which is the same as that for core 13–38 from 1080 meters where the canyon is cutting the slope, and only .001 mm greater than core 8–35 from 1280 meters. The largest medians which are found in surface sections of cores taken in the heads of the canyons range only up to about .04 mm.

Cores 12–38 and 13–38, 1450 and 1080 meters, reached the cold water fauna at 139 and 66 cm respectively. The two cores, 10–38 and 11–38, taken in shallow water nearer the head of the canyon failed to penetrate the cover of Recent material, although core 10–38 is 184 cm long. The four 1935 cores were not examined for Foraminifera. They show, however, the same mechanical characteristics as those described above, with a tendency for deeper water to produce a finer texture.

Norfolk Canyon

The sedimentation in this canyon is a good deal like that in Washington at comparable depths. Two long cores were taken from the middle of the canyon, one 15–38 in 610 meters of water at a point where the canyon is still within the shelf, and another 19–38 in 1430 meters at a point where it is crossing the slope. Both are uniform throughout their length and the shallower one is slightly coarser in texture.The sortings range from 4.06–2.58 and are typical of the sortings shown by the sediments of all the southern canyons.

Deposition on the Continental Slope

Deep Water South of Georges Bank

Three cores, 3–39, 2–39, and 1–39, were taken in progressively deepening water from the lower part of the slope. In spite of the depth many sections are silty, although there is a distinct tendency for the core to become progressively finer with depth. It should be noted that the textures are not significantly different from those of cores from the upper parts of the slope which are described below. The bottom section of 3–39 contains a cold water fauna, as does that of 2–39. In 1–39 this fauna is found at 72–78 cm.

Between Veatch and Atlantis Canyons

A short line of cores was run offshore in this area to 1100 meters of water. The top sections of all the cores except the deepest are sandy silts becoming clays at the bottom. 1728–37 is clay throughout. The Foraminifera from 1–39 and 2–39 show a cold water fauna coming in at 72–78 cm in the first core and at 99–107 in the second.

Between Atlantis and Block Canyons

A second traverse roughly parallel to the first was run down the slope to 2740 meters of water. The shallowest core is a silty sand as are the top sections of the second, third and seventh. In general, the top sections of all the cores are coarser than the material that lies below, which becomes silty clay and clay. The upper portions of all the cores contain a warm water fauna, while the bottom portion contains a fauna which had been living in colder water.

Hudson "Delta"

On either side of the lower part of the Hudson Canyon is a fan shaped formation with much more regular contours than are found on other parts of the continental slope. Veatch once speculated that this might be the submerged portion of the Pleistocene delta of the Hudson into which the canyon was later incised (personal communication). Cores were taken at various depths in each half of this formation. The material is a remarkably uniform clay throughout each core with the exception of an occasional surface section. It is somewhat finer than the sediment from the Hudson Canyon at comparable depths but has about the same texture as the canyon sediments farther out. Without exception, the upper portions of every core contain a warm water fauna and the bottom portions a cold water assemblage.

Off Wilmington and Washington Canyons

With the exception of the top section of core 1088–32 and both sections of 8–38, which is shallow, the sediment of all these cores is clay size material and remarkably uniform.

This is well demonstrated by 11–40 which was sampled continuously. Core 12–40 penetrated a cold water sediment at 59–65 cms, but the fauna of the rest is warm water throughout.

Core 9–38, from relatively shallow water, did not penetrate the Recent silt. Core 14–38 from deeper water is entirely in clay and contains a warm water fauna throughout, except at 73–80 cm where it is apparently mixed.

Traverses

Three traverses of surface samples were run across Lydonia, Gilbert, and Oceanographer Canyons from rim to rim in order to get the sequence of the vertical distribution of the sedimentary fill. For sandy material the same rotary dredge was used that had been employed for sampling the continental shelf (Stetson, 1938), and on the softer bottoms short cores were taken of which only the top two or three centimeters are considered here. For the positions and statistical constants see Table 5.

Lydonia Canyon

This traverse which is 3⅔ miles long, with samples evenly spaced, starts on the flat surface of the shelf in 152 meters of water to the east of Lydonia Canyon. It is a clean-washed sand with a median of .65 mm, containing no clay and silt. The next sample, likewise from the top of the shelf, is also a sand though a little finer. The third, taken just below the canyon rim, in 240 meters of water, is still a sand but of finer texture than the other two. In this sample, the silt and clay grades make their appearance for the first time. From this point down to sample No. 5 in 543 meters of water the sediment becomes steadily finer with increasing proportions of silt and clay, although the percentage of sand remains high in all of them. The two samples from the deepest parts of the cross section are not as fine textured as those which lie immediately above them. Possibly this may be due to a swifter flow of the tidal currents in the very bottom of this canyon than higher up, which prevents the finest material from settling out. The sequence of the sediments on the west wall is the same as that found on the east.

Gilbert Canyon

The cross section of Gilbert Canyon is very similar to that of Lydonia with sandy sediments lying on the upper parts of the walls and displaced by silts as the water deepens. In this canyon, however, the deepest part of the cross section is occupied by the finest sediments of the traverse, which are clays.

Oceanographer Canyon

The sediments on this cross section are all sands but without the regular gradation from coarse to fine and back to coarse again which was found in the other traverses. However, it was taken a good deal nearer the head of the canyon in shallower water than either of the others, and the bottom is probably subjected to more vigorous current scour than is the case in deeper water.

STRUCTURE OF CONTINENTAL SHELVES AND SLOPES

General Considerations

In his lectures in his course in stratigraphy, P. E. Raymond used to develop the concept of overlap relationships, in conjunction with Barrell's (1917) ideas concerning wave base and the profile of equilibrium, to explain the formation of sedimentary terraces which are deposited seaward of any shoreline. Grabau (1906) was, perhaps, the first to clearly grasp the significance of overlap in the accumulation of sedimentary deposits, although the general idea in a somewhat vague form appears in the older literature. Recently, the concept is receiving considerable attention from petroleum geologists in connection with the search for stratigraphic traps. Swain (1949) has recently discussed the terms used in this concept and has cited pertinent references.

The present writer considers that the east coast continental shelf in particular, and probably all shelves in their formational stages, can be best explained by combining these processes. Many, however, tell us little as to their origin as they have obviously undergone extensive diastrophic alteration. The present day shelf off the coast of California, particularly its southern portions, and the one off Norway can scarcely be considered prototypes. Their primitive characteristics have been largely obliterated, and this should be kept in mind when evaluating the various theories in explanation of their origin. It seems difficult to get away from the fact that the continental shelves are fundamentally sedimentary features as Shepard (1948) attempts to do by a variety of explanations. In special instances, such as the Norwegian strand flat, marine planation may be an important factor, but by and large they are depositional features to start with, however much they may have been modified by other geological processes in their subsequent history. Shepard makes much of the point that many of the shelves show rock bottom, but except for two occurrences of granite in two of the minor California submarine canyons (which may be local intrusions) the rock is all sedimentary; which implies erosion from the land mass with subsequent deposition along its margin at some stage in the cycle. In the following discussion of the east coast shelf, an attempt will be made to show that here is a simple, ancestoral type of shelf that has been built up since Cretaceous time as a great longitudinal terrace of overlapping sediments, controlled by the profile of equilibrium, but essentially unmodified by any orogenic forces that have so altered the shelf off southern California from its original form. The Gulf Coast shelf is another huge accumulation of sediments which in this case are so thick that they have probably bowed down the basement rocks in the form of a geosyncline (Storm 1945). Only if conditions remain relatively stable for long periods of time can we find the forces still at work which must have been in operation at the inception of all shelves; and here also we should expect to find the thickest sedimentary accumulations. Any deviations from this simple prototype must be explained by subsequent events, as not all shelves have had the same geological history, for some have been subjected to forces which have not affected others. Most of the explanations of shelf origin as summarized by Shepard (1948) are really explanations of this subsequent history and have no bearing whatsoever on shelf origin.

There has been equally much speculation regarding the continental slope. In regard to the one off the northern half of the east coast of the United States, there can be little doubt that it is a depositional feature, somewhat modified by erosion during an unknown period, and possibly by minor faulting. There can be no other adequate explanation for the seaward edge of a primitive shelf such as this one. The same applies to the shelf in the western Gulf of Mexico, although this lacks erosional features, and there is a strong possibility that extensive step faulting has taken place. A discussion of many other slopes takes the reader into a highly speculative zone because few of them have been adequately surveyed and, fewer still, adequately sampled. Doubtless for some, faulting on a major scale is a dominant control as Shepard (1948) contends, but the fact that sedimentary processes are also operative must not be excluded. The fallacy lies in comparing the seaward slope of a shelf like the one found south of the Aleutian Islands arc, fronting a major trench, with that of the enormous pile of detritus which is the Gulf Coastal Plain and shelf. They have little in common today except the fact that they are both inclined sea bottoms going down into deep water.

Transgressive and Regressive Overlap

Every advance or retreat of the sea produces conditions of onlap or offlap which clearly show in the stratigraphic record. Under the simplest conditions during rising sea-level, progressive overlap, or onlap, means that the younger deposits overlap the older in a shoreward direction. The nearshore facies are sandy, while the younger offshore facies resulting from the same sea-level will be sandy muds and muds, with possible calcareous sediments still further seaward if conditions of deposition are suitable. In a vertical section this eventually results in an overlapping of shales on sandstones, and possibly an overlapping of limestone on shales. It is a time of continuous accumulation of sediment in a deepening sea, and the continental shelf grows in thickness as well as in length as successive layers are added to its surface as well as to its forward slope.

Conversely, under the simplest conditions of falling sea-level, regressive overlap, or offlap, means that younger deposits overlap the older in a seaward direction. An advance of the shoreline may also be caused theoretically by a greater supply of sediment delivered by the rivers than the waves can redistribute and remove. At or near the shoreline, coarse clastics are deposited which grade seaward into sandy shales or shales. As the sea continues to retreat the sands and gravels of what has now become the shoal water zone overlap the finer deposits which had been previously laid down in deeper water. The surface of the shelf is undergoing erosion, with the reduction in thickness or entire removal of strata deposited near the shore during the previous onlap.

These are the simplest cases. When successive advances of the sea follow successive retreats, such as have occurred many times in the history of the Atlantic and Gulf Coastal Plains, the result is a complicated sedimentary and stratigraphic sequence. These compound features have been recently illustrated diagrammatically by Malkin & Echols (1948). Regression followed by transgression results in a wedge of the coarser clastics pinching out down dip between two shales, whereas transgression followed by regression results in an offshore wedge of shale pinching out up dip in a shoreward direction between two sand facies which pinch out seaward. At the strand line, marine deposits of sand and gravel grade into continental sediments, and the relative position of these deposits fluctuates back and forth as the sea advances and retreats. As this phase of the problem is beyond the scope of the data presented here for the continental margin, the reader is referred to Malkin and Jung (1941) and Grabau (1924).

Stillstand, which really continues offlap conditions, further complicates the situation because it allows the development of a profile of equilibrium, its size depending on the length of time involved and the amount and type of materials with which the sea must work. If conditions remain uniform this subaqueous plain may be extended seaward for many miles. As Barrell (1917) and Grabau (1906) have pointed out, the process of establishing a profile of equilibrium limits the thickness of the formations which build it. Once equilibrium has been reached, deposition ceases at that particular zone, and the sediment which is transported over it is deposited in deeper water farther seaward, on the slope and ocean bottom below the grade of the profile. At no time is there an interruption of offshore deposition, and at some point the sedimentary sequence is complete and of maximum thickness during each successive stage. During stillstand the continental slope grows in length but not in thickness.

Consequently, under conditions of offlap and onlap and particularly during equilibrium or near equilibrium, a continental shelf will grow seaward by additions to the slope at a much faster rate than the deposits can increase in thickness. Compare the width of the shelf to its thickness on a traverse normal to the slope passing through Cape May, New Jersey, from the Fall Line to the 100 fathom curve and over the thickest accumulation of sediment yet reported (Ewing, 1946). The former is about 175 miles, while the latter is approximately 3 miles.

There is one aspect of the problem which none of the writers cited above considers, namely, the inevitable thinning of the deposits seaward of the position of maximum thickness. In all the figures illustrating conditions of offlap and onlap with which the writer is familiar the sediments are shown as a wedge still thickening to the boundaries of the diagram. These conditions might conceivably be met in an interior sea of limited extent, where the central parts of the basin were close enough to shore to receive thick deposits from all sides, but they would hardly be valid for the continental shelf of a major ocean. In this case it is obvious the strata must start to thin and that progressive thinning away from the continental slope must continue seaward, as far as the terrigenous sediments are concerned, until they are partially replaced by the organic oozes of the more remote parts of the ocean basins. This should be kept in mind when considering probable stratigraphic and sedimentary conditions at a continental margin.

Shepard (1941) has called attention to what he calls nondepositional physiographic environments on certain portions of the shelves of the world. These are regions where no deposition is taking place because the bottom is found to be hard, either rocky or stony. He cites certain areas off the coast of California where his own dredging has demonstrated that such conditions obtain. Although plenty of sediment is being delivered to the sea, it is being bypassed to other areas. However, what he does not point out is that a nondepositional area does not necessarily have to be rocky. No sediment is at present being deposited over the greater part of the sandy east coast shelf. The shelf off southern California is somewhat abnormal due to its basin-range type of topography and the presence of strong submarine currents due probably to internal waves (Shepard and Revelle, 1939). The normal evolution according to Barrell's and Raymond's ideas is well demonstrated by the east coast continental shelf where a profile of equilibrium apparently has been developed over part of the area south of New England while south of Cape Hatteras the surface of the shelf is above wave base, and the Coastal Plain formations are being actively eroded, possibly out to the break in slope (Stetson, 1936).

ORIGIN OF ATLANTIC CONTINENTAL SHELF AND SLOPE

The Atlantic continental shelf and slope can best be explained by a series of transgressive and regressive overlaps, plus the establishments of long profiles of equilibrium during the stillstands. A conventionalized example of what could have taken place at the continental margin during the building of the shelf is shown in Fig. 4. It is not in any sense a stratigraphic diagram as the relative thickness and horizontal extent of the formations are not known. Furthermore, it is probable that there are other formations which should be included which have not yet been found. Based in part on existing data,

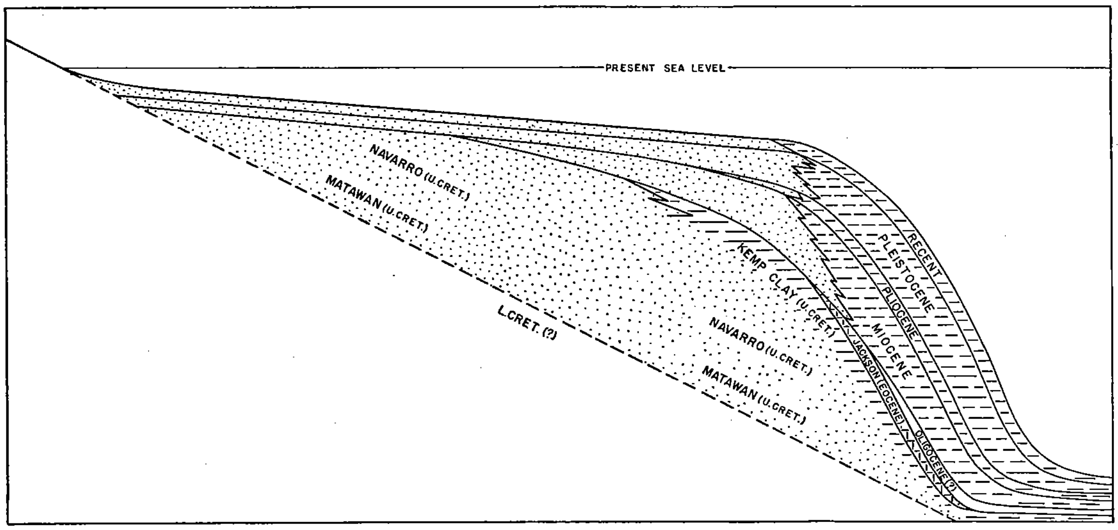

FIG. 4. Idealized transverse section through the continental shelf and slope illustrating off lap and on lap; the most probable process whereby this sedimentary structure was built.

and in part on inference, it is intended to be illustrative of a process rather than of actual conditions. Only that part of the shelf formed since the Lower Cretaceous is represented as no Lower Cretaceous was ever found in the canyons. Table I should be referred to.

Upper Cretaceous time was a period of transgressive overlap ending in offlap when the sea retreated at the very end. We have the coarse grained Matawan sandstone as the basal member overlain by a finer-grained, micaceous sandstone with friable greensand members of Navarro age. The shale facies of these sandstones is represented by a micaceous, semiconsolidated silt which has a fauna typical of the Kemp Clay. From the positions of these outcrops it should be noted that as we rise in the stratigraphic column the formations are found farther and farther from the then existing shoreline. New Jersey is the reference point nearest to Georges Bank where Cretaceous outcrops are found, and here as elsewhere, the Cretaceous seas recorded the maximum inland advance during the formation of what we now know as the Coastal Plain, and also produced thicker deposits than were formed during any succeeding period.

Eocene time saw another readvance of the sea. The equivalent of the thin New Jersey section was not found in the Georges Bank canyons, but farther to the south in the deeper water of the slope there are three occurrences of a foraminiferal marl with a Jackson fauna. The short camera core had practically no overlying Recent green silt, the second core had 10 cm, and the core from the gully off New Jersey 122 cm. The general concordance of depth of water indicates that the material is probably in place but the lack of overlying deposits should not be taken to indicate that there has been no deposition on the slope in these areas since the Eocene, *i.e.*, offlap or emergence. The evidence from Georges Bank precludes this. Here is clearly a case where submarine sliding has removed the overburden, in fact the core from "Toms" Canyon as was noted above, indicates that mud flows have occurred in this small gully.

The Oligocene is absent from New Jersey, Delaware, Maryland, Virginia, and North Carolina, and is represented in the rest of the Atlantic states only by thin formations. It has not been found in the Georges Bank canyons. Therefore, it is probable that a period of offlap had started and that erosion, or at least no deposition, was taking place over the shelf and possibly the upper part or the slope, in the northeastern section. Such deposits as were forming during this period would only be expected farther seaward.

During the Miocene, or at least a part of it, a short readvance can be postulated. A thick-bedded, greenish, sandstone was found in place in Lydonia Canyon and as talus in three other instances. The New Jersey section is represented by the clayey sand of the Kirkwood, and the coarser Cohansey formations. No shaly facies have been found on Georges.

The Pliocene might be regarded as a period of stillstand, or of near equilibrium conditions, during which there probably was little deposition in the shoaler waters. A greensand with a large admixture of quartz was found in place in Lydonia Canyon in what is now relatively deep water. The New Jersey section is thin.

The Pleistocene saw alternating regressions and transgressions, corresponding to the glacial and interglacial periods. From the position of various marine members of the Columbia formation in New Jersey and elsewhere, as well as the recognition of several ancient shorelines on the Coastal Plain, it is evident that during some of the interglacial stages the sea had advanced far beyond its present strandline. During emergence, outwash from the ice front must have accumulated on the shelf south of New England and on Georges, and there is also evidence that the ice stood on the higher parts of the latter (Shepard et al, 1934). South of the limits of glaciation flood plain deposits were laid down which must have been reworked by the next marine advance. Silts and clays containing cold water Foraminifera were laid down in the bottoms of the canyons and along their lower walls (Cushman, 1936; Phleger, 1939, 1941). The continental slope and the deeper bottoms offshore are mantled with these deposits as the cores described in this paper indicate. It seems probable that the lack of outcrops in any but the Georges Bank canyons, as evidenced by failure to secure samples in place despite repeated dredgings, can be explained by the fact that during periods of lowered sea level the rivers must have repeatedly crossed the shelf and dumped their load directly over the slope. Deposition must have been particularly heavy off the southern rivers which were not affected by the ice sheet, but even the northern ones, such as the Hudson, must have been able to deliver considerable sediment during periods of melting. The Georges Bank canyons received much less sediment because of their peculiarly isolated position, assuming the Gulf of Maine to have been in existence. Some deposition took place, as we have seen, probably directly from the front of the ice sheet which covered part of the bank, but during the periods of ice retreat, before sea level had risen appreciably, the rivers flowing out of the New England hinterland and crossing the Gulf of Maine had to pass around the northeasterly tip of this plateau through a deep channel between it and Browns Bank before they could discharge into the ocean. Only a limited amount of sediment could be supplied from the relatively small surface of the Bank itself at times when it was emergent. During times of glacial recession when sea level rose and the Gulf of Maine became a true gulf, it would act as a settling basin and effectively trap the material supplied by the rivers. Thus the canyons on its southerly slope would be receiving far less sediment than the small ones south of New England or the major ones from the Hudson to Norfolk. Even with rising sea level when the rivers could no longer deliver their loads directly to the continental margin, the silt and clay sizes would by-pass the flat surface of the shelf with its shallow water and eventually be deposited on the continental slope and in the canyons.

Post-Glacial time is marked by still another readvance on a fairly extensive scale, although transgression must have begun towards the end of the glacial period when the ice cap began to melt. On the shelf south of New England, the advancing sea reworked the deposits from the glacial streams which covered the surface of the shelf, carrying the finer material seaward and producing the present-day sea floor with its typically marine sands. Locally, sand dunes were flattened out and their sands mixed with the rest (Stetson, 1936); and, in addition, it is probable that on Georges some of the ground moraine has been reworked and incorporated. South of the limits of glacial influence the same process went on, except that here the sea was readvancing over normal flood plain deposits as it had many times before during the interstadials. The result of this latest transgression is sandy bottom, broken only by minor silty or stony areas, covering the entire shelf bordering the eastern United States from the northeastern tip of Georges Bank to Florida. A sandy plain of such vast extent is unique among the continental shelves of the world. The sandy shelf off Argentina is the only one approaching it in area.

What is known about the structure and thickness of the Atlantic Coastal Plain and its offshore counterpart, the continental shelf, shows conclusively that it is a depositional feature. The processes under which this wedge of sediment has been accumulating have apparently been operating in much the same way since the Cretaceous. Richards (1945) and Berry (1948) have compiled pertinent stratigraphic data for the Coastal Plain from well logs; and the latter has drawn a basement contour map for the North Carolina region. Ewing et al (1946) have reported on three additional seismic refraction profiles across the shelf; one south of Woods Hole, Massachusetts, another southeast of New York, and a third southeast of Cape May, New Jersey. These are in general agreement with the Cape Henry traverse of 1935. On the Cape May and New York traverses the sediment is thicker over the basement under the central parts of the shelf than at the continental margin where the underlying hard rock starts to slope up. Greatest thicknesses are of the order of three miles. The oil well lying farthest east on the Coastal Plain, Hatteras Light No. 1, which hit basement granite at 9878 ft., checks with these figures. The seismic data also indicate that the sedimentary prism thins towards the northeast.

The east coast continental shelf is a perfect example of the hypotheses set forth many years ago by Grabau, by Barrell, and by Raymond. It is constructed by the normal sedimentary processes of onlap, offlap, and stillstand. It grows forward by additions to the slope while upward growth is controlled and limited during stillstand by the development of a profile of equilibrium as well as by erosion when the water is shallow. At the present day, the shelf is not increasing in thickness. Except possibly in the mud areas south of New England, all sediment today is either being carried across the shelf or else eroded from it and deposited on the slope and ocean bottom. The mode of origin described above eliminates the necessity of postulating a major fault between the continental margin and the ocean floor to account for the break in slope. A "non-depositional environment," as mentioned above, exists at present over most of the east coast continental shelf, only the bottom is sandy instead of rocky as is the case off California. A hard bottom, therefore, is not the only criterion for the recognition of nondeposition. Obviously, the types of material which are available must be taken into consideration.

Toward the bottom of the slope the formations composed of terrigenous detritus must start to thin and probably continue this process out into the ocean basins until replaced or mixed with the organic oozes of the deeper waters. The thin veneer of glacial and post-glacial sediment, as recorded in the tops of the cores, is spread far from shore, and it is probable that the Tertiary and Cretaceous sediments have a similar distribution.

THE CANYON PROBLEM

It cannot be said that even today the problem of the origin of the canyons has been solved. The question is still controversial. The latest contributions to the subject are a paper by Kuenen (1947) and a chapter by Shepard (1948) in his recent book. Both review the existing theories and conclude by citing what they consider additional evidence to back their rival theories. Kuenen presents data supporting his contention that density (suspension) currents are the chief agents in canyon cutting and assigning a lesser role to slumping and sliding, while Shepard points out the "advantages of the glacial control and marginal warping hypothesis" as explaining erosional features which, according to him, can only be excavated by rivers. To the impartial observer the chief criticism is the almost complete rejection of rival theories by the partisans. Shepard's hypothesis, which must be considered in the light of tectonic problems, lies beyond the scope of the present paper which is concerned with the sedimentary and oceanographic conditions resulting in the present day east coast shelf. Therefore, only suspension currents will be discussed here.

The main difficulty in accepting suspension currents as the cutting mechanism is the lack of clear-cut supporting data. In spite of Kuenen's attempt to explain his theory quantatively, the amount of work they can accomplish is, at present, based largely on inference and hypothesis. There is no doubt about the existence of currents of this type, but there should be considerable uncertainty with regard to their mechanics, their energy, and the amount of work which they can accomplish, as well as the environmental conditions which may produce and control them, particularly in the ocean.

His calculations of velocities, based on a well known formula of fluid mechanics (Kuenen, 1937), should be checked by careful experimental work in which model effects are considered, before being applied to the prototype, and in which all other factors are evaluated. For instance, boundary layer problems may be different in currents of this type, and the boundary layer is all important when considering problems of erosion and transportation.

According to Kuenen (1947, p. 62), "Once an eroding velocity is attained the added turbidity helps to accelerate the flow. All material building up the continental shelf possesses potential energy. Given a lead, the canyon erodes itself." This is almost the equivalent of saying the more sediment there is in suspension, the faster the current goes; and the faster it goes, the more sediment there will be in suspension. The obvious question is will terminal velocity be reached before scour results? Attention has been so focused on the potential energy of the postulated suspension that factors tending to dissipate this energy have been largely forgotten. As the velocity of a stream increases, instability of flow results at all surfaces of discontinuity. These zones of discontinuity will eventually develop into a series of vortices, after the flow of a viscous fluid has become unstable, and eddies will spread rapidly over the entire flow section. Turbulent flow has now started with the stream lines hopelessly intertwined. "In other words, one may visualize turbulent flow as a haphazard and everchanging system of eddies superposed on the mean motion of the fluid; the viscous stresses within each individual eddy resulting in a rate of energy dissipation which is far in excess of that due to mean flow alone." (Rouse, 1946, p. 117). Further loss of energy results from friction along all boundaries.

It has also been observed by Matthes (1947) that the Mississippi is less turbulent (and consequently scours less) when it is carrying a heavy suspended load delivered to it when its muddy tributaries are flooding, than when high water occurs on the clearer ones.

Mixing is another factor which will reduce the energy of a density current of any type, as has been called to my attention by C. O'D. Iselin, citing the outflow of the Mediterranean as an example. The relatively cold, saline water from the deeper parts of this sea pours over the sill at the Straits of Gibraltar with a salinity of 38.1 o/oo and a temperature of 13.0°, and is replaced by warmer, less saline water flowing in from the Atlantic. The heavier water starts down the continental slope under water less dense, but as it goes it entrains this lighter water and mixes with it. The result is that when it encounters cold Atlantic water at intermediate depths, it is no longer denser than its surroundings and is compelled to leave the slope, spreading out across the Atlantic, mainly between surfaces of $\sigma_t = 27.6$ and $\sigma_t = 27.8$ (Sverdrup et al 1942, p. 745).

How effective this mechanism is in causing loss of energy, and thereby acting as a brake on a suspension current starting down the continental slope, cannot be estimated without experimental data, but it must be operative to a greater or lesser degree. It is probable that with even a small amount of mixing, with consequent reduction in velocity, settling will commence and reduce it still further. These factors may eventually counterbalance a supposed velocity increase; in which case the greatest velocity of a suspension current would be near the start as it is in an ordinary density current. It may be that a current of this type has not the energy to do work upon the bottom that the wave generated currents had which produced the original suspension, and, therefore, instead of acceleration what we should postulate is retardation.

Furthermore, in the stratified oceans where increasing density is mainly due to decreasing temperature, a progressively higher viscosity of the water is encountered with increasing depth. This would create greater frictional resistance along the boundaries and tend to slow the currents still more. Stratification probably was not as pronounced during the glacial periods as during the interglacial, but some layering must have been present at all times. Today, stratification is present on the northern part of the Atlantic slope even in winter, and it is very pronounced in summer (Stetson and Smith, 1938).

The unknown element, of course, always will be the amount of sediment which was actually in suspension. The analogies with notably muddy streams such as the Colorado, which Kuenen uses, and the resulting suspension currents in the reservoirs into which they empty do not seem particularly pertinent when compared with marine conditions. Suspensions containing the amounts of sediment cited by Stetson and Smith (1938, Table 2) would indeed make a very muddy ocean, and these amounts are minimum for movement down the slope. Furthermore, the problem of flocculation in sea water has not been considered. In suspensions of these densities, as anyone familiar with the procedures of mechanical analysis well knows, peptizers usually have to be added to keep them dispersed, even in distilled water. The addition of even small quantities of electrolytes causes slow flocculation; and if sea water were used for the original suspensions, nothing but vigorous stirring could keep them standing.

The retreating sea of the glacial periods is the mechanism which Daly (1936) and Kuenen (1937) use for producing these suspensions; and they postulate that during this withdrawal, wave generated currents could stir up fine grained deposits on the shelf which had formerly lain below wave base. The rate at which this lowering took place is an all important consideration. Thousands of years were involved in this process; and although it is a short interval of time from the geological point of view, it does not seem a fast enough drop to produce the rather violent effects on the bottom required under this hypothesis. It seems more likely that the fine grained deposits would be slowly removed and carried seaward during this gradual offlap, and that no great amount would be stirred up at any one time, although the total amount removed over the whole period might, of course, be very large.

In the writer's opinion, if a submarine origin of the canyons is favored, the chief emphasis should be placed on slumping and mud flows as the main erosional agents. Suspension currents would then be assigned the role of slowly distributing the finer sediments throughout the ocean basins in the same manner that the saline Mediterranean water is distributed throughout the North Atlantic. Slides resulting from the concentration of unconsolidated sediment in pre-existing furrows have been postulated by Daly (1936), Kuenen (1947), and Shepard (1948) has observed them in operation in some of the smaller nearshore canyons off California. Kuenen's explanation (1947, fig. 12) of how slumping and mud flows can widen and deepen a canyon, and at the same time dispose of resistant strata by undercutting, is perfectly logical. There is no reason why the furrows left by a submarine mud flow should look anything like the lunate scars of a sub-aerial landslide, an objection often cited. Likewise, there is no reason why there should be any markedly hummocky topography off the lower ends of the canyons. Saturated material of this type would probably travel for a long distance and the mass would tend to flatten itself out.

However, as foundation engineers well know, the angle at which different sedimentary slopes will stand differs greatly. One of the chief factors to be considered is the original water content of the material. Because certain sediments in the Lake of Geneva slide on slopes as low as 2 to 3 degrees (Heim, 1908), it does not follow that sediment on the Atlantic continental slope will behave in the same way. Unless the properties of the material in question are known as the result of laboratory tests, nothing quantative about their behavior in this respect can be assumed. The stratigraphic implications of submarine slumping have recently been commented upon by Fairbridge (1946 and 1947). He has demonstrated what complicated sedimentary sequences might result from a succession of slides down the continental slope.

Perhaps the attempt to assign one single comprehensive cause for canyon formation has been overemphasized. When so many seemingly valid objections can be raised against even the two most plausible theories, it is evident that we are not yet in possession of all the facts. Witness the complete lack of canyons in the western Gulf of Mexico, a muddy shelf today and one which should be ideal for the development of suspension currents and also for slumping and sliding on the slope. The water over shallower portions is turbid during heavy weather, and there is no reason to suppose, considering its geographical position, that the Pleistocene shelf was any less muddy. On the other hand, this stretch of coast has plenty of rivers, some of them large, which fact requires explanation from those who favor sub-aerial erosion during the periods of lowered sea level accompanying the glacial advances, plus possible marginal warping. The impartial observer is forced to admit that certain pieces of the puzzle have not yet been fitted into place.

SUMMARY AND CONCLUSIONS

1. Four new formations, ranging from Upper Cretaceous to Miocene, have been found in place in the cliffs of the Georges Bank canyons.

2. Because the Georges Bank canyons are cut into the seaward margin of a plateau isolated from the mainland by the deep basin of the Gulf of Maine, they received relatively little sedimentation in glacial and post-glacial time in contrast to those lying further to the southwest. These latter canyons lie directly off the broad shelf, and during times of lowered sea level the eastern rivers were able to cross the shelf and dump their loads directly over the continental slope.

3. Although many tows were made, the dredge never encountered any sediments in place other than glacial or post-glacial except in the Georges Bank canyons. The thick mantle of this material effectively blankets the older formations, in all canyons from Hydrographer to Norfolk.

4. The sediment which is being deposited today on the slope and in the canyons is easily recognized from that which was laid down during what was probably part of the Wisconsin. Usually the former is greenish in color and is composed of silts and silty clays, while the latter is usually pink or gray and is generally finer, more often a clay. Age identifications are made on the basis of warm and cold water Foraminifera.

5. The present day sediments that have settled into the canyons are of finer grade than those covering the adjacent shelf. However, some of the formations which have been laid down on the former continental slope, and into which the canyons have been cut, are relatively coarse sandstones.

6. The east coast continental slope is a sedimentary feature which has been developing under essentially the same set of conditions at least since the Lower Cretaceous. The continental slope is not regarded primarily as a fault scarp, but as the face of a terrace, modified by local faulting, that has gradually been working seaward.

7. Shelves of this type are regarded as prototypes of what all shelves have been at one stage of their evolution before alteration by diastrophism. It is produced by transgressive and regressive marine overlap balanced by a profile of equilibrium during stillstand. Probably all portions of it have at one time or another been modified by continental and lagoonal deposition. The shelf in the western Gulf of Mexico is of the same primitive type, and in this case the slope has likewise been modified by local faulting.

8. Suspension currents are regarded as one possible means of distributing sediment over the continental slopes and ocean floor, but serious difficulties arise when they are assigned the chief role in canyon cutting. Several factors are described which tend to dissipate their energy. Slumping and sliding are considered to be much more important agents of erosion. When everything is taken into account it is obvious that there are still many unknown factors in the canyon problem.

TABLE I

CRETACEOUS AND TERTIARY FORMATIONS

AGE	SAMPLE	POSITION (At start of tow)	DEPTH (Meters)
Upper Cretaceous			
Matawan Formation		Oceanographer Canyon east side	
Coarse sandstone (in place)	Tow 5–34	N. Lat. 40° 24′ 30″ W. Long. 68° 07′ 30″	596–480
Massive, friable, brown sandstone slabs (talus)	Tow 10–36	N. Lat. 40° 23′ 00″ W. Long. 68° 08′ 30″	585–231
Navarro		Gilbert Canyon east side	
Friable greensand (in place)	Tow 6–34	N. Lat. 40° 20′ 40″ W. Long. 67° 51′ 15″	600–530
Micaceous sandstone stained with limonite (in place)	Tow 14–36	N. Lat. 40° 19′ 00″ W. Long. 67° 51′ 30″	758
		Oceanographer Canyon east side	
Micaceous silt (in place) (Kemp Clay)	Tow 2–39	N. Lat. 40° 17′ 00″ W. Long. 68° 06′ 20″	950
Eocene			
Jackson Formation		Small gully south of Marthas Vineyard	
Foraminiferal marl	Core 12–36	N. Lat. 39° 50′ 00″ W. Long. 70° 57′ 30″	880
Jackson Formation Foraminiferal marl	Camera core	N. Lat. 39° 43′ 00″ W. Long. 70° 48′ 00″	1000
Jackson Formation		Small gully southwest of Hudson Canyon	
Foraminiferal marl	Core 21–38	N. Lat. 38° 58′ 00″ W. Long. 72° 28′ 30″	1565
Miocene			
Yorktown		Lydonia Canyon east side	
Massive greenish sandstone (in place)	Tow 20–36	N. Lat. 40° 23′ 00″ W. Long. 67° 38′ 30″	283
		Hydrographer Canyon east side	
Massive greenish sandstone (talus)	Tow 1–36	N. Lat. 40° 09′ 00″ W. Long. 69° 03′ 20″	319–140
		west side	
Massive greenish sandstone (talus)	Tow 2–36	N. Lat. 40° 09′ 00″ W. Long. 69° 04′ 00″	402–164
		Corsair Canyon east side	
Massive greenish sandstone (talus)	Tow 23–36	N. Lat. 40° 21′ 20″ W. Long. 66° 08′ 20″	493–237

TABLE I

CRETACEOUS AND TERTIARY FORMATIONS, (*Continued*)

AGE	SAMPLE	POSITION (At start of tow)	DEPTH (Meters)
Pliocene			
		Lydonia Canyon east side	
Greensand with a large admixture of quartz (in place)	Tow 9–34	N. Lat. 40° 27′ 00″ W. Long. 67° 39′ 30″	640–512
Late Pliocene or Pleistocene			
		Lydonia Canyon east side	
Hard, green silt (in place)	Tow 9–34	N. Lat. 40° 27′ 00″ W. Long. 67° 39′ 30″	640–512
		Gilbert Canyon east side	
Hard, green silt (in place)	Tow 6–34	N. Lat. 40° 20′ 40″ W. Long. 67° 51′ 15″	600–530
		Oceanographer Canyon east side	
Hard, green silt (in place)	Tow 5–34	N. Lat. 40° 24′ 30″ W. Long. 68° 07′ 30″	596–480
		Lydonia Canyon east side	
Hard, green silt (in place)	Tow 11–34	N. Lat. 40° 29′ 45″ W. Long. 67° 41′ 45″	458–452
Unknown Age			
		Norfolk Canyon northeast side	
Fine-grained sandstone with calcareous cement, and greensand (talus)	Tow 1–40	N. Lat. 37° 03′ 00″ W. Long. 74° 37′ 30″	604–530
Fine-grained sandstone with calcareous cement, greensand (talus), coarse sandstone (talus) calcareous cement, and clean washed sandstone (fragment)	Tow 2–40	N. Lat. 37° 03′ 30″ W. Long. 74° 38′ 00″	549–457

Table 2

Tows and Cores from the Canyons*

STATISTICAL CONSTANTS

	Location	Description	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Tow 22, 1936							
Depth 603–219 meters....	Corsair	Hard green	.11	.025	.003	6.05	−.28
N. Lat. 40° 21′ 50″.....	Canyon	silt					
W. Long. 66° 09′ 30″.....	east side						
Tow 23, 1936							
Depth 493–237 meters....	Corsair	Hard green	.042	.016	.0009	6.82	−.83
N. Lat. 40° 21′ 20″.....	Canyon	silt					
W. Long. 66° 08′ 20″.....	east side						
Tow 17, 1936							
Depth 475–338 meters....	Lydonia	Hard green	.104	.036	.006	4.16	−.32
N. Lat. 40° 28′ 10″.....	Canyon	silt					
W. Long. 67° 40′ 10″.....	east side						
Tow 19, 1936							
Depth 575–347 meters....	Lydonia	Hard green	0.40	.01055	.00195	4.53	−.15
N. Lat. 40° 26′ 20″.....	Canyon	silt					
W. Long. 67° 39′ 30″.....	west side						
Tow 20, 1936							
Depth 640–283 meters....	Lydonia	Hard green	.056	.023	.0056	3.16	−.23
N. Lat. 40° 23′ 00″.....	Canyon	silt					
W. Long. 67° 39′ 00″.....	east side						

	Location	Length cm.	Section cm.	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Core 4, 1939								
Depth 658 meters.......	Lydonia	146	1, 0–11	.0195	.0054	.00175	3.34	.07
N. Lat. 40° 23′ 50″.....	Canyon		2, 68–75	.108	.079	.022	2.22	−.42
W. Long. 67° 39′ 20″.....	middle		3, 139–146	.088	.029	.00391	4.75	−.39
Core 5, 1939								
Depth 759 meters........	Lydonia	196	1, 0–7	.0405	.0158	.00285	3.77	−.33
N. Lat. 40° 21′ 00″....	Canyon		2, 49–56	.022	.0143	.00123	4.24	−.88
W. Long. 67° 39′ 50″.....	middle		3, 84–94	.038	.0036	.0175	3.25	−.35
			4, 117–126	.049	.012	.0026	4.35	−.05
			5, 189–196	.036	.0144	.0024	3.88	−.38
Core 6, 1939								
Depth 933 meters.......	Lydonia	159	1, 0–6	.093	.06	.0094	3.15	−.61
N. Lat. 40° 18′ 00″.....	Canyon		2, 43–50	.052	.0176	.0027	1.39	−.34
W. Long. 67° 40′ 20″.....	west of		3, 79–87	.042	.0115	.0024	4.19	−.22
	middle		4, 155–159	.06	.017	.0025	4.9	−.28
Core 7, 1939								
Depth 1993 meters.......	Lydonia	178	1, 0–9	.146	.06	.016	3.02	−.19
N. Lat. 40° 09′ 00″.....	Canyon		2, 57–67	.114	.014	.0017	8.2	−.40
W. Long. 67° 38′ 00″.....	west of		3, 107–114	.104	.0128	.0037	5.31	.37
	middle		4, 140–150	.034	.006	.0009	6.15	−.07
			5, 169–178	.0088	.0023	.00038	4.82	−.20

* In each case proceeding down the canyon.

TABLE 2

TOWS AND CORES FROM THE CANYONS (*Continued*)

STATISTICAL CONSTANTS

	Location	Length cm.	Section cm.	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Core 8, 1939								
Depth 1919 meters.......	Small	219	1, 0–9	.236	.098	.0132	4.24	−.49
N. Lat. 40° 08′ 00″.....	gully between		2, 40–45	.265	.119	.0116	4.78	−.66
W. Long. 67° 41′ 00″.....	Lydonia		3, 103–108	.02	.00465	.0011	4.27	.01
	and Gilbert		4, 134–142	.026	.0062	.0009	5.37	−.21
	Canyons		5, 166–175	.0313	.0072	.0012	5.04	−.13
			6, 187–193	.038	.0087	.00133	5.35	−.17
			7, 214–219	.0162	.0042	.00072	4.75	−.18

	Location	Description	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Tow 13, 1936							
Depth 475–283 meters ...	Gilbert	Hard green	.104	.0072	.0013	8.94	.42
N. Lat. 40° 22′ 00″.....	Canyon	clay					
W. Long. 67° 52′ 10″.....	east side						
Tow 25, 1936							
Depth 548–274 meters....	Gilbert	Green clay	.020	.0042	.00045	6.65	−.29
N. Lat. 40° 20′ 50″.....	Canyon						
W. Long. 67° 51′ 30″.....	east side						
Tow 16a, 1936							
Depth 521–426 meters....	Gilbert	Hard coarse	.092	.052	.0125	2.71	−.38
N. Lat. 40° 20′ 30″.....	Canyon	silt					
W. Long. 67° 51′ 10″.....	east side						
Tow 16b, 1936							
	Gilbert	Soft green	.022	.0035	.00052	6.50	−.03
	Canyon	clay					
	east side						
Tow 14, 1936							
Depth 777–758 meters....	Gilbert	Green clay	.074	.012	.0017	6.59	−.06
N. Lat. 40° 19′ 20″.....	Canyon						
W. Long. 67° 51′ 50″.....	east side						

	Location	Length cm.	Section cm.	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Core 9, 1939								
Depth 768 meters........	Gilbert	177	1, 0–8	4.95	2.72	.146	5.83	−.01
N. Lat. 40° 22′ 00″.....	Canyon		2, 20–28	.0738	.0174	.0024	5.55	−.23
W. Long. 67° 52′ 30″.....	middle		3, 60–68	.034	.0085	.00175	4.42	−.08
			4, 102–108	.1	.0246	.0029	5.88	−.32
			5, 132–139	.084	.0148	.00214	6.26	−.08
			6, 168–177	.062	.0135	.0047	3.64	.20
Core 10, 1939								
Depth 825 meters........	Gilbert	164	1, 0–4	.099	.074	.006	4.06	.03
N. Lat. 40° 17′ 00″.....	Canyon		2, 74–71	.058	.0108	.002	5.40	.00
W. Long. 67° 50′ 00″.....	middle		3, 158–164	.031	.0063	.00135	4.79	.02
Core 11, 1939								
Depth 2194 meters.......	Gilbert	72	1, 0–11	.57	.192	.108	7.26	.21
N. Lat. 40° 05′ 00″.....	Canyon		2, 33–38	.198	.112	.038	2.28	−.22
W. Long. 67° 52′ 10″.....	west of middle		3, 66–72	.016	.0042	.0013	3.51	.07

Table 2

Tows and Cores from the Canyons (*Continued*)

STATISTICAL CONSTANTS

	Location	Description	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Tow 26, 1936							
Depth 502–214 meters	Oceanographer	Green silty	.019	.006	.0034	2.36	.25
N. Lat. 40° 25′ 10″.	Canyon east	clay					
W. Long. 68° 07′ 50″.	side						
Tow 12, 1936							
Depth 502–256 meters	Oceanographer	Hard green	.028	.0058	.0012	4.82	.00
N. Lat. 40° 20′ 40″.	Canyon east	clay					
W. Long. 68° 07′ 20″.	side						
Tow 7, 1936							
Depth 548–237 meters	Oceanographer	Hard green	.047	.0086	.00135	5.90	−.07
N. Lat. 40° 24′ 50″.	Canyon west	silt					
W. Long. 68° 08′ 10″.	side						
Tow 27, 1936							
Depth 603–182 meters	Oceanographer	Hard and	.0375	.011	.0012	5.59	−.43
N. Lat. 40° 20′ 20″.	Canyon west	soft green					
W. Long. 68° 09′ 10″.	side	silt					

	Location	Length cm.	Section cm.	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Core 12, 1939								
Depth 567 meters....	Oceanographer	56	1, 0–5	.088	.046	.018	2.21	−.12
N. Lat. 40° 24′ 30″.	Canyon middle		2, 52–56	.062	.031	.0089	2.64	−.22
W. Long. 68° 08′ 00″								
Core 13, 1939								
Depth 512 meters....	Oceanographer	60	1, 0–5	.126	.0455	.015	2.90	−.04
N. Lat. 40° 23′ 00″.	Canyon west		2, 57–60	.053	.0308	.004	3.65	−.65
W. Long. 68° 09′ 00″.	of middle							
Core 14, 1939								
Depth 494 meters....	Oceanographer	20	1, 0–3	.042	.007	.0018	4.83	.19
N. Lat. 40° 18′ 00″.	Canyon east		2, 16–20	.053	.0092	.0017	5.59	.03
W. Long. 68° 06′ 20″.	of middle							
Core 17, 1939								
Depth 1179 meters...	Oceanographer	65	1, 0–7	.143	.122	.0245	2.42	−.63
N. Lat. 40° 18′ 00″.	Canyon middle		2, 34–38	.135	.0515	.0052	5.10	−.58
W. Long. 68° 07′ 30″			3, 61–65	.021	.0042	.00072	5.40	−.07
Core 16, 1939								
Depth 2158 meters...	Oceanographer	158	1, 0–5	.056	.03	.0067	2.89	−.38
N. Lat. 40° 13′ 00″.	Canyon west		2, 78–88	.024	.0061	.00092	5.11	−.23
W. Long. 68° 05′ 30″.	of middle		3, 152–158	.02	.0056	.00115	4.18	−.13

	Location	Description	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Tow 1, 1936							
Depth 319–140 meters	Hydrographer	Gray silt	.1125	.027	.0045	5.00	−.16
N. Lat. 40° 09′ 40″.	Canyon east						
W. Long. 69° 03′ 20″.	side						
Tow 2, 1936							
Depth 402–164 meters	Hydrographer	Hard green	.064	.0245	.003	4.62	−.49
N. Lat. 40° 09′ 00″.	Canyon west	silt					
W. Long. 69° 04′ 00″.	side						

TABLE 2

TOWS AND CORES FROM THE CANYONS (*Continued*)

DESCRIPTION

	Location	Description	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Tow 3, 1936 Depth 537–528 meters N. Lat. 40° 07′ 50″. W. Long. 69° 02′ 30″.	Hydrographer Canyon east side	Hard green sandy silt	.370	.16	.031	3.45	−.35
Tow 5, 1936 Depth 448–146 meters N. Lat. 40° 06′ 50″. W. Long. 69° 02′ 20″.	Hydrographer Canyon east side	Hard green clay	.033	.0046	.0012	5.25	.27
Tow 28, 1936 Depth 475–256 meters N. Lat. 40° 05′ 50″. W. Long. 69° 02′ 50″.	Hydrographer Canyon west side	Hard green clay	.0198	.0049	.00059	5.80	−.31

	Location	Length cm.	Section mm.	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Core 20, 1939 Depth 210 meters.... N. Lat. 40° 00′ 00″. W. Long. 69° 37′ 00″.	Veatch Canyon head, west side	33	1, 0–4	.068	.0465	.0359	1.38	.05
			2, 30–33	.021	.0055	.00125	4.10	−.06
Core 22, 1939 Depth 567 meters.... N. Lat. 39° 55′ 00″. W. Long. 69° 35′ 30″.	Veatch Canyon east of middle	105	1, 0–7	.056	.032	.0112	2.24	−.21
			2, 50–56	.06	.0335	.01	2.45	−.27
			3, 100–105	.0485	.022	.0055	2.97	−.26

	Location	Description	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Tow 4, 1935 Depth 600–212 meters N. Lat. 39° 30′ 20″. W. Long. 72° 16′ 50″	Hudson Canyon northeast side	Sandy silt	.105	.037	.0042	5.00	−.50
Tow 21, 1935 Depth 567–220 meters N. Lat. 39° 32′ 20″. W. Long. 72° 23′ 00″	Hudson Canyon southwest side	Clay	.0081	.0026	.00054	3.88	−.19
Tow 22, 1935 Depth 759–411 meters N. Lat. 39° 31′ 00″. W. Long. 72° 21′ 00″	Hudson Canyon southwest side	Sandy green silt	.078	.017	.0017	6.78	−.34
Tow 23, 1935 Depth 594–448 meters N. Lat. 39° 29′ 10″. W. Long. 72° 17′ 00″	Hudson Canyon southwest side	Green silt	.048	.0072	.0013	6.08	.08

	Location	Length cm.	Section cm.	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Core 1, 1935 Depth 417 meters.... N. Lat. 39° 37′ 00″. W. Long. 72° 25′ 00″.	Hudson Canyon middle, near head	108	1, 0–5	.330	.230	.120	1.66	−.13
			2, 101–108	.023	.0063	.001	4.80	−.23

TABLE 2

TOWS AND CORES FROM THE CANYONS (*Continued*)

STATISTICAL CONSTANTS

	Location	Length cm.	Section cm.	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Core 1, 1940								
Depth 408 meters......	Hudson	130	1, 0–10	.0308	.0169	.0054	2.39	−.23
N. Lat. 39° 37′ 30″...	Canyon		2, 27–33	.223	.146	.058	1.96	−.22
W. Long. 72° 25′ 30″ ..	middle,		3, 50–57	.051	.0113	.0024	4.60	−.02
	near head		4, 93–98	.0148	.00226	.00065	4.78	−.64
			5, 112–117	.033	.022	.0169	1.40	.06
			6, 125–130	.072	.023	.0071	3.18	−.01
Core 2, 1940								
Depth 348 meters......	Hudson	194	1, 0–9	.14	.068	.009	3.94	−.56
N. Lat. 39° 36′ 30″...	Canyon		2, 9–18	.173	.112	.011	3.97	−.82
W. Long. 72° 25′ 20″...	middle,		3, 18–27	.19	.125	.015	3.56	−.74
	near head		4, 27–36	.0144	.00284	.00041	5.93	−.13
			5, 36–45	.027	.00425	.0005	7.35	−.12
			6, 45–54	.0097	.0017	.00031	5.60	.02
			7, 54–63	.0088	.00188	.00041	4.63	.01
			8, 63–72	.08	.019	.00275	5.40	−.21
			9, 72–81	.104	.0325	.005	4.57	−.31
			10, 81–90	.0142	.0042	.00051	5.28	−.39
			11, 90–99	.0185	.0045	.00056	5.75	−.29
			12, 99–108	.0098	.0022	.0004	4.96	−.09
			13, 108–117	.0117	.00365	.00053	4.71	−.33
			14, 117–126	.0222	.00455	.00059	6.15	−.20
			15, 126–135	.0165	.0086	.0027	2.48	−.22
			16, 135–144	.0235	.005	.00062	6.16	−.23
			17, 144–154	.0215	.0052	.00072	5.48	−.24
			18, 154–164	.0405	.0094	.00188	4.65	−.06
			19, 164–174	.0275	.0066	.0009	5.54	−.24
			20, 174–184	.0248	.00643	.00071	5.92	−.37
			21, 184–194	.024	.0036	.00033	8.54	−.21
Core 2, 1935								
Depth 344 meters......	Hudson	177	1, 0–5	.104	.0235	.0029	5.99	−.26
N. Lat. 39° 35′ 00″...	Canyon		2, 83–89	.105	.030	.00785	3.66	−.04
W. Long. 72° 25′ 00″...	middle,		3, 170–177	.115	.085	.0066	4.18	.02
	near head							
Core 4, 1935								
Depth 664 meters......	Hudson	147	1, 0–6	.0188	.0086	.0033	2.39	−.08
N. Lat. 39° 30′ 40″...	Canyon		2, 68–74	.022	.0094	.0027	2.86	−.17
W. Long. 72° 19′ 40″...	northeast		3, 143–147	.12	.0163	.0045	5.18	−.69
	side							
Core 4, 1940								
Depth 668 meters......	Hudson	136	1, 0–7	.375	.187	.0133	5.31	−.87
N. Lat. 39° 30′ 20″...	Canyon		2, 44–51	.108	.0183	.0044	4.97	.15
W. Long. 72° 19′ 00″...	middle		3, 84–90	.104	.0132	.0034	5.54	.31
			4, 128–136	.04	.011	.0031	3.60	.01
Core 5, 1940								
Depth 815 meters......	Hudson	210	1, 0–6	.022	.0081	.00265	2.88	−.05
N. Lat. 39° 29′ 00″...	Canyon		2, 44–50	.03	.0124	.0065	2.15	.11
W. Long. 72° 15′ 00″...	middle		3, 81–87	.0019	.0008	.00024	2.82	−.15
			4, 120–126	.0123	.00555	.00173	2.67	−.16
			5, 151–157	.0164	.0069	.00224	2.71	−.11
			6, 205–210	.0158	.0057	.00143	3.33	−.16

TABLE 2

TOWS AND CORES FROM THE CANYONS (*Continued*)

	Location	Length cm.	Section cm.	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Core 4, 1938								
Depth 1042 meters.....	Hudson	127	1, 4–14	.039	.012	.0031	3.56	−.08
N. Lat. 39° 22′ 00″...	Canyon		3, 120–127	.0056	.00127	.0003	4.33	.02
W. Long. 72° 01′ 30″...	northeast							
	side							
Core 5, 1938								
Depth 1160 meters.....	Hudson	147	1, 0–12	.0325	.0087	.0043	2.75	.27
N. Lat. 39° 21′ 30″...	Canyon		2, 52–67	.0175	.0049	.0008	4.69	−.23
W. Long. 72° 02′ 00″...	northeast		3, 78–86	.019	.0043	.00055	5.89	−.25
	side, near		5, 112–117	.0065	.00185	.00036	4.25	−.16
	middle		7, 142–147	.205	.038	.004	7.12	−.24
Core 6, 1938								
Depth 1710 meters.....	Hudson	174	1, 0–10	.0125	.00305	.00094	3.65	.10
N. Lat. 39° 20′ 30″...	Canyon		2, 109–113	.0092	.00275	.00056	4.06	−.17
W. Long. 72° 03′ 30″...	middle		3, 118–126	.0092	.00185	.0003	5.24	−.09
			5, 168–174	.0053	.0021	.00044	3.48	−.28
Core 7, 1938								
Depth 1125 meters.....	Hudson	153	1, 0–10	.011	.0065	.00185	2.44	−.32
N. Lat. 39° 19′ 00″...	Canyon		2, 76–84	.031	.0076	.0017	4.27	−.04
W. Long. 72° 05′ 00″...	southwest		3, 144–153	.0165	.00315	.00038	6.60	−.20
	side							
Core 9, 1940								
Depth 1197 meters.....	Large gully	141	1, 0–8	.016	.0056	.0014	3.38	−.15
N. Lat. 39° 01′ 40″...	west of		2, 43–49	.016	.0058	.0016	3.16	−.12
W. Long. 72° 33′ 00″...	Hudson Delta,		3, 85–91	.0145	.0055	.0023	2.51	.04
	west of		4, 135–141	.0135	.0046	.001	3.68	−.19
	middle							
Core 20, 1938								
Depth 1455 meters.....	Large gully	208	1, 0–10	.0174	.0049	.0013	3.66	−.03
N. Lat. 38° 57′ 30″...	west of		2, 52–61	.0125	.0052	.00033	6.16	−.82
W. Long. 72° 30′ 00″...	Hudson Delta,		3, 89–97	.0087	.002	.00038	4.79	−.48
	west of		4, 130–137	.0108	.0024	.0006	4.25	.05
	middle		5, 161–168	.0096	.0029	.0006	4.00	−.16
			6, 199–208	.0086	.0022	.00043	4.48	−.12
Core 21, 1938								
Depth 1565 meters.....	Large gully	156	1, 0–7	.0135	.0053	.00146	3.04	−.15
N. Lat. 38° 58′ 00″...	west of		2, 51–60	.0113	.0024	.00061	4.31	.08
W. Long. 72° 28′ 30″...	Hudson Delta,		4, 77–85	.0093	.00305	.00094	3.15	−.03
	west of		5, 109–116	.0078	.0041	.00086	3.02	−.40
	middle							
Core 10, 1940								
Depth 1260 meters.....	Slope	121	1, 0–6	.0086	.0027	.0007	3.51	−.08
N. Lat. 38° 57′ 20″...	southwest		2, 31–36	.0045	.0014	.00046	3.13	.19
W. Long. 72° 35′ 00″...	of gully		3, 74–81	.0071	.002	.00049	3.81	−.06
			4, 115–121	.027	.0035	.0007	6.22	.19

	Location	Description	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Tow 18, 1935							
Depth 566–274 meters..	Wilmington	Recent	.128	.06	.0042	5.53	−.83
N. Lat. 38° 25′ 50″...	Canyon	green silt					
W. Long. 73° 32′ 00″...	northwest side						

TABLE 2

TOWS AND CORES FROM THE CANYONS (*Continued*)

STATISTICAL CONSTANTS

	Location	Description	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Tow 19, 1935							
Depth 457–549 meters..	Wilmington	Gray clay	.013	.0028	.00055	4.87	−.04
N. Lat. 38° 25′ 40″...	Canyon						
W. Long. 73° 31′ 40″...	east side						
Tow 20, 1935							
Depth 549–366 meters..	Wilmington	Recent	.163	.069	.0053	5.55	−.74
N. Lat. 38° 25′ 10″...	Canyon	green silt					
W. Long. 73° 32′ 20″...	east side						
Tow 6, 1940							
Depth 896–375 meters..	Wilmington	Gray clay	.0098	.0028	.00064	3.92	−.10
N. Lat. 38° 22′ 30″...	Canyon						
W. Long. 73° 32′ 30″...	west side						
Tow 15a, 1935							
Depth 692–1152 meters.	Wilmington	Pink clay	.013	.0027	.00057	4.78	.01
N. Lat. 38° 21′ 50″....	Canyon						
W. Long. 73° 32′ 40″....	east side						
Tow 15b, 1935		Greenish clay	.013	.0037	.0006	4.66	−.24

	Location	Length cm.	Section cm.	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Core 14, 1935								
Depth 457 meters......	Wilmington	148	1, 7–13	.055	.012	.0054	3.20	.30
N. Lat. 38° 26′ 10″...	Canyon		2, 83–87	.042	.016	.0043	3.13	−.15
W. Long. 73° 32′ 00″...	middle,		3, 144–148	.041	.014	.0041	3.16	−.07
	near head							
Core 13, 1935								
Depth 1124 meters.....	Wilmington	141	1, 8–13	.032	.013	.004	2.83	−.12
N. Lat. 38° 22′ 20″...	Canyon		2, 78–82	.057	.017	.0046	3.52	−.04
W. Long. 73° 31′ 20″...	middle,		3, 136–141	.028	.0105	.0032	2.96	−.09
	near mouth							

	Location	Description	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Tow 12, 1935							
Depth 582–256 meters..	Baltimore Canyon	Gray silt	.066	.029	.004	4.07	−.50
N. Lat. 38° 10′ 20″...	west side						
W. Long. 73° 51′ 50″...							
Tow 10, 1935							
Depth 548–216 meters..	Baltimore	Chocolate	.028	.0069	.0008	5.92	−.33
N. Lat. 38° 10′ 00″...	Canyon	clay					
W. Long. 73° 50′ 50″...	east side						
Tow 3, 1940							
Depth 795–439 meters..	Baltimore	Brown clay	.0135	.0028	.00034	6.31	−.23
N. Lat. 38° 08′ 00″...	Canyon						
W. Long. 73° 51′ 00″...	west side						
Tow 13, 1935							
Depth 704–384 meters..	Baltimore	Hard green	.093	.017	.0015	7.88	−.32
N. Lat. 38° 07′ 00″...	Canyon	silt					
W. Long. 73° 50′ 40″...	west side						

TABLE 2

TOWS AND CORES FROM THE CANYONS (*Continued*)

	Location	Description	Q1 mm.	M mm.	Q8 mm.	So	Log sk
Tow 4, 1940							
Depth 732–366 meters..	Baltimore	Hard green	.0165	.00335	.00055	5.49	−.09
N. Lat. 38° 07′ 20″...	Canyon	silt					
W. Long. 73° 49′ 50″...	northeast side						
Tow 14, 1935							
Depth 640–256 meters..	Baltimore	Gray clay	.011	.0027	.00043	5.06	−.19
N. Lat. 38° 07′ 10″...	Canyon						
W. Long. 73° 49′ 20″...	east side						
Tow 5, 1940							
Depth 786–329 meters .	Baltimore	Hard green	.011	.0033	.00063	4.18	−.20
N. Lat. 38° 06′ 30″ ..	Canyon	silt					
W. Long. 73° 49′ 00″ ..	east side						

	Location	Length cm.	Section cm.	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Core 10, 1935								
Depth 512 meters.....	Baltimore	152	1, 0–5	.058	.025	.0027	4.64	−.60
N. Lat. 38° 09′ 20″...	Canyon		2, 145–152	.0155	.0038	.0007	4.72	−.12
W. Long. 73° 51′ 20″...	center							
Core 11, 1935								
Depth 585 meters......	Baltimore	245	1, 0–7	.037	.0156	.0019	4.42	−.54
N. Lat. 38° 07′ 10″...	Canyon		2, 238–245	.037	.014	.003	3.52	−.25
W. Long. 73° 49′ 40″...	center							
Core 12, 1935								
Depth 510 meters.....	Baltimore	151	1, 0–7	.052	.0195	.0078	2.58	−.03
N. Lat. 38° 06′ 40″...	Canyon		2, 146–151	.020	.0046	.00065	5.55	−.21
W. Long. 73° 48′ 50″...	east side							

	Location	Description	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Tow 5, 1935							
Depth 435–362 meters..	Washington	Gray clay	.0313	.0047	.0006	7.23	−.07
N. Lat. 37° 26′ 20″...	Canyon						
W. Long. 74° 29′ 30″...	northeast side						
Tow 6, 1935							
Depth 549–362 meters..	Washington	Hard gray	.066	.023	.004	3.97	−.28
N. Lat. 37° 25′ 20″..	Canyon	silt					
W. Long. 74° 29′ 00″...	southwest side						
Tow 8, 1935							
Depth 701–335 meters..	Washington	Pink clay	.067	.012	.001	6.92	−.19
N. Lat. 37° 25′ 10″...	Canyon						
W. Long. 74° 27′ 20″...	northeast side						
Tow 7, 1935							
Depth 829–344 meters..	Washington	Recent green	.044	.009	.002	4.70	.01
N. Lat. 37° 24′ 40″...	Canyon	silt					
W. Long. 74° 27′ 30″...	southwest side						

	Location	Length cm.	Section cm.	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Core 5, 1935								
Depth 344 meters......	Washington	230	1, 0–7	.075	.031	.0114	2.56	−.05
N. Lat. 37° 26′ 10″...	Canyon		2, 104–110	.064	.0233	.0096	2.58	.05
W. Long. 74° 28′ 10″...	northeast side, near middle		3, 223–230	.0365	.0162	.005	2.70	−.16

TABLE 2

TOWS AND CORES FROM THE CANYONS (*Continued*)

STATISTICAL CONSTANTS

	Location	Length cm.	Section cm.	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Core 6, 1935								
Depth 417 meters.....	Washington	186	1, 0–7	.175	.049	.0076	4.82	−.25
N. Lat. 37° 25′ 40″...	Canyon		2, 73–78	.0134	.055	.012	1.06	−.27
W. Long. 74° 28′ 00″...	northeast side, near middle		3, 180–186	.138	.07	.0106	3.61	.48
Core 7, 1935								
Depth 454 meters.....	Washington	186	1, 0–7	.133	.0485	.0156	2.92	−.06
N. Lat. 37° 25′ 00″...	Canyon		2, 80–87	.1035	.0405	.0094	3.32	−.23
W. Long. 74° 29′ 00″...	southwest side, near middle		3, 179–186	.114	.0435	.0195	2.42	.07
Core 10, 1938								
Depth 512 meters.....	Washington	186	1, 0–9	.023	.0093	.00215	3.28	−.24
N. Lat. 37° 25′ 00″...	Canyon		2, 80–92	.02	.0093	.0017	3.44	−.41
W. Long. 74° 27′ 00″...	middle		3, 175–186	.02	.0094	.00295	2.61	−.17
Core 11, 1938								
Depth 402 meters.....	Washington	134	1, 0–10	.041	.0165	.004	3.21	−.22
N. Lat. 37° 24′ 00″...	Canyon		3, 125–134	.0425	.018	.0037	3.39	−.31
W. Long. 74° 28′ 00″...	southwest side							
Core 8, 1935								
Depth 1280 meters....	Washington	177	1, 0–7	.017	.0056	.00175	3.12	−.02
N. Lat. 37° 22′ 50″...	Canyon		2, 171–177	.023	.0084	.0019	3.48	−.21
W. Long. 74° 21′ 00″	middle							
Core 12, 1938								
Depth 1450 meters....	Washington	143	1, 0–10	.0135	.0035	.00125	3.29	.14
N. Lat. 37° 21′ 00″...	Canyon		2, 72–77	.0315	.0061	.00045	8.40	−.42
W. Long. 74° 21′ 00″...	southwest side		3, 139–143	.011	.0028	.00055	4.48	−.11
Core 13, 1938								
Depth 1080 meters....	Washington	120	1, 0–10	.0225	.0093	.0035	2.54	−.04
N. Lat. 37° 22′ 00″...	Canyon		2, 44–51	.023	.0069	.00175	3.62	−.07
W. Long. 74° 20′ 00″...	northeast side		3, 62–71	.016	.00475	.00084	4.37	−.22
			4, 111–120	.0078	.00187	.00037	4.59	−.08
Core 15, 1938								
Depth 610 meters.....	Norfolk	180	1, 0–10	.215	.14	.0325	2.58	−.45
N. Lat. 37° 03′ 30″...	Canyon		2, 85–91	.133	.085	.015	2.98	−.56
W. Long. 74° 38′ 00″...	middle		4, 175–180	.127	.08	.0132	3.11	−.58
Core 19, 1938								
Depth 1430 meters....	Norfolk	173	1, 0–9	.0132	.0055	.00172	2.78	−.12
N. Lat. 37° 02′ 10″...	Canyon		3, 107–118	.014	.0048	.0015	3.06	−.04
W. Long. 74° 29′ 00″...	middle		4, 163–173	.019	.008	.00115	4.06	−.47

Table 2

Tows and Cores from the Canyons (*Continued*)

SIZE FRACTIONS
Based on percentage of total weight

	Section	Gravel 30–1 mm.	Sand 1–.05 mm.	Silt .05–.005 mm.	Clay .005–.001 mm.	Colloid .001–0 mm.
Tow 22, 1936		0	39	33	6	22
Tow 23, 1936		0	20	48	7	25
Tow 17, 1936		18	20	39	13	10
Tow 19, 1936		0	21	42	22	15
Tow 20, 1936		0	30	46	14	10
Core 4, 1939	1	0	11	41	28	20
	2	0	60	30	6	4
	3	0	44	30	11	15
Core 5, 1939	1	0	18	50	19	13
	2	0	6	54	18	22
	3	0	17	54	22	7
	4	0	24	40	21	15
	5	0	14	52	19	15
Core 6, 1939	1	0	56	21	4	19
	2	0	26	42	15	17
	3	0	20	45	19	16
	4	0	30	38	15	17
Core 7, 1939	1	0	56	28	10	6
	2	0	33	29	19	19
	3	0	31	37	16	16
	4	0	19	34	21	26
	5	0	2	33	25	40
Core 8, 1939	1	5	55	21	11	8
	2	2	63	14	9	12
	3	0	12	37	27	24
	4	0	16	38	20	26
	5	2	17	37	21	23
	6	0	20	37	21	22
	7	0	10	34	26	30
Tow 13, 1936		0	30	27	21	22
Tow 25, 1936		0	14	33	21	32
Tow 16a, 1936		0	51	39	9	1
Tow 16b, 1936		0	10	34	25	31
Tow 14, 1936		0	28	30	25	17
Core 9, 1939	1	66	22	6	4	2
	2	6	27	32	19	16
	3	0	17	41	24	18
	4	0	38	30	16	16
	5	1	32	31	19	17
	6	0	32	43	14	11
Core 10, 1939	1	0	56	21	11	12
	2	0	27	37	19	17
	3	0	16	38	26	20
Core 11, 1939	1	1	28	52	7	12
	2	0	36	37	16	11
	3	0	10	36	36	18
Tow 26, 1936		0	10	49	41	0
Tow 12, 1936		9	9	35	26	21
Tow 7, 1936		0	25	32	22	21
Tow 27, 1936		0	20	43	14	23
Core 12, 1939	1	1	46	40	9	4
	2	0	34	47	11	8
Core 13, 1939	1	0	46	39	9	6
	2	0	28	46	13	13
Core 14, 1939	1	0	23	31	28	18
	2	0	26	36	19	19
Core 17, 1939	1	0	60	23	9	8
	2	0	51	24	12	13
	3	0	16	31	23	30
Core 16, 1939	1	0	29	51	20	0
	2	0	10	43	21	26
	3	0	9	44	25	22
Tow 1, 1936		0	40	34	11	15
Tow 2, 1936		0	32	37	15	16
Tow 3, 1936		16	51	18	8	7
Tow 5, 1936		0	19	30	32	19
Tow 28, 1936		0	14	36	18	32
Core 20, 1939	1	0	43	51	6	0
	2	0	10	42	24	24
Core 22, 1939	1	0	29	55	12	4
	2	0	33	45	5	17
	3	0	24	52	8	16
Tow 4, 1935		0	45	28	12	15
Tow 21, 1935		0	3	36	27	34
Tow 22, 1935		0	35	30	15	20
Tow 23, 1935		0	25	30	24	21
Core 1, 1935	1	1	84	9	6	0
	2	0	7	47	21	25
Core 1, 1940	1	0	9	67	10	14
	2	0	76	12	8	4
	3	14	51	31	4	0
	4	0	6	32	28	34
	5	0	11	78	5	6
	6	0	3	31	33	33
Core 2, 1940	1	0	56	24	15	5
	2	3	56	24	10	7
	3	1	62	21	10	6
	4	0	10	33	19	38
	5	0	13	35	18	34
	6	0	5	31	20	44
	7	0	6	28	23	43
	8	0	5	29	23	43

TABLE 2

TOWS AND CORES FROM THE CANYONS (*Continued*)

SIZE FRACTIONS
Based on percentage of total weight

	Section	Gravel 30–1 mm.	Sand 1–.05 mm.	Silt .05–.005 mm.	Clay .005–.001 mm.	Colloid .001–0 mm.
Core 2, 1940	9	0	42	33	19	6
	10	0	6	41	21	32
	11	0	9	36	22	31
	12	5	4	24	29	38
	13	0	5	39	21	35
	14	0	14	35	17	34
	15	0	6	59	18	17
	16	0	11	39	20	30
	17	0	14	37	20	29
	18	0	21	39	22	18
	19	0	17	37	20	26
	20	0	15	40	15	30
	21	0	14	32	18	36
Core 2, 1935....	1	0	32	39	11	18
	2	0	42	39	9	10
	3	0	56	20	14	10
Core 4, 1935....	1	0	6	60	26	8
	2	0	11	54	21	14
	3	2	32	39	16	11
Core 4, 1940....	1	6	60	17	10	7
	2	3	29	41	19	8
	3	1	30	38	19	12
	4	0	22	43	22	13
Core 5, 1940....	1	0	9	52	27	12
	2	0	13	68	16	3
	3	0	9	52	24	15
	4	0	13	41	36	10
	5	0	6	52	30	12
	6	0	9	44	27	20
Core 4, 1938....	1	0	18	52	16	14
	3	0	5	21	28	46
Core 5, 1938....	1	0	14	57	24	5
	2	0	3	47	23	27
	3	0	10	36	19	35
	5	0	1	29	30	40
	7	0	48	26	21	5
Core 6, 1938.....	1	0	3	39	32	26
	2	0	6	28	35	31
	3	0	2	24	29	45
	5	0	1	26	34	39
Core 7, 1938.....	1	0	8	49	25	18
	2	0	18	41	23	18
	3	0	10	28	29	33
Core 9, 1940.....	1	0	1	52	29	18
	2	0	3	51	27	19
	3	0	3	49	31	17
	4	0	1	47	27	25
Core 20, 1938....	1	0	6	44	27	23
	2	0	6	45	11	38
	3	0	1	33	23	43
	4	0	3	33	30	34
	5	0	4	33	26	37
	6	0	4	33	22	41
Core 21, 1938....	1	0	5	47	31	17
	2	0	1	34	34	31
	4	0	1	38	35	26
	5	0	4	37	33	26
Core 10, 1940....	1	0	6	31	32	31
	2	0	2	21	35	42
	3	0	2	30	33	35
	4	0	9	37	24	30
Tow 18, 1935........		0	51	23	12	14
Tow 19, 1935........		0	13	27	27	33
Tow 20, 1935........		1	53	22	14	10
Tow 6, 1940.........		0	7	31	30	32
Tow 15a, 1935.......		0	13	28	23	36
Tow 15b, 1935.......		0	12	33	24	31
Core 14, 1935....	1	0	28	48	19	5
	2	0	22	50	18	10
	3	0	22	50	20	8
Core 13, 1935....	1	0	15	56	17	12
	2	0	28	46	17	9
	3	0	18	49	17	16
Tow 12, 1935........		0	31	42	13	14
Tow 10, 1935........		0	17	38	18	27
Tow 3, 1940.........		1	8	31	24	36
Tow 13, 1935........		0	43	20	20	17
Tow 4, 1940.........		0	9	36	21	34
Tow 14, 1935........		0	10	33	21	36
Tow 5, 1940.........		0	4	38	26	32
Core 10, 1935....	1	0	30	38	17	15
	2	0	11	35	24	30
Core 11, 1935....	1	0	15	52	14	19
	2	0	21	47	20	12
Core 12, 1935....	1	0	26	52	11	11
	2	0	14	35	20	31
Tow 5, 1935.........		0	19	30	20	31
Tow 6, 1935.........		0	31	42	17	10
Tow 8, 1935.........		0	31	29	21	19
Tow 7, 1935.........		0	23	38	22	17
Core 5, 1935.....	1	0	37	54	9	0
	2	0	31	50	17	2
	3	0	18	57	6	19

Table 2

Tows and Cores from the Canyons (*Continued*)

SIZE FRACTIONS

Based on percentage of total weight

	Section	Gravel 30–1 mm.	Sand 1–.05 mm.	Silt .05–.005 mm.	Clay .005–.001 mm.	Colloid .001–0 mm.
Core 6, 1935	1	0	50	27	10	13
	2	0	52	33	8	7
	3	0	55	27	15	3
Core 7, 1935	1	0	49	38	11	2
	2	0	46	36	6	12
	3	0	44	49	6	1
Core 10, 1938	1	0	10	42	33	15
	2	0	6	62	16	16
	3	0	10	35	46	9
Core 11, 1938	1	0	16	55	23	6
	3	0	18	53	18	11
Core 8, 1935	1	0	7	48	34	11
	2	0	16	47	23	14
Core 12, 1938	1	0	7	32	39	22
	2	0	12	40	16	32
	3	0	6	35	27	32
Core 13, 1938	1	0	8	58	25	9
	2	0	15	44	22	19
	3	0	8	41	23	28
	4	0	4	27	27	42
Core 15, 1938	1	1	65	34	0	0
	2	0	63	22	8	7
	4	0	62	22	7	9
Core 19, 1938	1	0	4	48	29	19
	3	0	3	46	30	21
	4	0	9	52	28	11

Table 3

Cores from the Continental Slope*

STATISTICAL CONSTANTS

	Location	Length cm.	Section cm.	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Core 3, 1939								
Depth 2465 meters.....	Between	162	1, 0–11	.133	.11	.0333	2.00	−.44
N. Lat. 40° 09′ 00″...	Veatch and		2, 48–57	.017	.0039	.0005	5.84	−.25
W. Long. 67° 02′ 00″...	Atlantis		3, 92–100	.0068	.00132	.00015	6.64	−.23
	Canyons		4, 123–132	.007	.00265	.0006	3.43	−.22
			5, 154–162	.0061	.00195	.0001	7.82	−.81
Core 2, 1939								
Depth 3100 meters.....	Between	107	1, 0–6	.018	.0036	.00052	5.90	−.14
N. Lat. 39° 59′ 00″...	Veatch and		2, 36–45	.0133	.0026	.00056	4.88	.04
W. Long. 66° 49′ 00″...	Atlantis		3, 67–75	.007	.00051	.0001	8.38	.40
	Canyons		4, 99–107	.01	.00057	.0001	10.0	.49
Core 1, 1939								
Depth 3713 meters.....	Between	256	1, 0–6	.207	.118	.029	2.68	−.36
N. Lat. 39° 57′ 00″...	Veatch and		2, 24–29	.084	.0145	.0019	6.65	−.12
W. Long. 66° 49′ 00″...	Atlantis		3, 45–50	.10	.0116	.00105	9.76	−.11
	Canyons		4, 72–78	.0335	.0058	.00076	6.65	−.12
			5, 108–112	.12	.0145	.00225	7.30	.11
			6, 142–149	.077	.013	.00204	6.15	−.03
			7, 188–193	.048	.0097	.0014	5.86	−.15
			8, 221–227	.0335	.0091	.0007	6.92	−.65
			9, 250–256	.021	.00385	.00076	5.26	.03
Core 31, 1939								
Depth 366 meters......	Between	18	1, 0–6	.185	.12	.033	2.37	−.37
N. Lat. 39° 56′ 30″...	Veatch and		2, 11–18	.032	.0064	.00044	8.53	−.46
W. Long. 70° 02′ 00″...	Atlantis							
	Canyons							
Core 30, 1939								
Depth 750 meters......	Between	93	1, 0–5	.074	.048	.0185	2.00	−.23
N. Lat. 39° 55′ 00″...	Veatch and		2, 19–25	.103	.0495	.0183	2.38	−.11
W. Long. 70° 00′ 00″...	Atlantis		3, 87–93	.011	.00168	.00037	5.45	.17
	Canyons							
Core 1726, 1937								
Depth 643 meters......	Between	47	1, 0–6	.125	.086	.046	1.65	−.11
N. Lat. 39° 53′ 00″...	Veatch and		2, 41–47	.062	.016	.00196	5.63	−.32
W. Long. 69° 59′ 00″...	Atlantis							
	Canyons							
Core 1727, 1937								
Depth 1000 meters.....	Between	58	1, 0–5	.035	.0185	.0044	2.82	−.35
N. Lat. 39° 49′ 00″...	Veatch and		2, 52–58	.022	.0092	.002	3.32	−.28
W. Long. 69° 56′ 00″...	Atlantis							
	Canyons							
Core 1728, 1937								
Depth 1100 meters.....	Between	61	1, 0–5	.0285	.007	.0018	3.98	.02
N. Lat. 39° 45′ 00″...	Veatch and		2, 56–61	.0315	.0072	.002	3.97	.07
W. Long. 69° 53′ 00″...	Atlantis							
	Canyons							

* Proceeding from North to South.

Table 3

Cores from the Continental Slope (*Continued*)

STATISTICAL CONSTANTS

	Location	Length cm.	Section cm.	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Core 1, 1936								
Depth 216 meters......	Between	85	1, 0–4	.185	.140	.07	1.62	−.18
N. Lat. 40° 01′ 00″...	Atlantis		2, 81–85	.160	.140	.115	1.18	−.03
W. Long. 70° 42′ 00″...	and Block							
	Canyons							
Core 2, 1936								
Depth 457 meters......	Between	239	1, 0–8	.175	.115	.054	1.80	−.14
N. Lat. 39° 57′ 00″...	Atlantis		2, 46–56	.0165	.0018	.00066	5.00	.53
W. Long. 70° 41′ 00″...	and Block		3, 109–118	.0175	.0037	.0003	7.65	−.42
	Canyons		4, 233–239	.015	.003	.00025	7.75	−.38
Core 3, 1936								
Depth 647 meters......	Between	289	1, 0–10	.125	.11	.035	1.90	.44
N. Lat. 39° 53′ 00″...	Atlantis		3, 281–289	.015	.0045	.00085	4.20	−.20
W. Long. 70° 41′ 00″...	and Block							
	Canyons							
Core 4, 1936								
Depth 1050 meters.....	Between	234	1, 0–5	.047	.033	.0054	2.95	−.63
N. Lat. 39° 50′ 00″...	Atlantis		2, 118–123	.074	.017	.00235	5.62	−.22
W. Long. 70° 41′ 00″...	and Block		3, 226–234	.0135	.0031	.0008	4.11	.05
	Canyons							
Core 5, 1936								
Depth 1954 meters.....	Between	90	1, 0–4	.0455	.026	.0052	2.96	−.45
N. Lat. 39° 45′ 00″...	Atlantis		2, 48–52	.048	.025	.004	3.47	−.51
W. Long. 70° 39′ 00″...	and Block		3, 85–90	.170	.019	.00215	8.90	.01
	Canyons							
Core 6, 1936								
Depth 2190 meters.....	Between	105	1, 0–4	.0086	.0028	.00062	3.73	−.16
N. Lat. 39° 36′ 00″...	Atlantis		2, 51–54	.0125	.0043	.00105	3.45	−.15
W. Long. 70° 36′ 00″...	and Block		3, 99–102	.039	.0093	.0022	4.21	.00
	Canyons							
Core 7, 1936								
Depth 2579 meters.....	Between	245	1, 0–6	.300	.245	.200	1.22	.00
N. Lat. 39° 26′ 00″...	Atlantis		2, 69–74	.028	.0031	.00065	6.56	.28
W. Long. 70° 37′ 00″...	and Block		3, 150–155	.013	.0037	.0003	6.58	−.55
	Canyons		4, 237–245	.011	.00425	.0011	3.16	−.17
Core 8, 1936								
Depth 2740 meters.....	Between	109	1, 0–8	.021	.005	.00092	4.78	−.11
N. Lat. 39° 15′ 00″...	Atlantis		2, 103–109	.0135	.0032	.00065	4.56	−.07
W. Long. 70° 42′ 00″...	and Block							
	Canyons							
Core 1, 1938								
Depth 1097 meters.....	Easterly	290	1, 5–14	.011	.0036	.0007	3.97	−.22
N. Lat. 39° 30′ 00″...	Section of		2, 129–137	.0095	.00115	.00057	4.09	.61
W. Long. 71° 53′ 00″...	Hudson		3, 282–290	.031	.0084	.00075	6.44	−.48
	Delta							
Core 3, 1938								
Depth 1025 meters.....	Easterly	270	1, 18–27	.0365	.012	.00072	7.13	−.74
N. Lat. 39° 24′ 00″...	Section of		2, 118–127	.007	.00124	.00048	3.82	.34
W Long. 71° 57′ 00″ ..	Hudson		3, 262–270	.014	.0015	.00038	6.08	.37
	Delta							

TABLE 3

CORES FROM THE CONTINENTAL SLOPE (*Continued*)

STATISTICAL CONSTANTS

	Location	Length cm.	Section cm.	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Core 6, 1940								
Depth 350 meters......	Westerly	194	1, 0–6	.247	.152	.043	2.40	−.34
N. Lat. 39° 18′ 00″...	Section of		2, 39–46	.011	.0048	.00265	1.52	.10
W. Long. 72° 14′ 30″...	Hudson		3, 84–90	.0345	.0057	.00078	6.65	−.08
	Delta		4, 144–149	.05	.0062	.00056	9.46	−.14
			5, 188–194	.0137	.0028	.00072	4.37	.10
Core 7, 1940								
Depth 710 meters......	Westerly	232	1, 0–6	.071	.034	.0079	3.00	−.31
N. Lat. 39° 13′ 00″...	Section of		2, 62–68	.036	.0095	.00108	5.78	−.36
W. Long. 72° 15′ 30″...	Hudson		3, 105–111	.034	.005	.00066	7.18	−.05
	Delta		4, 146–153	.034	.00735	.00049	8.34	−.51
			5, 186–192	.0236	.00455	.00058	6.39	−.18
			6, 224–232	.0084	.0019	.00042	4.48	−.01
Core 8, 1940								
Depth 902 meters......	Westerly	189	1, 0–13	.034	.013	.0022	3.94	−.35
N. Lat. 39° 08′ 00″...	Section of		2, 56–62	.0082	.00175	.00026	5.63	−.16
W. Long. 72° 21′ 30″...	Hudson		3, 107–113	.0305	.009	.0016	4.37	−.22
	Delta		4, 144–150	.014	.003	.00056	5.00	−.06
			5, 183–189	.011	.0023	.0005	4.70	−.04
Core 22, 1938								
Depth 1641 meters.....	Southwest	168	1, 0–7	.0108	.0054	.00047	4.80	−.76
N. Lat. 39° 02′ 00″...	Edge of		2, 66–74	.014	.0049	.00078	4.24	−.34
W. Long. 72° 21′ 30″...	Hudson		4, 113–120	.0125	.006	.001	3.54	−.46
	Delta		7, 162–168	.0096	.0036	.0011	2.96	−.09
Core 23, 1938								
Depth 1665 meters.....	Westerly	228	1, 0–10	.0105	.0037	.00096	3.31	−.13
N. Lat. 39° 01′ 30″...	Section of		3, 90–98	.011	.0037	.00062	4.21	−.30
W. Long. 72° 17′ 00″...	Hudson		5, 141–147	.0125	.0031	.00059	4.61	−.11
	Delta		7, 220–228	.0175	.005	.0014	3.54	−.01
Core 1088, 1931								
Depth 1800 meters.....	Between	60	1, 0–11	.03	.014	.0025	3.47	−.42
N. Lat. 38° 04′ 00″...	Wilmington		2, 32–36	.013	.005	.0011	3.44	−.24
W. Long. 73° 22′ 00″...	and		3, 56–60	.011	.0035	.0009	3.50	−.09
	Washington							
	Canyons							
Core 12, 1940								
Depth 1880 meters.....	Between	115	1, 0–6	.022	.0065	.0022	3.16	.06
N. Lat. 37° 45′ 20″...	Baltimore		2, 53–59	.0115	.004	.00105	3.31	−.12
W. Long. 73° 50′ 00″...	and		3, 108–115	.0093	.0027	.0006	3.94	−.11
	Washington							
	Canyons							

Table 3

Cores from the Continental Slope (*Continued*)

STATISTICAL CONSTANTS

	Location	Length cm.	Section cm.	Q1 mm.	M mm.	Q3 mm.	So	Log sk
Core 11, 1940								
Depth 1865 meters.....	Between	137	1, 0–9	.0082	.0031	.0005	4.05	−.37
N. Lat. 37° 40′ 20″...	Baltimore		2, 9–18	.0088	.00245	.00051	4.16	−.13
W. Long. 73° 50′ 00″...	and		3, 18–27	.007	.0019	.00041	4.14	−.10
	Washington		4, 27–36	.014	.0036	.0008	4.19	−.06
	Canyons		5, 36–45	.011	.0031	.0007	3.97	−.10
			6, 45–54	.0155	.0025	.00041	6.24	0.1
			7, 54–63	.0105	.0034	.00074	3.77	−.17
			8, 63–72	.0265	.0055	.00115	4.80	.00
			9, 72–81	.0145	.0016	.00028	7.20	.20
			10, 81–90	.0125	.0044	.001	3.54	−.19
			11, 90–99	.0105	.0028	.00096	3.31	.11
			12, 99–108	.0083	.0028	.00096	2.94	.01
			13, 108–117	.012	.0045	.0015	2.83	−.05
			14, 117–127	.011	.0042	.0013	2.91	−.09
			15, 127–137	.013	.005	.0016	2.86	−.08
Core 8, 1938								
Depth 192 meters......	Northeast of	109	1, 0–8	.245	.165	.11	4.71	.00
N. Lat. 37° 28′ 30″...	Washington		2, 103–109	.23	.173	.086	1.64	−.18
W. Long. 74° 23′ 00″...	Canyon							
Core 9, 1938								
Depth 542 meters......	Northeast of	109	1, 0–10	.0266	.0128	.004	2.58	−.19
N. Lat. 37° 27′ 00″...	Washington		3, 102–109	.0435	.019	.004	3.3	−.32
W. Long. 74° 24′ 00″...	Canyon							
Core 14, 1938								
Depth 1990 meters.....	Southeast of	145	1, 0–10	.0157	.00445	.0015	3.24	.08
N. Lat. 37° 17′ 00″...	Washington		2, 66–78	.0113	.00304	.00097	3.42	.08
W. Long. 74° 09′ 00″...	Canyon		3, 135–145	.015	.0041	.00061	4.97	−.26

Table 3

Cores from the Continental Slope (*Continued*)

SIZE FRACTIONS
Based on percentage of total weight

	Section	Gravel 30–1 mm.	Sand 1–.05 mm.	Silt .05–.005 mm.	Clay .005–.001 mm.	Colloid .001–0 mm.
Core 3, 1939....	1	0	61	29	7	3
	2	0	10	38	18	34
	3	0	0	27	33	40
	4	0	6	27	31	36
	5	0	4	26	31	39
Core 2, 1939....	1	0	12	30	26	32
	2	0	10	27	24	39
	3	0	14	23	9	54
	4	0	16	16	10	58
Core 1, 1939....	1	0	68	18	9	5
	2	1	33	29	15	22
	3	5	26	29	16	24
	4	0	19	33	18	30
	5	0	32	32	21	15
	6	3	29	30	18	20
	7	2	23	34	18	23
	8	1	16	43	8	32
	9	1	17	26	25	31
Core 31, 1939...	1	5	66	12	5	12
	2	0	20	34	16	30
Core 30, 1939...	1	0	48	40	8	4
	2	0	50	40	9	1
	3	0	11	24	21	44
Core 1726, 1937.	1	0	73	21	4	2
	2	0	30	34	18	18
Core 1727, 1937.	1	0	14	58	21	7
	2	0	0	65	21	14
Core 1728, 1937.	1	0	0	63	24	13
	2	0	0	55	31	14
Core 1, 1936....	1	0	84	11	3	2
	2	0	84	12	3	1
Core 2, 1936....	1	0	77	17	3	3
	2	0	7	40	18	35
	3	0	5	41	20	34
	4	0	6	39	17	38
Core 3, 1936....	1	0	66	27	5	2
	3	0	9	39	25	27
Core 4, 1936....	1	0	22	55	16	7
	2	0	32	35	16	17
	3	0	10	30	33	27
Core 5, 1936 ...	1	0	20	56	16	8
	2	0	24	48	14	14
	3	0	40	24	19	17
Core 6, 1936....	1	0	6	30	32	32
	2	0	7	39	30	24
	3	0	21	41	22	16
Core 7, 1936....	1	0	94	4	1	1
	2	0	10	35	24	31
	3	0	5	39	20	36
	4	0	8	36	35	21
Core 8, 1936....	1	0	15	35	24	26
	2	0	13	30	24	33
Core 1, 1938....	1	0	2	42	24	32
	2	0	3	25	26	46
	3	0	16	39	16	29
Core 3, 1938....	1	0	16	45	10	29
	2	0	4	27	23	46
	3	0	2	42	11	45
Core 6, 1940....	1	4	69	18	7	2
	2	0	3	34	26	37
	3	0	15	37	21	27
	4	0	25	27	16	32
	5	0	6	31	34	29
Core 7, 1940....	1	0	37	43	16	4
	2	0	18	42	16	24
	3	0	17	33	20	30
	4	0	17	37	14	32
	5	0	12	37	20	31
	6	0	5	29	26	40
Core 8, 1940....	1	0	14	52	16	18
	2	0	7	28	23	42
	3	0	14	46	12	18
	4	0	10	34	23	33
	5	0	9	30	24	37
Core 22, 1938 ..	1	0	2	51	19	28
	2	0	5	44	23	28
	4	0	7	49	19	25
	7	0	1	43	32	24
Core 23, 1938...	1	0	5	40	30	25
	3	0	11	33	26	30
	5	0	5	33	27	35
	7	0	5	45	16	34
Core 1088, 1932.	1	0	10	56	14	20
	2	0	7	40	26	27
	3	0	6	37	30	27
Core 12, 1940...	1	0	11	56	21	12
	2	0	4	39	33	24
	3	0	6	32	28	34
Core 11, 1940...	1	0	2	35	25	38
	2	0	3	33	28	36
	3	0	6	26	28	40
	4	0	10	34	28	28

Table 3

Cores from the Continental Slope (*Continued*)

SIZE FRACTIONS
Based on percentage of total weight

	Section	Gravel 30–1 mm.	Sand 1–.05 mm.	Silt .05–.005 mm.	Clay .005–.001 mm.	Colloid .001–0 mm.
	5	0	5	35	29	31
	6	0	4	41	19	36
	7	0	7	34	29	30
	8	0	12	40	25	23
	9	0	3	42	12	43
	10	0	7	41	27	25
	11	0	6	32	36	26
	12	0	8	28	38	26
	13	0	4	42	35	19
	14	0	4	41	34	21
	15	0	5	45	32	18
Core 8, 1938....	1	0	82	12	6	0
	2	0	81	11	8	0
Core 9, 1938....	1	0	10	62	17	11
	3	0	19	53	16	12
Core 14, 1938...	1	0	9	38	38	15
	2	0	3	38	33	26
	3	0	5	40	23	32

Table 4

Traverses

STATISTICAL CONSTANTS

Across Lydonia Canyon from N. Lat. 40° 24′ 30″, W. Long. 67° 41′ 30″ to N. Lat. 40° 25′ 30″, W. Long. 67° 36′ 30″. 3⅔ miles. Samples evenly spaced.

Sample	Depth meters	Q1 mm.	M mm.	Q3 mm.	So	Log sk
1	152	2.0	.65	.3	2.57	.15
2	145	.80	.48	.33	1.56	.06
3	240	.49	.335	.19	1.61	−.08
4	398	.094	.072	.0009	10.25	−1.79
5	543	.13	.072	.021	2.49	−.28
6	731	.19	.14	.031	2.48	−.52
7	876	.17	.14	.115	1.22	.00
8	686	.115	.054	.019	2.45	−.12
9	581	.072	.02	.00024	17.34	−1.63
10	507	.094	.069	.031	1.74	−.21
11	270	.235	.19	.16	1.21	.02
12	183	1.10	.41	.22	2.24	.16

Across Gilbert Canyon from N. Lat. 40° 22′ 10″, W. Long. 67° 54′ 10″ to N. Lat. 40° 22′ 40″, W. Long. 67° 50′ 40″. 2 4/5 miles. Samples evenly spaced.

Sample	Depth meters	Q1 mm.	M mm.	Q3 mm.	So	Log sk
15	182	1.20	.37	.225	2.31	.30
16	308	.5	.33	.235	1.46	.03
17	670	.037	.0054	.0005	8.6	−.20
18	560	.0175	.007	.00086	4.52	−.51
19	277	.21	.165	.14	1.22	.03
20	166	.26	.215	.165	1.25	−.03

Across Oceanographer Canyon from N. Lat. 40° 26′ 40″, W. Long. 68° 09′ 00″ to N. Lat. 40° 27′ 00″, W. Long. 68° 07′ 20″. 1½ miles. Samples evenly spaced.

Sample	Depth meters	Q1 mm.	M mm.	Q3 mm.	So	Log sk
21	162	.62	.39	.25	1.57	.01
22	226	.225	.17	.145	1.24	.06
23	479	.16	.13	.105	1.23	.00
24	439	2.3	.45	.135	4.13	.18
25	180	.245	.15	.10	1.56	.04

SIZE FRACTIONS
Based on percentage of total weight

Across Lydonia Canyon

Section	Gravel 30–1 mm.	Sand 1–.05 mm.	Silt .05–.005 mm.	Clay .005–.001 mm.	Colloid .001–0 mm.
1	38	62	0	0	0
2	19	81	0	0	0
3	5	75	15	5	0
4	0	61	9	5	25
5	0	68	22	9	1
6	0	71	15	9	5
7	0	85	12	3	0
8	0	52	34	7	7
9	0	40	26	4	30
10	0	65	29	2	4
11	0	96	3	1	0
12	27	70	2	1	0

Across Gilbert Canyon

Section	Gravel 30–1 mm.	Sand 1–.05 mm.	Silt .05–.005 mm.	Clay .005–.001 mm.	Colloid .001–0 mm.
15	27	73	0	0	0
16	6	94	0	0	0
17	0	22	30	16	32
18	0	0	56	18	26
19	0	96	3	1	0
20	0	97	2	1	0

Across Oceanographer Canyon

Section	Gravel 30–1 mm.	Sand 1–.05 mm.	Silt .05–.005 mm.	Clay .005–.001 mm.	Colloid .001–0 mm.
21	14	82	3	1	0
22	0	96	3	1	0
23	0	91	4	3	2
24	37	58	3	2	0
25	5	85	5	3	2

APPENDIX A

Foraminifera from Canyon Tows in Semi-Consolidated Sediments

BY

Fred B Phleger

The purpose of this study is to determine whether the semi-consolidated sediments dredged from the canyon walls contain faunas similar to those being deposited at the present time, or whether they represent conditions other than those now obtaining. In many of the submarine cores from the continental slope, previously described (Phleger, 1939, 1942), a sub-Arctic foraminiferal fauna occurs beneath the Recent temperate fauna. This older fauna is distinguished by an assemblage at present restricted to sub-Arctic environments, and is late Pleistocene (Wisconsin) in age where found in middle latitudes.

The tow faunas were analyzed quantitatively as in the preceding study (Phleger, 1942). Only the more common species were recorded; those occurring only rarely were omitted. In computing the percentages, the planktonic and benthonic groups were treated separately (see Tables 5–7); in each sample both the planktonic and the benthonic assemblage contain 100%. The percentages of the species in each tow sample examined are listed in Tables 5-7.

In analyzing the core faunas, the lower ones were compared with those occurring in the tops which are being deposited at the present time. The assembled data on distribution of Foraminifera are, at present, incomplete, and direct comparison with modern faunas from the same area is advisable. The faunas from the tows from each canyon were compared with the faunas occurring in the tops of the cores from the same canyon and from the same approximate water depth. This served as a check on the relative temperatures indicated by the faunas in the tows. It is on the basis of inferred differences in water temperatures, based upon the faunas, that determinations of Pleistocene or Recent age are founded.

The submarine tow faunas examined by the writer came from the following canyons:

- Georges Bank Area
  - Corsair Canyon
  - Lydonia Canyon
  - Gilbert Canyon
  - Oceanographer Canyon
  - Hydrographer Canyon
- Southern Area
  - Hudson Canyon
  - Wilmington Canyon
  - Baltimore Canyon

The tows (Fig. 5) examined from the Georges Bank Area and from Hudson Canyon in the Southern Area contain a fauna distinctly sub-Arctic in aspect and which is significantly different from the fauna found in the tops of the cores in the same areas. The faunas are similar to the sub-Arctic ones reported beneath the surface of the ocean bottom and penetrated by submarine cores (Phleger, 1939, 1942). These tow faunas indicate that the sediments enclosing them were deposited under sub-Arctic conditions, and may be late Pleistocene, probably Wisconsin, in age. It is suggested that they are to be correlated with the sub-Arctic Pleistocene core faunas occurring in warm-temperate parts of the North Atlantic.

Most of the tows (Fig. 5) examined from Wilmington and Baltimore canyons contain a fauna characteristic of warm-temperate regions which is not significantly different from the faunas found in the tops of the cores from the same canyons. This fauna, and the sediment in which it is contained, undoubtedly is Recent in age. Two tows from Baltimore Canyon appear to indicate sub-Arctic affinities, but there is no certainty of this. Twelve of the fourteen tows examined from the southern canyons contain a modern type fauna which is now living in the area.

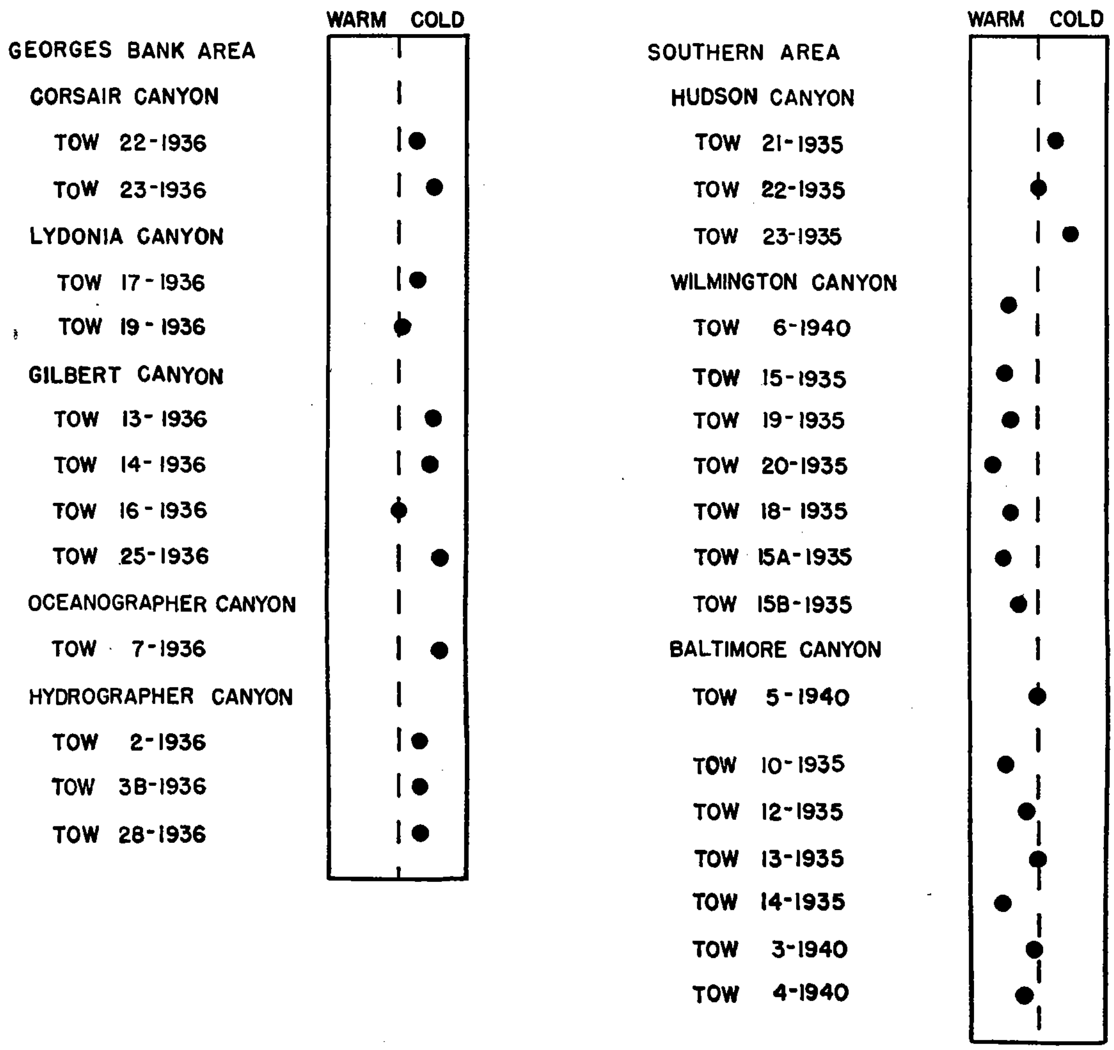

FIG. 5. Approximate relative water temperature indicated by the Foraminifera in the tows.

More detailed analysis of the faunas in each tow may be obtained by examining the species occurrences in Tables 5–7 and these may be compared with the top samples of adjacent cores. The writer's interpretation of the relative water temperatures indicated by the tow faunas is included in figure 1.

TABLE 5

PERCENTAGE FREQUENCIES OF MOST IMPORTANT FORAMINIFERA IN TOW FAUNAS AND NEARBY CORE FAUNAS FROM CORSAIR, LYDONIA, GILBERT, AND OCEANOGRAPHER CANYONS. PLANKTONIC SPECIES EQUAL 100% AND BENTHONIC SPECIES EQUAL 100%.

	CORSAIR		LYDONIA				GILBERT						OCEAN-OGRAPHER		
	Tow 22 1936	Tow 23 1936	Tow 17 1936	Tow 19 1936	Core Top 5 1939	Core Top 4 1939	Tow 13 1936	Tow 14 1936	Tow 16 1936	Tow 25 1936	Core Top 9 1939	Core Top 10 1939	Tow 7 1936	Core Top 13 1939	Core Top 12 1939
Globigerina bulloides	89	66	60	74	56	63	88	80	91	74	38	68	32	68	83
G. inflata	11	2	20	3	15	5	13	2	2	2	30	9	23	16	3
G. dubia				9	15	6		2	1		8	15	5	10	2
G. pachyderma		31	10	14				16		22			41		
Globigerinoides rubra		1			15	24		1	6		14	6		2	7
Other pelagic species, percent			10		9	2				2	10	1		3	5
Other pelagic species, number			1		2	5				1	10	6		3	5
Robulus															
Lagena					4	2		1	10		4	1		2	1
Nonion grateloupi			1		3				4			1		2	5
N. labradoricum			1						1					2	
N. sp. 1															
N. stelligerum												1	4	7	3
Nonionella sp. 1															
Elphidium incertum	68	43	4	9	2	3	23	23	1	81	6	4	29	20	39
Bulimina marginata				20	2	3	8	3		1		2		2	1
B. aculeata					2			1	2		2	2	2	1	
B. exilis					14	4						2			
B. inflata							8				12				
B. sp. 1					3	1			9			1		8	16
Uvigerina sp.			58	1					1		10			1	
U. canariensis															
Angulogerina angulosa	18			67	41	43	54	33	6	2		2		7	2
A. sp. 1					3	2					10	36			
Virgulina schreibersiana											4			1	
V. squammosa		16	12	1	5	5		3	44		4	11		3	7
V. sp. 1											2			1	1
Bolivina subaenariensis					1			1	1			1			
B. subspinescens												1			
B. sp. 1					5	8		14			2	12			
Gyroidina soldanii			2										2	22	2
Cassidulina laevigata			1	1	4	4		5	17	2	8	4	16	1	
C. subglobosa	8	14	1		3	2		5	1	14	2	1	6	15	4
C. crassa	2		3										14		
Cassidulinoides bradyi															
Cibicides pseudoungeriana	1				3	6		1				3		2	1
Eponides frigida					2	6						3		7	16
E. frigida var. 1		25	16	1			8	6		?1					
E. frigida var. 2	1	1	1					3		?1					
E. sp. 2					3	7			3		4				
Valvulineria exigua					2							11			

Table 6

Percentage Frequencies of Most Important Foraminifera in Tow Faunas and Nearby Core Faunas from Hydrographer, Hudson, and Wilmington Canyons. Planktonic Species Equal 100% and Benthonic Species Equal 100%.

	Hydrographer			Hudson							Wilmington Pt. 1				
	Tow 2 1936	Tow 28 1936	Tow 3b 1936	Tow 21 1935	Tow 22 1935	Tow 23 1935	Core Top 2 1940	Core Top 1 1940	Core Top 5 1940	Core Top 4 1940	Core Top 13–1935	Core Top 14–1935	Tow 6 1940	Tow 15 1935	Tow 20 1935
Globigerina bulloides	67	88	80	49	88	59	72	77	31	64	84	86	85	74	47
G. inflata				8	3	2	12	15	25	20	5	6	3	16	40
G. dubia				2		2	11	2	53	9	3	4	1	2	6
G. pachyderma		6	20	38	8	33			1		3		9	7	1
Globigerinoides rubra					2	2	5	4	7	2	5	2		1	2
Other pelagic species, percent	33	6		3	1	3	2	3		3	1	2	3	2	4
Other pelagic species, number	1	1		1	4	1	3	3	2	7	2	5	1	4	8
Robulus				1	1			2		1	1	1			1
Lagena	2	4						2	8	1	6	3	1		1
Nonion grateloupi					1				4	1	1	2	3	1	
N. labradoricum	1					1	1		3	1			2	1	
N. sp. 1					1						1	1		1	4
N. stelligerum	6														
Nonionella sp. 1		12				1									
Elphidium incertum	1	5		13	10	93	2		2	1	9	5	35	36	17
Bulimina marginata		2		41	10		50	44	6	36	17	27		14	25
B. aculeata									2	1	1				
B. exilis									7	1	4				
B. inflata									2	1					
B. sp. 1	3	43	1	7	2		2	1		5	1	3	4	1	10
Uvigerina sp.			98						1	1					1
U. canariensis				1			1	2	4	7	1			3	
Angulogerina angulosa	1			1	18		8	11	3	7	7	14		12	16
A. sp. 1									1		1	1			
Virgulina schreibersiana				1			1	1		1					
V. squammosa	23	27		2	7	3	1	5	12		22	15	12	6	6
V. sp. 1											1				
Bolivina subaenariensis				9	1		25	17	20	25	4	12			2
B. subspinescens															
B. sp. 1				6	3	1	3	10	2		12	6			3
Gyroidina soldanii	13				1					1					
Cassidulina laevigata		5		6	36	1	1	2	5		5	1	18	8	1
C. subglobosa	8			4	1	1					1		5	9	2
C. crassa											2	1	1	1	4
Cassidulinoides bradyi				1			2	1	2			2			
Cibicides pseudoungeriana	4			2	1		1		5	6	3	2		5	5
Eponides frigida	31														
E. frigida var. 1	1			1								1		1	
E. frigida var. 2	1			1	4						1		2	2	
E. sp. 2												1			
Valvulineria exigua															

TABLE 7

PERCENTAGE FREQUENCIES OF MOST IMPORTANT FORAMINIFERA IN TOW FAUNAS AND NEARBY CORE FAUNAS FROM WILMINGTON AND BALTIMORE CANYONS. PLANKTONIC SPECIES EQUAL 100% AND BENTHONIC SPECIES EQUAL 100%.

	WILMINGTON PT. 2				BALTIMORE									
	Tow 19 1935	Tow 18 1935	Tow 15a 1935	Tow 15b 1935	Core Top 10–35	Core Top 11 1935	Tow 5 1940	Tow 10 1935	Tow 12 1935	Tow 13 1935	Tow 14 1935	Tow 3 1940	Tow 4 1940	Core Top 12–1935
Globigerina bulloides	51	65	66	77	93	86	60	69	58	64	72	85	84	87
G. inflata	17	17	11	6	1	3	8	13	8	5	15	3	4	3
G. dubia	16	2	8	1		2		8	14	8	3			1
G. pachyderma	6	2	9	15	4	2	31	2	12	17	3	11	7	7
Globigerinoides rubra	3	6	2	1	1	7		6	8	4	3	1	4	1
Other pelagic species, percent	7	8	4					2	2	2	4	1	1	2
Other pelagic species, number	6	6	5			1	1	2	1	2	7	2	2	1
Quinqueloculina cf. *seminulum*		1		1										
Q. sp.						1						1		
Robulus	2	1						2						
Lagena	3	1	5		1	9		1	2	2	2			
Nonion grateloupi					1		1	1						
N. labradoricum										1				
N. sp. 1	4											1		1
N. stelligerum		2		2				2	4	2				
Nonionella sp. 1	1										39		6	
Elphidium incertum	9	43	21	18	70	4	1	21	20	32	10	22	16	10
Bulimina marginata	27	17	13	25	2	18	19	31	28	2	12	15		27
B. aculeata			1			1				2			2	
B. exilis								2						1
B. inflata														
B. sp. 1	14	3	6	3	2	2		6		1	5		1	
Uvigerina sp.										1	1			
U. canariensis	1	1		1		1		3			2	1		1
Angulogerina angulosa	9	9	8	3		4		13	17	1	9	2		4
A. sp. 1		1	1					1						
Virgulina schreibersiana								1						
V. squammosa	1	3	1	6	13	26		2	2	10	2	2	1	5
V. sp. 1				1	1				6			1		1
Bolivina subaenariensis	12	1	4			3	75	2				1		1
B. subspinescens		1												
B. sp. 1	3	2	7			9		3			1	1	1	39
Gyroidina soldanii		1								19	1		15	
Cassidulina laevigata	1	2	6	21		7	3	4	7	4	3	25	26	2
C. subglobosa	1	1	12	16				2	2	1		24		1
C. crassa	2	4	3			4		2			1	1		2
Cassidulinoides bradyi			5			1		1						
Cibicides pseudoungeriana	5	4		2		4		4	6		1	1		1
Eponides frigida														
E. frigida var. 1	1			1					9	22	6		33	3
E. frigida var. 2	1	1	2	2						5	1			2
E. sp. 2														
Valvulineria exigua														

BIBLIOGRAPHY

BARRELL, J., 1917: Rhythms and the measurements of geologic time. *Bull. Geol. Soc. Amer.* 28(4):745–904, pls. 43–46.

BERRY, W., 1948: North Carolina Coastal Plain floor. *Bull. Geol. Soc. Amer.* 59(2):87–90, 1 fig., 1 pl.

CUSHMAN, J. A., 1936: Geology and paleontology of the Georges Bank Canyons. Pt. 4, Cretaceous and Late Tertiary Foraminifera. *Bull. Geol. Soc. Amer.* 47: 413–440, 5 pls.

————, 1939: Eocene Foraminifera from submarine cores off the eastern coast of North America. *Contrib., Cushman Lab. of Foraminiferal Res.* 15(3):49–76, pls. 9–12.

DALL, W. H., 1903: Tertiary Fauna of Florida. *Trans. Wagner Free Inst. Sci., Phila.* 3(6): 1580.

DALY, R. A., 1936: Origin of submarine "Canyons." *Amer. Jour. Sci.*, 5th ser., 31(187): 401–420.

DANA, J. D., 1863: Manual of Geology. Phila., Theodore Bliss & Co. 441 pp., 978 text figs., 1 pl.

EWING, M., J. L. WORZEL, N. C. STEENLAND, and F. PRESS, 1946: Geophysical investigations in the emerged and submerged Atlantic Coastal Plain. Pt. 5. Cape May, New York, and Woods Hole Sections. *Bull. Geol. Soc. Amer.* 57(12), Abstracts: 1192.

FAIRBRIDGE, R. W., 1946: Submarine slumping and location of oil bodies. *Bull. Amer. Assoc. Petrol. Geol.* 30(1):84–92, 3 text figs.

————, 1947: Coarse sediments on the edge of the continental shelf. *Amer. Jour.Sci.* 245(3):146–153, 1 text fig.

GRABAU, A. W., 1906: Types of sedimentary overlap. *Bull. Geol. Soc. Amer.* 17: 567–636.

————, 1924: Principles of stratigraphy. New York, A. G. Seiler & Co. 1185 pp., 264 pls.

HEIM, A., 1908: Ueber rezente und fossile subaquatische Rutschungen und deren Lithologische Bedeutung. *Neues Jahr. Mineralogie* 2:136–157.

HVORSLEV, M. J. and H. C. STETSON, 1946: Free-fall coring tube: a new type of gravity bottom sampler. *Bull. Geol. Soc. Amer.* 57:935–950, 4 pls., 4 text figs.

KRUMBEIN, W. C., 1932: The mechanical analysis of fine-grained sediments. *Jour. Sed. Pet.* 2(3): 140–149, 2 text figs.

————, 1939: Graphic presentation and statistical analysis of sedimentary data. In: Recent Marine Sediments, a Symposium, edited by Parker D. Trask, pp. 558–591, 12 text figs. Tulsa, Okla., *Bull. Amer. Assoc. Pet. Geol.*

KUENEN, Ph.H., 1937: Experiments in connection with Daly's hypothesis on the formation of submarine canyons. *Leidsche Geol. Med.* 8(2):327–351.

————, 1947: Two problems of marine geology: atolls and canyons. *Verh.Akad. Wet., Amsterdam,* 2nd ser., 43(3): 5–68.

MALKIN, D. S., and D. A. JUNG, 1941: Marine sedimentation and oil accumulation on the Gulf Coast. 1. Progressive marine overlap. *Bull. Amer. Assoc. Pet. Geol.* 25(11): 2010–2020, 7 text figs.

MALKIN, D. S. and D. J. ECHOLS, 1948: Marine sedimentation and oil accumulation. 2. Regressive marine offlap and overlap-offlap. *Bull. Amer. Assoc. Pet. Geol.* 32(2):252–261, 4 text figs.

MATTHES, G. H., 1947: Macroturbulence in natural stream flow. *Trans. Amer. Geophys. Union.* 28(2):255–262.

PHLEGER, F. B, 1939: Foraminifera of submarine cores from the continental slope. *Bull. Geol. Soc. Amer.* 50:1395–1422, 3 pls., 4 text figs.

————, 1942: Foraminifera of submarine cores from the continental slope. Pt. 2. *Bull. Geol. Soc. Amer.* 53:1073–1098, 3 pls., 6 text figs.

PHLEGER, F. B, and W. A. HAMILTON, 1946: Foraminifera of two submarine cores from the North Atlantic Basin. *Bull. Geol. Soc. Amer.* 57:951–966, 1 pl., 3 text figs.

PIGGOT, C. S., 1936: Apparatus to secure core samples from the ocean bottom. *Bull. Geol. Soc. Amer.* 47:675–684, 3 pls., 1 text fig.

REVELLE, R. and F. P. SHEPARD, 1939: Sediments off the California Coast. In: Recent Marine Sediments, a Symposium, edited by Parker D. Trask, pp. 245–282, 9 text figs. Tulsa, Okla., *Bull. Amer. Assoc. Pet. Geol.*

RICHARDS, H. G., 1945: Subsurface stratigraphy of the Atlantic Coastal Plain between New Jersey and Georgia. *Bull. Amer. Assoc. Pet. Geol.* 29:885–995, 27 text figs.

ROUSE, H., 1946: Elementary mechanics of fluids. New York, John Wiley & Sons. 376 pp., 196 text figs., 28 pls., 11 tables.

RUDÉ, G. T., 1938: New methods of marine surveying. *Proc. Amer. Phil. Soc.* 79(1):9–25.

SHEPARD, F. P., 1933: Submarine valleys. *Geograph. Rev.* 23(1):77–89, 8 text figs.

————, 1941: Nondepositional physiographic environments off the California Coast. *Bull. Geol. Soc. Amer.* 52(12):1869–1886, 2 pls.

————, 1948: Submarine geology. New York, Harper and Bros., 348 pp., 106 text figs., 1 chart.

SHEPARD, F. P., J. M. TREFETHEN, and G. V. COHEE, 1934: Origin of Georges Bank. *Bull. Geol. Soc. Amer.* 45:281–302, 7 text figs.

STEPHENSON, L. W., 1936: Geology and paleontology of the Georges Bank Canyons, Pt. 2, Upper Cretaceous fossils from Georges Bank (including species from Banquereau. Nova Scotia). *Bull. Geol. Soc. Amer.* 47:367–410, 5 pls.

STETSON, H. C., 1936: Geology and paleontology of the Georges Bank Canyons. Pt. 1. Geology. *Bull. Geol. Soc. Amer.* 47:339–366, 3 pls., 3 text figs.

———, 1938: The sediments of the continental shelf off the eastern coast of the United States. *Pap. Phys. Oceanogr. and Meteor.* 5(4):5–48, 15 text figs.

STETSON, H. C., and J. F. SMITH, 1938: Behavior of suspension currents and mud slides on the continental slope. *Amer. Jour. Sci.*, 5th ser. 35(205):1–13, 2 text figs.

STORM, L. W., 1945: Résumé of facts and opinions on sedimentation in Gulf Coast region of Texas and Louisiana. *Bull. Amer. Assoc. Pet. Geol.* 29(9):1304–1335, 10 text figs.

SVERDRUP, H. U., M. W. JOHNSON, and R. H. FLEMING, 1942: The Oceans. New York, Prentice Hall, Inc. 1087 pp., 265 text figs., 7 charts.

SWAIN, F. M., 1949: Onlap, offlap, overstep, and overlap. *Bull. Amer. Assoc. Pet. Geol.* 33(4):634–636.

TRASK, P. D., 1932: Origin and environments of source sediments of petroleum. Houston, *Amer. Pet. Inst.* Gulf Pub. Co. 323 pp., 38 text figs.

VEATCH, A. C., and P. A. SMITH, 1939: Atlantic submarine valleys of the United States and the Congo submarine valley. *Geol. Soc. Amer., Spec. Papers* No. 7: 101 pp., 28 text figs., 10 pls., 5 charts.

(*Continued from inside front cover*)

Vol. VI,	No. 1.	H. R. Seiwell: Application of the Distribution of Oxygen to the Physical Oceanography of the Caribbean Sea Region, 1938.	0.75†
	No. 2.	R. B. Montgomery: Circulation in Upper Layers of Southern North Atlantic Deduced with Use of Isentropic Analysis, 1938.	0.75†
	No. 3.	H. G. Houghton and W. H. Radford: On the Local Dissipation of Natural Fog, 1938.	1.00*
	No. 4.	H. G. Houghton and W. H. Radford: On the Measurement of Drop Size and Liquid Water Content in Fogs and Clouds, 1938.	0.75*
Vol. VII,	No. 1.	C.-G. Rossby, Jerome Namias, and Ritchie G. Simmers: Fluid Mechanics Applied to the Study of Atmospheric Circulations, Part I. A Study of Flow Patterns with the aid of Isentropic Analysis, 1938.	1.50*
	No. 2.	S. Petterssen and J. M. Austin: Fronts and Frontogenesis in Relation to Vorticity, 1942.	0.75*
	No. 3.	H. R. Seiwell: The Effect of Short Period Variations of Temperature and Salinity on Calculations in Dynamic Oceanography, 1939.	0.75†
	No. 4.	R. B. Montgomery: Observations of Vertical Humidity Distribution above the Ocean Surface and their Relation to Evaporation, 1940.	Out of Print
Vol. VIII,	No. 1.	C. O'D. Iselin: Preliminary Report on Long-Period Variations in the Transport of the Gulf Stream System, 1940.	0.75†
	No. 2.	F. A. Brooks: Observations of Atmospheric Radiation, 1941.	0.50*
	No. 3.	R. A. Allen, R. Fletcher, J. Holmboe, J. Namias and H. C. Willett: Report on an Experiment in Five-Day Weather Forecasting, 1940.	Out of Print
	No. 4.	M. A. Garstens: Some Effects of Shearing Motion on the Propagation of Waves in the Prevailing Westerlies, 1941.	0.75*
Vol. IX,	No. 1.	H. C. Willett: Report of the Five-Day Forecasting Procedure, Verification and Research as Conducted between July, 1940 and August, 1941, 1941.	1.00*
	No. 2.	A. C. Redfield: The Processes Determining the Concentration of Oxygen, Phosphate and other Organic Derivatives within the Depths of the Atlantic Ocean, 1942.	0.50†
	No. 3.	J. M. Austin: Cloudiness and Precipitation in Relation to Frontal Lifting and Horizontal Convergence, 1943.	0.75*
	No. 4.	T. F. Malone: A Study of Interdiurnal Pressure and Temperature Variations in the Free Atmosphere over North America, 1946.	0.75*
Vol. X,	No. 1.	Richard A. Craig: Measurements of Temperature and Humidity in the Lowest 1000 feet of the Atmosphere over Massachusetts Bay, 1946.	0.75†
	No. 2.	Frederick C. Fuglister: Average Monthly Sea Surface Temperatures of the Western North Atlantic Ocean, 1947.	0.50†
	No. 3.	Gardner Emmons: Vertical Distributions of Temperature and Humidity over the Ocean between Nantucket and New Jersey, 1947.	1.00†
	No. 4.	H. R. Seiwell: Results of Research on Surface Waves of the Western North Atlantic, 1948.	1.00†
Vol. XI,	No. 1.	A. F. Bunker, B. Haurwitz, J. S. Malkus, and H. Stommel: Vertical Distribution of Temperature and Humidity over the Caribbean Sea, 1949.	1.00†
	No. 2.	Henry C. Stetson: The Sediments and Stratigraphy of the East Coast Continental Margin; Georges Bank to Norfolk Canyon, 1949.	1.00†

* Requests for this number should be addressed to Meteorological Department, Massachusetts Institute of Technology, Cambridge, Massachusetts.

† Requests for this number should be addressed to Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.