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UNITED STATES DEPARTMENT OF THE INTERIOR

**GEOLOGY AND BIOLOGY OF
NORTH ATLANTIC DEEP-SEA CORES**

PART 3. DIATOMACEAE

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GEOLOGY AND BIOLOGY OF
NORTH ATLANTIC DEEP-SEA CORES
BETWEEN NEWFOUNDLAND AND IRELAND

PART 3. DIATOMACEAE

BY

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OUTLINE OF THE COMPLETE REPORT

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General introduction, by W. H. Bradley.

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SUMMARY OF THE REPORT

In May and June 1936 Dr. C. S. Piggot of the Geophysical Laboratory, Carnegie Institution of Washington, took a series of 11 deep-sea cores in the North Atlantic Ocean between the Newfoundland banks and the banks off the Irish coast. These cores were taken from the Western Union Telegraph Co.'s cable ship *Lord Kelvin* with the explosive type of sounding device which Dr. Piggot designed. In the fall of that year he invited a group of geologists of the United States Geological Survey to study the cores and prepare a report. Biologists of the United States National Museum, the University of Buffalo, and chemists of the United States Department of Agriculture cooperated in the investigation and contributed to the report.

The westernmost core of the series (No. 3) was taken in the blue mud zone, but all the others were taken in parts of the ocean where the bottom is blanketed with globigerina ooze. The shortest cores are No. 8, taken on the mid-Atlantic ridge in 1,280 meters of water, and No. 11, taken where the core bit struck volcanic rock. The cores range in length from 0.34 to 2.93 meters and average 2.35 meters. They were taken at depths ranging from 1,280 to 4,820 meters.

Lithology and geologic interpretations.—In about 20 representative samples from each core the percentages of calcium carbonate, clay and silt, and sand were determined and plotted, and the relative abundance of Foraminifera, coccoliths, and diatoms was estimated. Material between these guide samples was examined microscopically, especially in certain critical zones.

Two zones were noted in which silicic volcanic ash (refractive index near 1.51) is common. The upper ash zone was found in all the cores except No. 11, but the lower one was found only in the lower part of cores 4 to 7. In core 3 the upper ash zone is represented by shards scattered very sparsely all through the core, as this core, despite its length of 2.82 meters, apparently did not reach the bottom of the ash zone. The upper ash zone, together with other adjacent lithologic zones, serves to correlate the cores, and the lower ash zone, found west of the mid-Atlantic ridge, helps to confirm the correlation.

Besides the zones of volcanic ash four other zones distinctive in lithologic character were found. These zones are characterized by a relative abundance of sand and pebbles, by a smaller percentage of calcium carbonate, and by a sparsity of Foraminifera and coccoliths. They are distinctive also in texture. The pebbles are subrounded to angular and include a wide variety of rock types—sandstone, gneiss, soft shale, and limestone—of which limestone is the most common. Some of the pebbles are as much as 2 centimeters across. These zones are interpreted as glacial marine deposits formed during the Pleistocene glacial epoch, when continental glaciers were eroding the land. Drift ice from the continental glaciers apparently transported considerable quantities of rock debris far out into the ocean basin.

Between the glacial marine zones found in the North Atlantic cores the sediments consist chiefly of foraminiferal ooze or marl, much like that which is forming today in the same area.

The uppermost glacial marine zone is represented in all the cores except Nos. 3 and 11 and lies just below the upper volcanic ash zone. In cores 4 to 7 the glacial zones are relatively thin and are spaced at approximately equal intervals; between the third and fourth glacial zones (in descending order) is the lower volcanic ash. East of the mid-Atlantic ridge only the uppermost glacial

zone has been identified. Other glacial marine deposits are recognizable but their correlation is less certain.

Three interpretations are offered as possible explanations of the four glacial marine zones. The first is that each glacial marine zone represents a distinct glacial stage of the Pleistocene and that each zone of foraminiferal marl separating two glacial marine zones represents an interglacial stage. This interpretation seems least probable of the three. The second interpretation is that the upper two glacial marine zones and the intervening sediment may correspond to the bipartite Wisconsin stage, whereas the lower two represent distinct glacial stages of the Pleistocene separated from each other and from the zone representing the Wisconsin stage by sediments that represent interglacial epochs no greater in length than postglacial time. This interpretation seems to imply too short a time for most of the Pleistocene epoch. The third interpretation, which is favored by the authors, is that each of the four glacial marine zones represents only a substage of the Wisconsin stage. This implies that the North Atlantic at approximately 50° north latitude for comparatively long periods of time alternately contained an abundance of drift ice and then was quite, or nearly, free of ice, while on land a continental ice sheet persisted, though it alternately waned and grew.

In the four cores in which the postglacial sediments are thickest the pelagic Foraminifera, according to Cushman and Henbest, reveal an interesting condition. These organisms indicate that during the middle part of the postglacial interval the temperature of the surface water in that part of the North Atlantic was somewhat higher than prevails today.

On the assumptions that the top of the uppermost glacial marine zone represents the beginning of the postglacial epoch as defined by Antevs, and that this was probably as much as 9,000 years ago, the postglacial sediment in these cores accumulated at a rate of about 1 centimeter in 265 years; but, because the sea probably cleared of detritus-laden drift ice long before the land in the same latitude was cleared of the retreating continental ice sheet, the average rate of accumulation may have been as low as 1 centimeter in 500 years.

Coarse-grained sediment on the tops of ridges and fine-grained sediment in the deeper basins indicate that currents move across these ridges with sufficient velocity to winnow out the finer particles and sweep them into deeper basins beyond.

The fact that the glass shards in the volcanic ash zones have been reworked and distributed without any gradation in size through many centimeters of the overlying sediments leads us to believe that mud-feeding animals are continually working over these shards and other particles of sand and silt so that they are redistributed at successively higher levels. The shards and other particles may also be reworked by gentle bottom currents that move the material from mounds and ridges on the sea floor and drift it about over the adjacent flatter areas.

Several layers in the cores are sharply set off by the coarser grain size of the sediment or by a regular gradation in grain size from coarsest at the base to fine at the top. These may be a result of submarine slumping.

The term globigerina ooze is used loosely in this report to designate sediment, half or more than half of which, by weight, consists of Foraminifera. This usage accords more closely with

the usage adopted by Correns in the *Meteor* reports than with the usage of Murray and Chumley in the *Challenger* reports, which was based solely on the carbonate content. Limy muds containing a lesser but still conspicuous number of Foraminifera are referred to as foraminiferal marl. The carbonate content of the globigerina ooze in these cores ranges from 46.6 to 90.3 percent and averages 68.2 percent. In 191 samples representing all the lithologic types, the carbonate content ranges from 10.0 to 90.3 percent and averages 41.3 percent. Coccoliths are abundant in many parts of the cores, but by reason of their small size they rarely make up as much as 10 percent of the sediment. Pteropods are rather numerous in parts of the cores taken on the mid-Atlantic ridge and on the continental slope off the Irish coast.

Most of the calcium carbonate in these sediments consists of the tests and comminuted fragments of calcareous organisms. The finest particles of carbonate are of indeterminate origin, but their irregular shape and range in size suggest that they are largely the finest debris of the comminuted organisms rather than a chemical precipitate. Clusters or rosettes of calcium carbonate crystals were found in many samples, but they are not abundant. They evidently formed in the mud on the sea floor.

No conclusive evidence of an increase in magnesium carbonate with depth was found, though some of the data suggest it. The magnesium carbonate is somewhat more abundant in the glacial marine zones than elsewhere, but its concentration in those zones is probably accounted for by the presence of clastic grains and pebbles of dolomite.

Diatom frustules, radiolarian skeletons, and sponge spicules are the most common siliceous organic remains found in the cores, and these generally form less than 1 percent of the sediment. One notable exception is the sediment in the middle part of core 9, just east of the mid-Atlantic ridge, which contains 50 percent or more of diatoms.

Ellipsoidal and elongate or cylindrical pellets that appear to be fecal pellets are plentiful in the mud at the tops of cores 10 and 12, taken in the eastern part of the North Atlantic, but were not found elsewhere. No attempt was made to identify them further.

The sand-size material showed no marked variation in the mineral composition of the clastic grains at different horizons within individual cores and no conspicuous lateral variation from core to core. The mineral grains in the sand-size portions were not separated into light and heavy fractions, but simple inspection showed that grains of the heavy minerals are somewhat more common in the glacial marine deposits than elsewhere. Well-rounded sand grains are sparsely scattered through all the cores, but they are rather more plentiful in the glacial marine zones. These grains, which range in diameter from about 0.1 to 1.0 millimeter and average 0.5 millimeter, have more or less frosted surfaces. They may have been derived from the reworking of glacial marine deposits or they may have been rafted by seaweeds. Little was done with the clay minerals other than to note that most of them have the optical properties of the beidellite or hydrous mica groups.

Six samples were tested with a 10-inch spectograph, which revealed the presence of appreciable amounts of barium and somewhat less of boron in each sample. All the samples gave negative tests for antimony, beryllium, bismuth, cadmium, germanium, lead, silver, tin, and zinc.

The original porosity of several samples in core 3 was calculated from the porosity of the dried samples. The original porosity plotted against depth in the core seems to indicate that fine-grained blue muds buried to a depth of 2 or 3 meters in the ocean floor are appreciably compacted.

Partial mechanical analyses of nearly 200 samples were made and plotted, but only four complete mechanical analyses were

made. The complete analyses were made by the sedimentation method and include four distinctive types of sediment.

Pumiceous fragments and smaller shards of basaltic volcanic glass (index of refraction near 1.60) are scattered throughout all the cores, but are somewhat more common east of the mid-Atlantic ridge than west of it. Unlike the alkalic volcanic ash it shows no conspicuous concentration in zones. Most of the basaltic glass and pumice has a thin surface alteration film of palagonite. The films are thickest on fragments in cores taken from ridges where oxygen-bearing waters had free access to the sediments. Two varieties of palagonite are recognized.

Core 11 represents only 34 centimeters of the sea floor because the core bit encountered deeply altered olivine basalt. About 15 centimeters of globigerina ooze rests on and within irregular cavities of the upper surface of a mass of clay that is apparently altered basalt. This clay is impregnated with manganese and contains nodular lumps of altered basalt. Part of the basalt near the base of the core is less altered. The clay contains scattered grains of sand and foraminiferal shells in which the original calcium carbonate has been replaced by a zeolite resembling philipsite. This core may have penetrated the upper, deeply altered part of a submarine lava flow, but the evidence is not conclusive.

Core 10 contains two rather thick beds of distinctive clayey mud. About half of this mud is a beidellite or hydrous mica type of clay and the other half is made up of silt-size particles of basaltic glass, magnetite, augite, and calcic plagioclase. It contains very little common clastic material and exceedingly few Foraminifera. The composition and texture suggest that this mud was derived largely from a submarine volcanic eruption that threw into suspension clay particles perhaps partly from the normal sediment and from deeply altered basalt. A complete chemical analysis of this mud is given.

Foraminifera.—From these cores 184 samples representing every lithologic zone were examined for calcareous fossils. All but five samples contained Foraminifera. As in existing oceans deeper than several hundred meters, pelagic Foraminifera greatly outnumber the bottom-dwelling forms, though in variety of form and in number of genera and species the bottom forms greatly exceed the pelagic. Several zones of relatively pure globigerina ooze were found, and many in which the ooze was clayey or sandy. Though variations in temperature were reflected by faunal changes, the general bathymetric facies of the faunas appear to be rather uniform throughout each core. The bottom faunas are least varied and prolific in cores from the deepest water, whereas in cores from the shallowest water they are by far the most varied and prolific. Cores from intermediate depths contain faunas of intermediate bathymetric facies. These relations to depth are, in general, characteristic also of faunas in the existing oceans. A few scattered specimens of *Elphidium* or *Elphidiella* were found. These genera thrive in shallow water, but in these cores the shells are so rare, so erratically distributed, and in some so poorly preserved that it seems probable they were rafted in by seaweeds or ice and therefore have no significance as indicators of depth. No species peculiar to the Miocene or Pliocene were found. It appears, therefore, that all the sediments penetrated by the cores are younger than Pliocene. Alternation of faunas that are characteristic of the warm and cold climates of the present day indicates great climatic changes during the time represented by these cores. The foraminiferal facies characteristic of cold and warm climates correlate with the alternating sequence of glacial-marine and warmer-water sediments indicated by the lithology. This correlation suggests that all the sediments in these cores are of Recent and Late Pleistocene age.

Diatomaceae.—Fifty-two species and varieties of diatoms were found in these cores. A large percentage of the species are neritic, warm-water forms that are foreign to the region today. Several

alternations of warm-water and cold-water diatom floras occur in most of the cores, but their position in the cores is not in accord with the alternations of temperature inferred from lithology and foraminiferal facies. It is suggested that this disagreement may be due to the much longer settling time of the diatoms and that allowance should be made for it. The time equivalent of this difference of phase, as calculated from the vertical displacement necessary for the best approximation to agreement between the foraminiferal and lithologic data on the one hand and the diatom data on the other is of the order of 23,000 years. This figure appears absurdly high and a figure of several hundred years, based on extrapolation of experimentally timed settling in a relatively small vessel, is considered more reasonable. The action of cold and warm currents, some surficial and some deep seated, is suggested as the possible cause of the apparently erratic distribution of the diatoms. The possibility that the phase difference of 23,000 years mentioned above is related to shifts of ocean currents caused by advances and recessions of drift ice is offered as a speculation. Of 52 species and varieties illustrated, 2 species and 1 variety are described as new.

Ostracoda.—In preparing a series of samples from the cores for the study of the Foraminifera about 175 specimens of Ostracoda were found. These belong to 13 genera and 27 species, all living forms, though 12 of the species are known also as fossils. Most of the ostracodes were found in three cores that were taken in the shallowest water (1,280 to 3,230 meters). One of these cores (No. 8) was from the top of the mid-Atlantic ridge and the other two (Nos. 12 and 13) were from the continental slope southwest of Ireland. In the cores from deeper water (3,250 to 4,820 meters) ostracodes were scattered very sparsely. Like most marine ostracodes, all the species found in the cores are bottom dwellers. Most of the species are decidedly cold-water forms that are found in tropical waters only at great depth, where the temperature is near freezing. Northern forms predominate; only 2 of the species have not previously been known from northern waters, and 10 species are definitely Arctic forms. A few species that have a wider temperature range live not only in cold waters but also in the deep warm water of the Mediterranean.

The predominance of distinctly cold-water ostracodes and the prevalence of Arctic forms suggest that the temperature of the water in this part of the North Atlantic was formerly somewhat lower. But, as might be expected from the fact that all the species in these cores are bottom dwellers, their distribution in the cores shows no evident relationship to the cold and warm zones indicated by the composition and texture of the sediments and by the pelagic Foraminifera.

Mollusca.—The mollusks recovered from these cores can be divided into two groups, the pteropods and the other gastropods and pelecypods. The pteropods are by far the more numerous. All the specimens of the pelecypods and gastropods, other than pteropods, are representatives of deep-water species that are now living in the same boreal or cold-temperate waters. Also, the fragments that could not be identified specifically belong to forms that have congeners now living in these waters. The fauna of these cores, even that taken from the lower parts of the cores, shows no appreciable difference from that now living in the same localities. Among these mollusks no evidence of shallower or considerably deeper water is demonstrable. Molluscan remains, other than those of pteropods, are too scarce to attempt to differentiate cold- and warm-water facies, as was done with the foraminiferal faunas.

The Pteropoda, which are far more abundant in the cores than the other mollusks, belong to two genera and three species. One of the species is new. The geographic distribution of the pteropods is limited more by the temperature of the surface water than by any other factor. Nevertheless, as one species is cosmopolitan, one boreal, and one a new species thought to be the

northern analogue of a more southern species, and as all three species occur together, they have no significance for differentiating cold- and warm-water facies. These organisms are pelagic and their shells have a rather wide distribution, but, as they are found on the sea floor at depths ranging from 247 to 3,750 meters, they are of little aid as indicators of depth of the ocean at the time these deposits were laid down.

Echinodermata.—The remains of 9 species of Echinodermata were found in the cores. These include 1 ophiuroid, 7 echinoids, and 1 crinoid. No remains of asteroids were found. All the echinoderms found belong to species now living in that part, or adjacent parts, of the North Atlantic. Echinoderm remains are rather uniformly distributed among the cores, but they are most numerous in core 8, which was taken in 1,280 meters of water on the crest of the mid-Atlantic ridge. By far the commonest species is *Pourtalesia miranda*, remains of which were found in nearly two-thirds of the 82 echinoderm-bearing samples and in all the cores except 8 and 11.

Because the association of species in the cores is closely similar to the association of living species in that part of the North Atlantic and because the association of species within each core is independent of the distance below the top of the core it appears that neither the distribution nor the composition of the echinoderm fauna has changed significantly during the interval represented by these cores. No evident relationship was found between the distribution of the various species of echinoderms and the cold- and warm-water facies of the sediments indicated by both the Foraminifera and the lithology.

Miscellaneous fossils and significance of faunal distribution.—The principal fossil groups represented in the cores, listed in order of abundance, are foraminifers, diatoms, echinoids, siliceous sponges, radiolarians, ophiuroids (spines and plates), ostracodes, and pteropods. Remains of barnacles, brachiopods, pelecypods, holothuroids, bryozoans, gastropods, and teleost fishes (otoliths) were also found, but all these are rare. The foraminifers, diatoms, ostracodes, echinoderms, pelecypods, and gastropods were studied separately by specialists. The other groups are briefly noted and illustrated for the sake of the record. The most varied and prolific faunas were found in the three cores that were taken from the shallowest water and the least varied and least prolific were found in those from the deepest water. The bottom-living faunas throughout each core have a broadly similar bathymetric facies, and the bathymetric facies of each core appears to correspond to that of the fauna now inhabiting that locality. Faunas having the characteristics of very shallow-water marine faunas are either absent or, if present, are so rare and erratically distributed that they appear to be foreign in origin rather than indigenous. Ostracodes and pteropods are locally abundant in the cores from the shallowest water, but are absent or rare at all horizons in those from the deeper water. The distribution and bathymetric facies of the faunas weigh heavily against the hypothesis of extreme changes in ocean level during the later part of the Pleistocene.

Organic matter content.—The content of organic matter, as determined from 123 samples, ranges from 0.1 to 1.0 percent of the total weight of the sediments, and the average is about 0.5 percent. As in near-shore sediments, it is influenced by the configuration of the sea bottom. It is small on ridges and large in the deeps. It is particularly large in the sediments at the base of the east slopes of ridges, owing in part, probably, to material washed from the vicinity of the ridges by eastward-sweeping ocean currents. The organic matter content of the upper layers of the sediments in the abyssal deeps is greater for a few hundred miles east of the mid-Atlantic ridge than it is for a similar distance west of the ridge. The organic content does not vary consistently with depth except in core three, taken at the foot of the continental slope east of the Grand

Banks, where it seems to decrease about 25 percent in the first 1.5 meters. The organic matter content of the sediments tends to be greater in the warm zones, than in the cold zones, and in general it is slightly greater in sediments which, according to Cushman's determination of the Foraminifera, were probably deposited in areas in which the surface water was relatively warm. The organic content is rather closely related to the texture, and increases with increasing fineness of the sediments. The rate of deposition of organic matter is greater east of the mid-Atlantic ridge than west of it, presumably owing in part to a greater supply of plankton and in part to a slower rate of decomposition of the organic matter after it is laid down in the sediments. The slower rate of decomposition within the sediments is inferred from the greater state of reduction of the sediments, which is indicated by the nitrogen-reduction ratio. The nitrogen-reduction ratio suggests a slight increase in state of reduction with increasing depth of burial in the upper part of the deposits, but indicates no significant change in the lower part. The percentage of organic content tends to increase as the percentage of Foraminifera in the sediments decreases, but it shows no relationship to the calcium-carbonate content.

Selenium content and chemical analyses.—As a part of a comprehensive investigation of the distribution of selenium in marine

sediments and soils derived from them complete fusion analyses were made of 20 samples from the suite of 11 cores. These samples were taken from the tops of the cores and at intervals of approximately 1 and 2 meters below the top. In addition, 1 core taken on the continental shelf off Ocean City, Md., and 3 cores from the Bartlett Deep were sampled and analyzed, making a total of 31 analyses. The results of the analyses include all the normal analytical data obtained in a so-called complete soil analysis by the fusion method, and, in addition, determinations of organic matter, nitrogen, chlorine (in all but 12 analyses), hygroscopic water, and selenium. All the samples were analyzed with the entrained sea salts. The core from the continental shelf off Ocean City contained the most selenium—at the top 0.6 part per million, at 1 meter 1.0, and at 2 meters 2.0 parts per million. The samples from the North Atlantic cores showed a selenium content ranging from 0.06 to 0.8 part per million. Of the samples from the Bartlett Deep one contained 0.2 part per million of selenium, but all the others contained less than 0.08 part per million. No evidence was found of a relation between the selenium content and volcanic activity.

The silica-sesquioxide and silica-alumina ratios are tabulated and their significance as means of comparing the analyses is discussed.

FOREWORD

By C. S. PIGGOT¹

During the last cruise (1927-29) of the nonmagnetic ship *Carnegie* of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington a number of samples of the deep ocean bottom were obtained by means of the telegraph snapper. The Geophysical Laboratory determined the radium content of these samples and found that they contained a concentration of radium² as astonishingly high as that reported by Joly³ and Pettersson⁴ from similar samples taken by the *Challenger* and *Princess Alice II*. This high radium concentration in the surface layer of the ocean bottom, which constitutes 72 percent of the surface of the globe, raises questions of great significance to both oceanography and geophysics. An obvious question is whether radium in so high a concentration is present down through all deep-sea sediments or only at the surface.⁵ If the first hypothesis is correct it indicates the presence of uranium throughout the sediments, whereas the second indicates the existence of radium itself, presumably separated out from the sea water. The study of this question requires samples of a type analogous to the cores so extensively used in subsurface exploration on land. Inquiries among oceanographic organizations established the fact that although some cores a meter or more in length had been obtained from relatively shallow water, many of them were much distorted by the time they reached the laboratory, and none as long as 1 meter had been obtained from a depth of 4,000 meters or more.⁶ Those engaged in such research emphasized the need of apparatus capable of obtaining undistorted cores from great depths. In 1933 the Council of the Geological Society of America approved a grant for the development of such apparatus.⁷ Fortunately, cooperation was obtained from several special

agencies, particularly the Burnside Laboratory of the E. I. du Pont de Nemours, whose ballistics expert, Dr. B. H. Mackey, offered fundamental suggestions and made many essential calculations and tests; also the United States Bureau of Lighthouses, from whose lightship tender, the *S. S. Orchid*, many experimental soundings were made. Several forms of the apparatus were developed and tested, and in August 1936 14 satisfactory cores were obtained from the canyons in the continental shelf off New Jersey, Delaware, and Maryland, and another from the ocean floor below 2,500 meters of water.⁸ This first deep-sea test was made possible by the cooperation of the Woods Hole Oceanographic Institution and was carried out in connection with an investigation of the submarine canyons by H. C. Stetson of that institution. This test demonstrated the feasibility of the apparatus as built but suggested some minor changes in design. These were incorporated in another apparatus, which was put aboard the cable ship *Lord Kelvin* at Halifax, Nova Scotia. Through the courtesy of Mr. Newman Carlton, Chairman of the Board of Directors of the Western Union Telegraph Co., the Carnegie Institution of Washington was invited to have a member of its staff accompany the *Lord Kelvin* while that ship was engaged in making repairs to the North Atlantic cables, in order to test the apparatus in deep water. This offer was gladly accepted, and in May and June of 1936 I was on board the *Lord Kelvin* with the apparatus.

Because of the personal interest and cooperation of the commanding officer, Lt. Comdr. Bredin Delap, Royal Navy, retired, the undertaking was more successful than had been anticipated, and a suite of 11 excellent cores was obtained, extending from the Grand Banks of Newfoundland to the continental shelf southwest of Ireland.

All but two of these cores (Nos. 8 and 11) are more than 2.43 meters (8 feet) long, and all contain ample material for study. Of the two short cores, No. 8 was taken from the top of the Faraday Hills, as that part of the mid-Atlantic ridge is known, where the material is closely packed and more sandy and consequently more resistant; No. 11 came from a locality where the

¹ Geophysical Laboratory, Carnegie Institution of Washington.

² Piggot, C. S., Radium content of ocean-bottom sediments: *Am. Jour. Sci.*, 5th ser., vol. 25, pp. 229-238, 1933.

³ Joly, J., On the radium content of deep-sea sediments: *Philos. Mag.*, vol. 16, pp. 190-197, 1908.

⁴ Pettersson, Hans, Teneur en radium des dépôts de mer profonde: *Resultats de Campagnes Scientifiques par Albert I^{er} Prince Souverain de Monaco*, vol. 81, 1930.

⁵ Piggot, C. S., *op. cit.*, p. 233.

⁶ Since these inquiries were made D. Wolansky has published her review in the *Geologische Rundschau* (Band 24, Heft 6, p. 399, 1933), in which she refers to the work of A. D. Archangelsky in the Black Sea (*Soc. Naturalistes Moscow Bull.*, new ser., vol. 35, pp. 264-281, 1927). Wolansky mentions cores 3 to 4 meters long from depths of 2,237 meters. See also *Wiss. Ergeb. Deutschen Atlantischen Exped. Meteor*, 1925-27, Band 3, Teil 2, Lief. 1, pp. 4-28, 1935.

⁷ Piggot, C. S., Apparatus to secure core samples from the ocean bottom: *Geol. Soc. America Bull.*, vol. 47, pp. 675-684, 1936.

⁸ Cushman, J. A., Henbest, L. G., and Lohman, K. E., Notes on a core sample from the Atlantic Ocean bottom southeast of New York City: *Geol. Soc. America Bull.*, vol. 48, pp. 1297-1306, 1937.

apparatus apparently landed on volcanic rock that may be part of a submarine lava flow. Soundings at the localities where the cores were taken show depths ranging from 1,280 meters at the top of the Faraday Hills to 4,820 meters in the deep water between the mid-Atlantic ridge and the continental shelf.

The thorough test made possible by the interested cooperation of everyone on board the *Lord Kelvin* fully demonstrated the capacity of the apparatus and produced material from strata of oceanic sediments deeper than have ever before been available.

In order that this pioneer material might be examined to the best advantage and an adequate estimate made of the potentialities of cores of this type, a group of investigators representing various fields of science was invited to examine them. Efforts have been made to arrange the sequence of these investigations in such a way that the maximum information may be obtained with the minimum destruction of the samples.

The cores are now at the Geophysical Laboratory of the Carnegie Institution of Washington, where they and others that may be obtained by this laboratory will be held available for further research.

GENERAL INTRODUCTION

By W. H. BRADLEY

SIGNIFICANCE OF THE INVESTIGATION

The long cores of deep-sea sediment considered in this report represent a longer span of the earth's late geologic history, as recorded in abyssal sediments, than has been heretofore accessible. In a measure, therefore, this study has been exploratory. Because of that exploratory aspect we have not only presented the observations but also have deliberately speculated upon various possible interpretations of the features observed in the cores and upon their relations with one another. Because the cores are few in number and widely spaced, we offer many of the interpretations not as definite conclusions but rather as suggestions to be tested by whatever coring may be done in the future in that part of the North Atlantic.

From this investigation it appears that glacial marine deposits may prove to be sensitive indicators of the climatic changes that caused the growth and decay of continental ice sheets during the Pleistocene. In particular, it seems that the glacial marine record may throw light on the climatic fluctuations that determined substages of the Pleistocene. The marine record was the result of a continuously operating series of causes such that the deposits of each glacial substage were separated from one another by the deposits of the intervening warmer substage. The record of each substage has remained intact and was not obliterated by readvances of the ice. As the equatorward extent of the glacial marine deposits implies a corresponding expansion of continental ice sheets, the extent of the deposits may be used as a measure of the intensity of the climatic changes, and their thickness may be used as a rough indicator of the duration of glacial substages. Similarly, the thickness and poleward extent of tongues of nonglacial sediment—the foraminiferal marl—are measures of deglaciation. The areal extent of these tongues of sediment can be determined by additional cores taken at properly located stations.

When the glacial marine record is more fully known it should provide a basis for correlating the Pleistocene history of Europe and North America.

Cores taken along the meridians in series extending from the Arctic regions into the tropical parts of the Atlantic should make it possible to map the southern limits of pack ice in the sea during successive glacial maxima, at least for the later part of the Pleistocene.

As the pelagic Foraminifera in these abyssal sediments are reliable indicators of surface-water temperatures in the Recent and Pleistocene epochs, it should be possible to trace southward into the tropics layers or beds of foraminiferal ooze that are the time equivalents of glacial marine zones. Such layers of foraminiferal ooze could then be correlated with the layer of globigerina ooze in the tropics that Schott⁹ identified as a relatively cold-water deposit that probably represents the last glacial epoch of the Pleistocene.

The study of climatology as well as geology may be advanced by the information to be derived from long sea-bottom cores. Significant evidence bearing on postglacial climatic changes may be obtained from minutely detailed study of the Foraminifera in cores taken in parts of the ocean where postglacial sedimentation has been comparatively rapid, as, for example, near the seaward edge of the blue-mud zone. On the assumption that such sediment accumulates at an essentially uniform rate, climatic fluctuations may be located approximately in time within the postglacial interval and may be correlated from place to place along the ocean margins from the Arctic to temperate or even tropical latitudes and perhaps also from continent to continent.

Archeology, also, might profit from the knowledge of a relatively timed and correlated sequence of climatic changes, for such changes may well have made a significant impress on the habits and migrations of peoples, particularly those that dwelt in regions where small changes in either temperature or rainfall were critical. As I have pointed out in an earlier paper,¹⁰ students of archeology and early history, particularly in the Mediterranean region, might profit much from detailed studies of long cores of the sediment in the deep basins of the Mediterranean. In cores from that sea, as elsewhere, changes in the foraminiferal faunas would indicate climatic changes, and the sediments would yield, in addition, evidence of volcanic eruptions and earthquakes. The time when the Sahara became a desert should also be recorded in the Mediterranean sediments by wind-blown sand. Such a change might conceivably be integrated with the wealth of archeo-

⁹ Schott, W., Die Foraminiferen in dem äquatorialen Teil des Atlantischen Ozeans: Wiss. Ergeb. Deutschen Atlantischen Exped. *Meleor*, 1925-27, Band 3, Teil 2, Lief. 1, pp. 120-128, 1935.

¹⁰ Bradley, W. H., Mediterranean sediments and Pleistocene sea levels: *Science* new ser., vol. 88, pp. 376-379, 1938.

logical records of the region, and the later volcanic eruptions and earthquakes might be correlated with early history.

Some of the problems sketched so briefly here are touched upon in the several chapters of this report, but most of them must be left for future investigators. Nevertheless, methods by which such problems may be attacked are described and discussed at considerable length, particularly in the chapters on "Lithology and geologic interpretations" and "Foraminifera."

LOCATION OF THE CORE STATIONS

The cores were taken along a slightly irregular line between the easternmost part of the Newfoundland Banks and the banks off the southwest coast of Ireland, as shown in plate 1. Each core obtained by the Piggot coring device is numbered to correspond with the station number of the cable ship *Lord Kelvin*. Stations 1 and 2 were trial stations at which preliminary tests were made to familiarize the crew with the apparatus, and no cores were preserved. The 11 cores studied are numbered consecutively, 3 to 13. The relation between

M. N. Bramlette, J. A. Cushman, L. G. Henbest, K. E. Lohman, and P. D. Trask. As the biologic phase of the work progressed it became evident that other organisms than the foraminifers and diatoms should be studied. Accordingly Mr. Henbest invited Dr. Willis L. Tressler, of the University of Buffalo, to examine the ostracodes, Dr. Austin H. Clark of the United States National Museum, to examine the echinoderms, and Dr. Harald A. Rehder, also of the United States National Museum, to examine the mollusks.

The organic matter content of the sediments was studied by Mr. Trask in collaboration with Messrs. H. Whitman Patnode, Jesse LeRoy Stimson, and John R. Gay, all members of the American Petroleum Institute.

As part of a comprehensive research project on the distribution of selenium in marine sediments and the soils derived from them Dr. H. G. Byers and Mr. Glen Edgington, of the Bureau of Chemistry and Soils, United States Department of Agriculture, made complete chemical analyses of 20 samples from these deep-sea cores. These analyses, together with analyses of

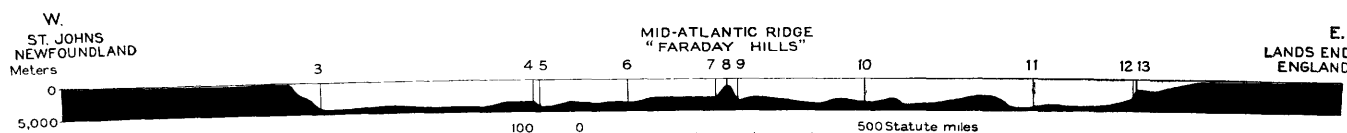


FIGURE 1.—Profile across the North Atlantic Ocean along the line of the numbered core stations shown on plate 1.

the core stations and the submarine topography is shown in figure 1, which is a profile along the dashed line in plate 1 that connects the stations and extends from St. Johns, Newfoundland, to Lands End, England.¹¹

TABLE 1.—Geographic location, length of the cores, and depth of the water from which they were taken

Core number	Depth of water (meters)	Length of core (meters)	Lat. N.	Long. W.
3.....	4,700	2.81	46°03'00"	43°23'00"
4.....	3,955	2.71	48°29'00"	35°54'30"
5.....	4,820	2.82	48°38'00"	36°01'00"
6.....	4,125	2.90	49°03'30"	32°44'30"
7.....	3,250	2.62	49°32'00"	29°21'00"
8.....	1,280	1.24	49°36'00"	28°54'00"
9.....	3,745	2.76	49°40'00"	28°29'00"
10.....	4,190	2.97	49°45'00"	23°30'30"
11.....	4,820	.34	48°38'00"	17°09'00"
12.....	3,230	2.43	49°37'00"	13°34'00"
13.....	1,955	2.21	49°38'00"	13°28'00"

PERSONNEL AND COMPOSITION OF THE REPORT

At the request of Dr. C. S. Piggot, of the Geophysical Laboratory of the Carnegie Institution of Washington, the following six members of the United States Geological Survey undertook a systematic study of the 11 deep-sea cores from the North Atlantic: W. H. Bradley,

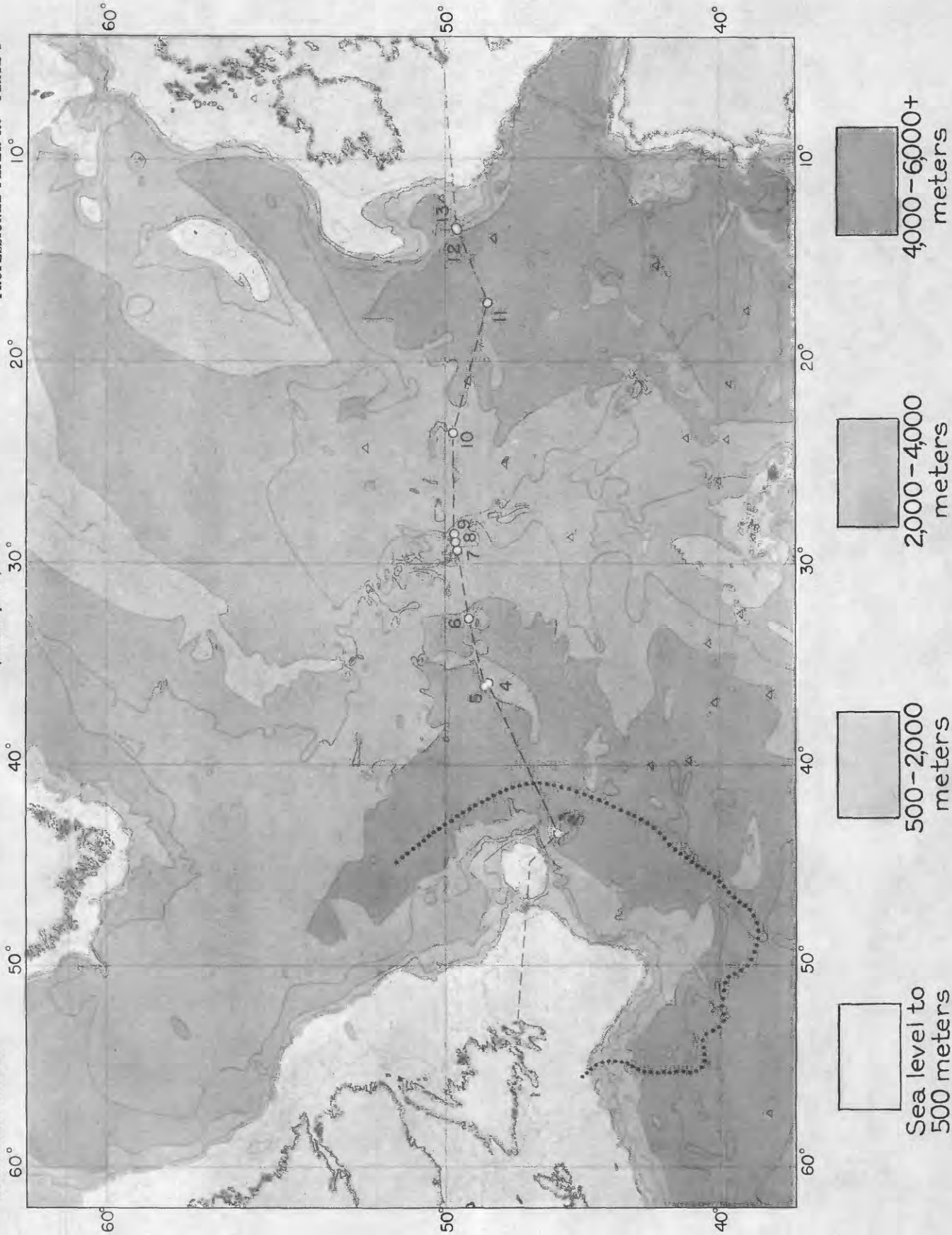
¹¹ Data for plate 1 and figure 1 were taken from *International Hydrographic Bureau, Carte Générale Bathymétrique des Océans*, 3d ed., sheets A-1 and B-1, copies of which were furnished by the U. S. Hydrographic Office.

samples from several other deep-sea cores and a discussion of the occurrence of selenium, are included in the chapter on "Selenium content and chemical analyses."

METHODS OF SAMPLING AND EXAMINATION

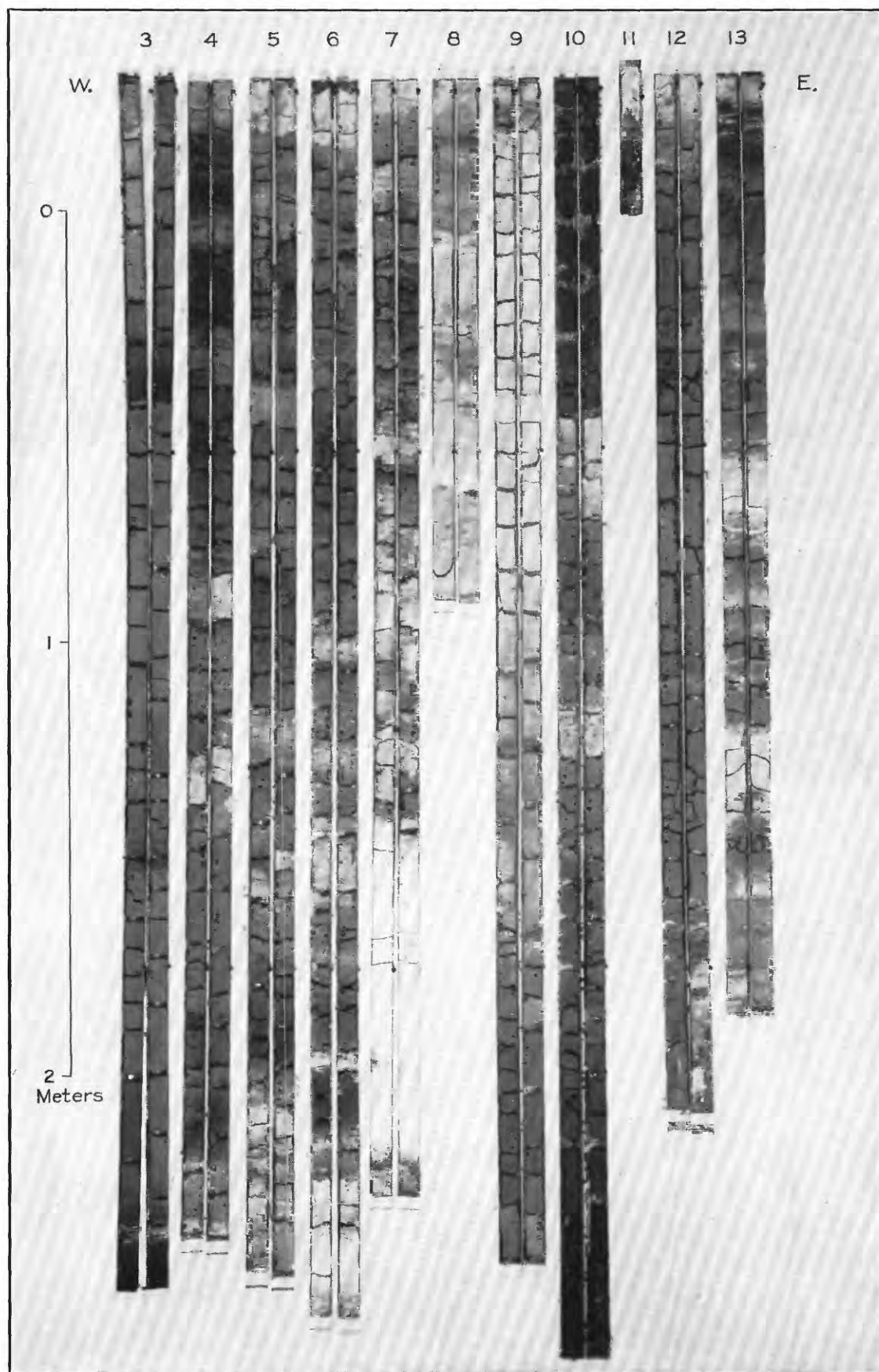
The Piggot coring device¹² takes the cores in brass sampling tubes that have an inside diameter of 4.9 cm. As soon as a core is taken, the tube is cut off at the approximate length of the core and sealed. The cores here discussed were opened under Dr. Piggot's direction at the Geophysical Laboratory of the Carnegie Institution of Washington. A longitudinal cut was made along one side of each brass core barrel by means of a milling cutter so adjusted that it did not cut quite through the wall of the tube. The thin strip remaining was then ripped out without letting brass chips get into the core. After allowing the mud cores to dry somewhat, but not enough to shrink away from the tube walls, the cores and core barrels were cut in half longitudinally with a metal-cutting band saw. In this cutting, the milled slot was held uppermost so that the saw cut only the lower wall of the core barrel and threw the cuttings downward, away from the core.

¹² Piggot, C. S., Apparatus to secure core samples from the ocean bottom: *Geol. Soc. America Bull.*, vol., 47, pp. 675-684, 1936.



BATHYMETRIC CHART OF A PART OF THE NORTH ATLANTIC OCEAN.

The numbered circles indicate the core stations. The dashed line connecting them is the line of the profile shown in figure 1. The light dotted line along the coasts is the 200-meter depth contour. The usual limit of drift ice is shown by the heavy dotted line. The small triangles indicate the position of icebergs reported far beyond their normal range during the period January 1900 to July 1916, according to information compiled by J. T. Jenkins (A Textbook of Oceanography, fig. 14, London, Constable & Co., 1921).



LONGITUDINAL SECTIONS OF THE AIR-DRIED CORES.

Half of the core barrel was removed from core 11, but the core itself was not cut. Photograph by Geophysical Laboratory, Carnegie Institution of Washington.

Each half core then remained undisturbed in its half cylinder cradle of brass core barrel. (See pl. 2.)

As several months elapsed between the time the cores were opened and the time this investigation began, the mud had dried thoroughly when Mr. K. E. Lohman took a succession of overlapping photographs of each core, about one fifth natural size. These photographs were then assembled as a key chart upon which were marked the parts from which samples for all phases of the investigation were taken. The dried segments of mud shifted somewhat from their original places each time samples were removed, though care was taken

to see that during sampling the segments kept their original order and orientation. By reference to this photographic key the findings of all the investigators have been correlated.

Most of the material was hard enough to be sawed into blocks with a hack saw, but a few of the most friable parts were sampled with small channel-shaped scoops of sheet metal after the loose material on the surface had been brushed away.

Samples for all phases of this investigation were taken from only one half of each core, the other half being held intact in the Geophysical Laboratory.

GEOLOGY AND BIOLOGY OF NORTH ATLANTIC DEEP-SEA CORES BETWEEN NEWFOUNDLAND AND IRELAND

PART 3. DIATOMACEAE

By K. E. LOHMAN

INTRODUCTION

This report is one of a series bearing on different phases of the investigation of the deep-sea cores collected in the North Atlantic by C. S. Piggot in 1936. (See Foreword of this professional paper.) Its scope is confined to the diatoms found in the cores. The report is divided into two parts. The first part deals with the distribution of diatoms in the cores, with a discussion of their ecologic and geologic significance; the second part gives a systematic description of the diatoms. The geographic location of these cores is shown on plate 1 in part 1 of this professional paper.

COLLECTION OF SAMPLES

During the winter of 1936-37, 67 samples were selected from the cores at the Geophysical Laboratory in Washington by W. H. Bradley, of the Federal Geological Survey, and myself. The location in the core of each sample and the location of all samples taken by the different investigators studying the material were carefully plotted by Mr. Bradley on a photographic chart that he had prepared. Portions sawed from pieces of the core were stored in labeled screw-cap bottles for future study. As the core had dried sufficiently, it was possible to get solid pieces, which reduced the possibility of contamination from neighboring parts of the core to a minimum. Although each sample was examined with a 10 × hand lens as it was collected, only the large discoid diatoms could be seen and then only when fairly abundant. The large amount of fine material present or the abundance of Foraminifera generally made it impossible to determine by inspection with a hand lens which sample contained diatoms.

Core 5 was sampled first at intervals ranging from 9 to 40 centimeters. The 14 samples from this core were prepared and studied before further sampling was done in an attempt to determine the justifiable frequency of sampling for the other cores. Diatoms were found in only 4 of the 14 samples collected from this core, and all were in the upper half.

In the meantime, M. N. Bramlette, who collected at short intervals from all the cores for his lithologic

studies, had looked at the whole lot under the microscope and had noted, among other things, the presence or absence of diatoms in each sample. The results of Mr. Bramlette's preliminary examination served as an excellent guide for sampling the remainder of the cores, and acknowledgment is here made to him for the very material saving in time effected by his help. Mr. Bramlette reported no diatoms from cores 8 and 11, and therefore they were not sampled by me.

The location of the samples collected, the numbers assigned to them for use in this report, to which reference will be made frequently, their permanent Federal Geological Survey diatom locality numbers, and the presence or absence of diatoms is indicated in the following table:

TABLE 8.—Locations and numbers of the diatom samples

Core No.	Location of station		Depth of water (meters)	Sample No.	Position of sample in core, in centimeters below top	Diatoms present (+) or absent (—)	U.S.G.S. diatom locality No.
	Lat. N.	Long. W.					
3	46°03'00"	43°23'00"	4,700	L-1	5-8	+	2863
				L-2	40-48	+	2864
				L-3	81-89	+	2865
				L-4	130.5-137	+	2866
				L-5	185-187	+	2867
				L-6	190-192	+	2868
				L-7	233-238	+	2869
4	48°29'00"	35°54'30"	3,955	L-8	7.5-9.5	+	2831
				L-9	29-33	—	2832
				L-10	74-79	+	2854
				L-11	83-87	—	2833
				L-12	132-136	—	2834
				L-13	177-179	—	2835
				L-14	207-210	—	2836
5	48°38'00"	36°01'00"	4,820	L-15	264-268.5	—	2837
				L-16	0-2	+	2817
				L-17	21-23	—	2818
				L-18	30-32	—	2819
				L-19	34-38	+	2830
				L-20	46-48.5	+	2820
				L-21	58-61	—	2821
				L-22	95-99	—	2822
				L-23	111-113	+	2823
				L-24	124-126	—	2824
				L-25	158-159	—	2825
				L-26	203-205	—	2826
				L-27	225-228	—	2827
				L-28	262-264	—	2828
6	49°03'30"	32°44'30"	4,125	L-29	277-281	—	2829
				L-30	0-4.5	+	2838
				L-31	38.5-42	+	2839
				L-32	81.5-85	+	2840
				L-33	118-122	+	2841
				L-34	152-158.5	—	2842
				L-35	183-188	+	2892
				L-36	200-203	—	2843
				L-37	226-230	+	2893
				L-38	244-248	—	2844
				L-39	275-281	+	2894

TABLE 8.—Locations and numbers of the diatom samples—Con.

Core No.	Location of station		Depth of water (meters)	Sample No.	Position of sample in core, in centimeters below top	Diatoms present (+) or absent (—)	U.S.G.S. diatom locality No.
	Lat. N.	Long. W.					
7-----	49°32'00"	29°21'00"	3,250	L-40	3.5-7	+	2845
				L-41	55-58	—	2846
				L-42	94-96	—	2847
				L-43	119-123	—	2848
				L-44	158-161	+	2849
				L-45	183-187	—	2850
				L-46	190-192.5	+	2853
				L-47	233-237	—	2851
				L-48	258-262	—	2852
9-----	49°40'00"	28°29'00"	3,745	L-49	0-6.5	+	2855
				L-50	47-53	+	2856
				L-51	108-114	+	2857
				L-52	142-151	+	2858
				L-53	178-188	+	2859
				L-54	206-213	+	2860
				L-55	246-250	+	2861
				L-56	267-272	+	2862
10-----	49°45'00"	23°30'30"	4,190	L-57	29-33	—	2870
				L-58	80-86	+	2871
				L-59	86-89	+	2872
				L-60	233-237	+	2873
				L-61	258-263	+	2874
12-----	49°37'00"	13°34'00"	3,230	L-62	0-5	+	2875
				L-63	30.5-33	+	2876
				L-64	90.5-95	—	2877
13-----	49°38'00"	13°28'00"	1,955	L-65	0-7	+	2878
				L-66	141-143	—	2879
				L-67	182-187.5	—	2880

PREPARATION OF MATERIAL

All the samples were given as nearly as possible the same treatment in the cleaning and concentrating operations in order that the relative abundance of species from the different samples would be comparable. All possible precautions were taken to prevent contamination from other samples or from outside sources. Briefly, the method used was as follows:

All outside (possibly contaminated) material was removed from each sample with a knife (washed between samples), leaving a small block with a volume of about 2 cc. This was boiled in 1:1 hydrochloric acid for about 30 minutes to remove calcareous and other acid-soluble constituents and to disintegrate the material. The remaining acid, various chlorides in solution, and fine clastic material in suspension were removed by repeated decantations after definitely timed settling periods. The coarse fraction, which had a more rapid settling rate than the diatoms, was removed by reversing the process. At this stage in the process the samples were carefully examined for diatoms, merely to determine their presence or absence. Several large drops of the concentrated residue were removed with a clean pipette and examined under a microscope. Those showing no diatoms or diatom fragments were discarded as barren.

Organic matter was removed by boiling the above residue in concentrated sulphuric acid until it was well blackened and then adding granular sodium nitrate. Another series of timed decantations removed the acid and the remaining fine clastic material. In some of the samples containing a large percentage of clay, the boiling in sulphuric acid caused a pronounced flocculation,

which was dispersed by adding 20 cc. of concentrated sodium hydroxide solution to one of the decantations. Contrary to popular belief, diatoms are not visibly affected by standing in cold sodium hydroxide solutions of medium strength for more than a year. In the treatment described here the diatoms were exposed to the caustic solution for a few hours at the most.

The residue from the above procedure was snow white and consisted of diatoms, radiolaria, sponge spicules, volcanic ash, and quartz and other resistant minerals, all of which were presumably present in the original sample. This was separated into a coarse and a fine fraction by short-time settling and decantation and bottled for study. The fine fraction contained most of the diatoms and fine ash particles whereas the coarse fraction contained the heavy minerals, quartz, radiolaria, coarse ash particles, and in some fractions a few very large diatoms. A drop of 40-percent formaldehyde solution was added to each bottle to prevent the growth of a mold, which, by some strange quirk of nature, can prosper on freshly washed diatoms and distilled water.

During the preparation described above, every effort was made to arrange the timing of the decantations so that few, if any, small diatoms were lost. This necessarily resulted in a final concentrate that still contained a little clastic material, but this was deemed of much less importance than the preservation of the original relative abundance of the diatoms as nearly as possible. The "beautifully cleaned material" of many diatomists is nearly always obtained at the cost of losing some of the smaller diatoms.

METHOD OF STUDY

As a result of the cleaning and concentrating operations described above, 29 samples were discarded as barren, leaving 38 samples containing diatoms in varying amounts. A total of 66 strewn slides mounted in Hyrax were made of the 38 samples, using 18-mm. round cover glasses. These were systematically traversed with a mechanical stage under a magnification of 350 diameters, and with sufficient overlap so that no part of the slide was missed. Diatoms were recorded in terms of the coordinates of the mechanical stage. A total of 380,000 separate fields were examined.

In addition, a number of arranged group slides on which the diatoms were individually selected and mounted under the microscope by means of the mechanical finger were prepared, primarily for convenience in making the photomicrographs used to illustrate this report.

The frequency of occurrence of each species on a slide was observed and recorded for each slide and furnished the basis for the fourfold grouping into abundant, common, frequent, and rare, indicated on the check list of species given in table 9.

[X Now living in North Atlantic Ocean. Ecology: M, Marine; B, brackish water; F, fresh water; N, neritic; O, oceanic; C, cold; T, temperate; W, warm. Relative abundance: R, Rare; F, frequent; C, common; A, abundant]

[illegible]

The barren samples contained Foraminifera in varying degrees of abundance, some ostracodes, coccoliths, radiolaria, sponge spicules, and molluscan fragments, clastic material ranging from extremely fine clay to coarse sand and pebbles, and a considerable amount of volcanic ash which was restricted to definite zones. As these constituents have been studied by other investigators, they will not be considered here.

The diatom flora from the cores consists of 52 species and varieties distributed, with respect to geologic age, as follows:

Recent only-----	12
Recent and fossil-----	36
Fossil only (?)-----	1
New species and varieties-----	3

The only diatom in the core (aside from the two species and one variety here described as new) that is not known definitely from floras living today is *Coscinodiscus convexus* Schmidt, described originally from Miocene rocks on the island of Barbados¹ and also reported from middle Miocene rocks in California by Hanna.² Heiden and Kolbe³ reported this species from Observatory Bay, Kerguelen, but did not state whether or not the diatom was in a living state when found. It was found commonly to rarely in most of the samples from core 9, but no geologic significance could be inferred from this occurrence. The remainder of the species are either Recent only or are found both in living material and in fossil beds ranging from Cretaceous to Pleistocene. Therefore, no geologic age can be assigned to any parts of the core purely on the basis of the diatoms.

An analysis of the ecologic conditions represented by the diatom flora proved much more fruitful.

Of the 52 species and varieties of diatoms found in the 38 diatomaceous samples from the cores, only 17, or 33 percent, have been reported by Lebour,⁴ as living in the North Atlantic at the present time. These have been indicated in the first column of the check list. Although it is true that the 67 percent that are missing from the cores include many plankton diatoms that are only slightly silicified and hence might not have been preserved in the sediments, the fact remains that some of these slightly silicified plankton diatoms were found. *Chaetoceros atlanticum* Cleve, a planktonic diatom of this type, was found in an excellent state of preservation in the top of core 6 and in a sample taken 142–151 centimeters below the top of core 9. *Rhizosolenia styliformis* Brightwell, another species of the same type, was found at various depths in three cores down to 238 centimeters below the top. Furthermore, many of the species in the missing 67 percent are heavy-walled, massive species belonging to the genera *Biddulphia*, *Triceratium*, and *Hemiaulus*, which would have been preserved had they been present.

Diatoms, particularly the planktonic species, are necessarily so constructed that they have a very large surface per unit weight and hence are able to float in the water. Their settling time in 2 to 3 miles of sea water, turbulent in the upper part and having relatively high density and viscosity in the lower part, must be very long. The large number of variables present, many of which are unknown, make any computation of the settling time uncertain, but it must be measured in hun-

dreds of years. If this is true the difference between the flora from the cores and that living in the overlying sea today is not so surprising as it appears to be at first sight. Apparently many of the species found at present in the upper waters of this part of the North Atlantic are not deposited on the sea floor directly beneath but are carried away by currents and deposited elsewhere.

This idea is greatly strengthened by the fact that a very large percentage of the diatoms from the cores are warm-water forms that thrive in subtropical and even in tropical waters today and were probably introduced into the North Atlantic by currents such as the northward-flowing Gulf stream.

In order to obtain some roughly quantitative data that would lead to an approximate determination of the origin of the diatoms found in the cores, three columns giving the ecology have been included in the check list, table 9.

In these columns, the second, third, and fourth, an attempt has been made to list the broader subdivisions of ecologic conditions into which the living counterparts of the diatoms from the cores are found today. The type of water (marine, brackish, or fresh) in which the species lives today is indicated in the second column. The type of environment with respect to the coast line, oceanic (living and reproducing in the open sea) or neritic (living and reproducing near the coast), is indicated in the third column. In the fourth column are listed the dominant temperature facies for each species in a threefold qualitative classification of warm, temperate, and cold. In all three columns species that are found living in two or more ecologic subdivisions are so indicated; for example, C-W indicates that a species is more or less indifferent to considerable temperature differences and can prosper in all types of water from cold to warm.

The distribution of species with respect to the ecologic facies represented is summarized according to two methods of approach in table 10. In the first column on the right, the percentage of the total number of species and varieties found (52) is given for each classification. In the second column on the right the percentage of the total number of individuals in each classification is given. This second column has been computed from the data given in the check list, weighting the different diatoms according to their abundance as follows: R (rare)=1; F (frequent)=3; C (common)=6; and A (abundant)=10. These figures are purely arbitrary but represent the order of magnitude of the relative abundance and certainly give a much more accurate ecologic census than the unweighted figures in the first column.

The high percentage of marine species is to be expected, as the nonmarine forms are obviously accidentally introduced, either by ocean currents carrying fresh-water and brackish-water forms out from the mouths of rivers or by floating icebergs.

¹ Schmidt, Adolf, Atlas der Diatomaceenkunde, pl. 60, fig. 15, 1878.

² Hanna, G. D., The diatoms of Sharktooth Hill, Kern County, California: California Acad. Sci. Proc., 4th ser., vol. 20, No. 6, p. 179, pl. 6, figs. 2, 3; pl. 7, fig. 1, 1932.

³ Heiden, Heinrich, and Kolbe, R. W., Die marinen Diatomeen, in Von Drygalski, E., Die deutsche Sudpolar-Expedition 1901–1903, Band 8, Botanik, Heft 5, p. 497, 1928.

⁴ Lebour, M. V., The planktonic diatoms of northern seas, Ray Soc. Mon. 116, 244 pp., 1930.

TABLE 10.—*Ecologic census of the cores as a whole*

	Percent (un- weighted, based on number of species)	Percent (weight- ed according to relative abun- dance)
A. Type of water:		
Marine-----	82. 8	96. 8
Marine and brackish-----	7. 7	2. 5
Brackish-----	1. 9	. 2
Brackish and fresh-----	3. 8	. 2
Fresh-----	3. 8	. 3
	100. 0	100. 0
B. Relation to coast:		
Neritic-----	52. 0	45. 9
Oceanic-----	19. 2	23. 0
Neritic and oceanic-----	7. 7	23. 7
Indeterminate-----	21. 1	7. 4
	100. 0	100. 0
C. Temperature:		
Warm-----	28. 8	28. 6
Warm-temperate-----	7. 7	9. 5
Temperate-----	27. 0	14. 6
Temperate-cold-----	3. 8	5. 2
Cold-----	15. 4	32. 0
Cold to warm-----	7. 7	4. 1
Indeterminate-----	9. 6	6. 0
	100. 0	100. 0

The relatively high percentage of neritic forms is much more significant, as most of the diatoms constituting the present-day plankton of the North Atlantic are oceanic forms.

The distribution of different temperature facies for the cores as a whole shows a slight predominance of cold-water forms, although the percentage of warm-water forms is high for the latitude in which the cores were taken.

In order to show the change in the various ecologic factors from core to core the percentages of the different classifications were determined for each core, weighted according to relative abundance by the method used above. The results are shown in table 11.

The presence in core 7 of only five species, represented by a very small number of individuals, makes the percentages from this core erratic and misleading. For this reason core 7 will not be considered in the discussion to follow.

In all the cores the percentage of neritic species is much higher than the percentage of oceanic species. Furthermore, there is an increase in the percentage of neritic species going from core 3 to core 13, that is, from west to east. The percentage of oceanic species is much less in the eastern cores than in the western ones.

The change in temperature indicated by the diatoms is equally striking. The percentage of warm-water forms increases from west to east, with an even more rapid decrease in the percentage of cold-water forms in the same direction.

One of the most striking features on the profile across the North Atlantic along the line of the cores (see fig. 1) is the sharp mid-Atlantic ridge, which at that locality is known as the Faraday Hills. It seems reasonable to believe that such a pronounced topographic feature must affect ocean currents, at least in the immediate vicinity. To test this hypothesis with the data at hand, the percentages of diatoms falling in the last two groups (relation to coast and temperature) were determined and weighted according to the method

TABLE 11.—*Ecologic census by cores, percent, weighted according to relative abundance*

[illegible]

described above and placed in two columns (table 12), one containing the percentages of all diatoms occurring west of the ridge (cores 3, 4, 5, and 6) and the other containing the percentages of all diatoms occurring east of the ridge (cores 9, 10, 12, and 13). The group for the type of water is not included as it does not appear to have any significance.

TABLE 12.—*Ecology of diatoms west and east of the Faraday Hills*

	Percent, weighted according to relative abundance	
	West of Faraday Hills	East of Faraday Hills
B. Relation to coast:		
Neritic.....	47	52
Oceanic.....	26	11
Neritic-oceanic.....	22	25
Indeterminate.....	5	12
	100	100
C. Temperature:		
Warm.....	25	41
Warm-temperate.....	13	8
Temperate.....	14	12
Temperate-cold.....	4	13
Cold.....	38	15
Cold-warm.....	3	1
Indeterminate.....	3	10
	100	100

The distribution shown in table 12 indicates a marked difference in the ecologic significance of the diatom floras on each side of the mid-Atlantic ridge.

The flora from the cores east of the ridge contains a much larger proportion of neritic species than the one from the cores west of the ridge. Still more obvious is the marked difference in temperature shown by the two

floras. The eastern flora contains more than twice as many warm-water species as the western flora. In figure 22 the directions of ocean currents according to Schott are shown. The cores west of the mid-Atlantic ridge lie in the path of contact of the warm Gulf Stream and the cold Labrador Current, which means that a large percentage of the flora was probably introduced by the cold waters from the north. On the east side of the mid-Atlantic ridge, however, the warmer Gulf Stream is the dominant current and has undoubtedly contributed a large share of the diatoms found in cores 9 to 13, inclusive. In addition to the warm-water species introduced by the Gulf Stream, the sediments on the east side of the ridge probably received many warm-water diatoms brought northward along the European coast by a warm deep current from the Mediterranean Sea, which, according to Harvey⁵ has been found by Nansen as far north as Ireland. The proportion of the warm-water species found in the cores east of the mid-Atlantic ridge that were introduced by this deeper current is not known, but it may be rather high, as the percentage of warm-water forms increases rapidly going east from the ridge.

Although the mid-Atlantic ridge may not have a pronounced effect on the dominantly surficial currents of the sea, such as the Gulf Stream, it appears highly probable that the deep-seated outflow from the Mediterranean would be largely restricted to the eastern basin of the North Atlantic by it.

The lithologic studies of Bramlette and Bradley in part 1 of this report have shown the existence of two zones of volcanic ash and four zones in which sand and

⁵ Harvey, H. W., *Biological chemistry and physics of sea water*, p. 116, 1928.

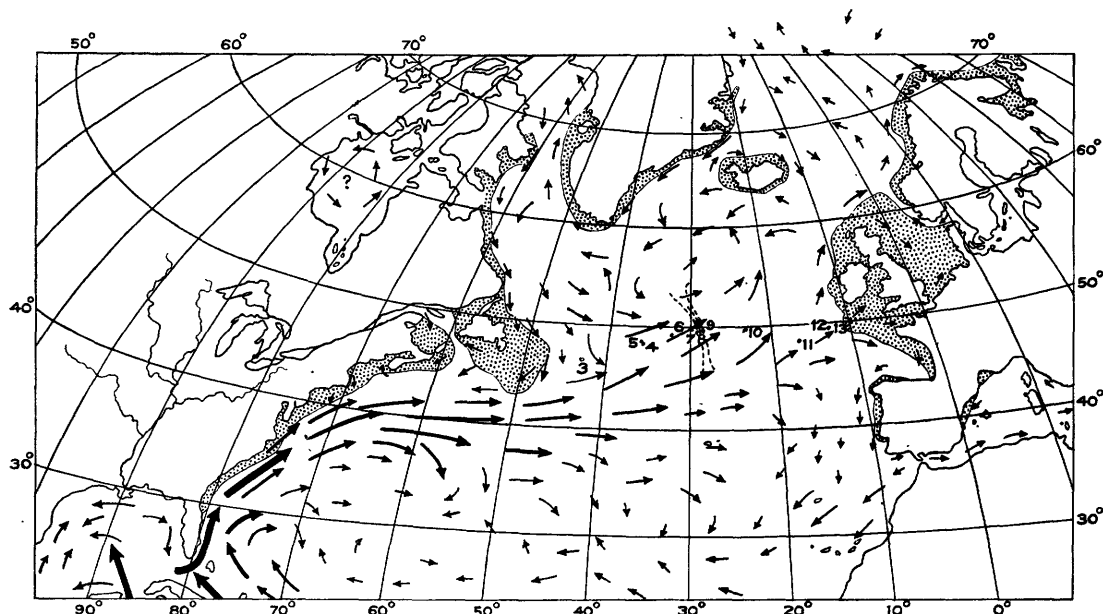


FIGURE 22.—Map of the North Atlantic Ocean showing the location of the core stations, by numbers, and the distribution of the surface currents, by arrows. The larger arrows indicate the most rapid currents and the smaller arrows slower currents. The stippled areas represent places where tidal currents predominate. (After Schott, Gerhard, *Geographie des atlantischen ozeans*, 2d ed., pl. 15, 1926.)

pebbles are relatively abundant and calcareous organisms are scarce. The zones of sand and pebbles are interpreted as glacial marine deposits formed probably during the latter part of the Pleistocene. The alternation of warmer and colder zones was substantiated by the independent work of Cushman and Henbest, who studied the Foraminifera from the cores. (See part 2, Foraminifera.)

In order to determine whether or not the evidence offered by the diatoms agreed with this determination, the distribution of the diatoms in each core was studied statistically by the following method, suggested by Parker D. Trask, of the Geological Survey, to whom acknowledgment is here made.

The diatoms were weighted according to relative abundance in a threefold classification of warm, temperate, and cold, for each sample. Species having more than one temperature facies represented in the check list, such as warm-temperate or temperate-cold, etc., were given equal counts for each temperature. The warm-water totals were multiplied by +1, the temperate totals by 0 and the cold-water totals by -1. The algebraic sum of the totals for the warm-water and cold-water columns was then divided by the sum of the totals for warm, temperate, and cold forms, and the resulting ratio was taken as the mean for each sample. The means, obviously, varied between the limits of +1 and -1 and were used as numerical indicators of the temperature facies represented by the diatom flora as a whole in each sample. The probable error was computed by the method of least squares in order to give some idea of the reliance (from a purely statistical point of view) to be placed on each determination.

The results are given in table 13 and are shown graphically on plate 11.

The temperature facies indicated by the diatoms from different parts of the cores when plotted by the above method bear no apparent relation to those obtained by Bramlette and Bradley from the lithologic evidence and by Cushman from foraminiferal evidence. In the most extreme disagreement, sample L-20 in core 5, the diatoms show an abrupt change to relatively warm conditions during the middle of one of the glacial stages outlined by the above authors. W. H. Bradley⁶ has suggested that the temperature picture given by the diatoms may be correct but out of phase with the lithological and foraminiferal evidence on account of the much longer settling time of the diatoms. This appeared to be a promising lead, which was tested by sliding the chart for the lithologic and foraminiferal evidence (pl. 4, pt. 1) up and down over plate 11. It seems reasonable to believe that, if this hypothesis were correct, the difference in phase might be approximately the same for all the cores. When the diatom chart was superimposed upon the lithologic chart of Bramlette

TABLE 13.—*Distribution of the diatoms according to temperature facies*

	Sample No.	Weighted totals			Mean	Probable error
		Warm	Temperate	Cold		
Core 3-----	L-1	4	3	7	-0.21	±0.16
	L-2	23	11	26	-.05	±.08
	L-3	10	10	23	-.30	±.10
	L-4	31	23	38	-.08	±.05
	L-5	1	1	1	.00	-----
	L-6	10	5	13	-.11	±.12
	L-7	4	3	5	-.08	±.17
Core 4-----	L-8	1	1	1	.00	-----
	L-10	15	12	13	+.05	±.09
Core 5-----	L-16	1	3	4	-.37	±.24
	L-19	10	9	13	-.09	±.10
	L-20	8	3	3	+.36	±.19
	L-23	2	2	5	-.33	±.23
Core 6-----	L-30	21	8	21	.00	-----
	L-31	14	13	19	-.11	±.09
	L-32	12	11	13	-.03	±.09
	L-33	12	10	5	+.26	±.12
	L-35	0	1	1	Indet.	-----
	L-37	21	7	17	+.09	±.09
	L-39	0	1	0	Indet.	-----
Core 7-----	L-40	1	1	0	+.50	±.16
	L-44	1	3	3	-.29	±.22
	L-46	0	2	0	Indet.	-----
Core 9-----	L-49	4	3	4	.00	-----
	L-50	2	2	8	-.50	±.24
	L-51	18	16	15	+.06	±.08
	L-52	19	13	21	-.04	±.08
	L-53	1	1	3	-.40	±.34
	L-54	17	12	19	-.04	±.08
	L-55	10	4	5	+.26	±.16
	L-56	13	6	9	+.14	±.12
Core 10-----	L-58	3	2	1	+.33	±.27
	L-59	16	6	8	+.27	±.12
	L-60	5	4	3	+.17	±.17
	L-61	1	3	2	-.17	±.21
Core 12-----	L-62	8	3	4	+.27	±.17
	L-63	0	3	3	-.50	±.29
Core 13-----	L-65	28	16	5	+.47	±.11

and Bradley and displaced downward a distance equal to 46 centimeters of the core, a good agreement was obtained in cores 5 and 12, and a fair agreement in cores 6 and 9. The displacement is in the right direction, but the amount of the displacement necessary for a reasonably good agreement seems excessive. W. H. Bradley,⁷ in calculating probable rates of deposition for the sediments comprising the deep-sea cores, arrived at a figure of approximately 15,000 years per foot of sediment. The 46 centimeters difference in phase mentioned above would correspond to some 23,000 years as the difference in settling time between the coarse clastic material and the diatoms, which does not appear at all reasonable or probable.

Attempts to apply Stoke's law concerning the settling velocity of spherical particles in a viscous medium to the problem of determining the settling time of diatoms

⁶ Oral communication.

⁷ Oral communication.

in sea water were abandoned, owing to the difficulty in arriving at an adequate means of correcting for the deviation from a sphere in the shape of the diatoms and in arriving at an even reasonably accurate figure for their effective density. It appeared that a figure giving more nearly the correct order of magnitude would be obtained by extrapolating an experimentally determined rate of settling under known conditions.

Experiments on the settling time of some of the diatoms from the cores were, therefore, made in a short vertical column 10 centimeters high, and an average time of 60 minutes for the smaller forms (10μ to 20μ in diameter) was found to be necessary for settling in undisturbed distilled water at 20° C. The difference in density between sea water and distilled water was disregarded, but the relatively great increase in viscosity with reduced temperature was considered in the calculation. The figures obtained were 52 years for distilled water at 5° C. and 64 years for distilled water at 0° C. These figures appear to be very small, especially when compared with the former figure of 23,000 years, but they are at least reasonable, if several factors are taken into account whose magnitudes are difficult to estimate even approximately. The figures of 52 years for water at 5° C. and 64 years for water at 0° C., are probably of the right order of magnitude for the conditions stated but are only very roughly approximate at best. Furthermore, they are tremendous extrapolations from very meager data and even if correct would be so only for undisturbed distilled water. The conditions in a deep ocean basin, such as the North Atlantic, are so much more complex than the ideal conditions under which the calculations were made that the figures when applied to the ocean basin are no longer even of the right order of magnitude. Amid all these uncertainties, however, one thing is certain. The actual settling time for the diatoms found in the cores must have been much greater than the 64 years computed for the hypothetical conditions. A large part of this increase is due to the greater density and viscosity of sea water. The net effect of turbulence in the surficial waters on the settling time is probably zero because as many diatoms would be accelerated as retarded, but the slow upwelling of deeper waters might locally retard settling. A final broad approximation of several hundred years appears to be the order of magnitude of the settling time for the diatoms in the cores from the North Atlantic. This order of magnitude, although approaching the realm of pure speculation, appears at least qualitatively reasonable.

This figure is not sufficiently precise to offer a means of adjustment for the discrepancies between the temperature variations plotted on plate 11 and those of Bramlette and Bradley, but it does offer a means of investigation of some of the anomalies that have occurred in the data presented previously.

Even if the minimum figure of several hundred years for the settling time of diatoms in deep ocean basins is accepted, it is obvious that any interpretation of the ecologic factors involved in the composition of a diatom flora found at great depth is greatly complicated by other factors. The lack of light at great depths rules out the possibility of any diatoms living attached to the bottom. The turbulence of the upper waters and various ocean currents render it extremely improbable that any diatoms living in the surface waters will be eventually deposited on the sea floor directly beneath. It follows, then, that the path of a diatom from the surface to the bottom is never along a vertical line but always along an inclined one, the direction and degree of inclination of which may change many times before the final landing. The path is further complicated by the fact that diatoms are used as food by many marine animals, and the frustules may be transported unknown distances before being ejected and allowed to begin new paths toward the bottom. Furthermore, according to Bramlette and Bradley (pt. 1, Lithology and geologic interpretations), the alkalic volcanic glass shards have apparently been reworked from the tops of mounds and ridges on the sea floor and have been drifted about over large areas by bottom currents so that they are now distributed through a considerable thickness of sediment above the original ash layers. Any such bottom currents would of course also move diatoms about over the sea floor and tend further to augment the randomness of their ultimate distribution in the sediments. All these variable factors affect the final resting place, but, unfortunately, few can be evaluated even to the order of magnitude.

Thus the discrepancy between the present-day surface diatom flora in the North Atlantic and that found in the cores is not surprising and needs no further comment.

The large percentage of warm-water species in the cores is not surprising as more than sufficient time was available for their transportation from warm habitats. Some of the diatoms necessarily started for the bottom many hundreds or possibly thousands of miles from their final resting place. Even if no other agency influenced its course, a diatom might travel many miles before it got out of the zone of influence of the Gulf Stream alone.

The fact that, even by displacing vertically the plotted temperature deviations indicated by the diatoms (pl. 11) from those obtained by other means, only partial agreement was obtained is not anomalous when the slow settling rate is considered. Although the settling rate for diatoms in still water might be nearly the same in different parts of the ocean of equal depth, it is highly improbable that the various complicating factors operated to produce the same net effect on the settling rates for the diatoms in all of the cores, or even for all the samples in any one core. For example, in

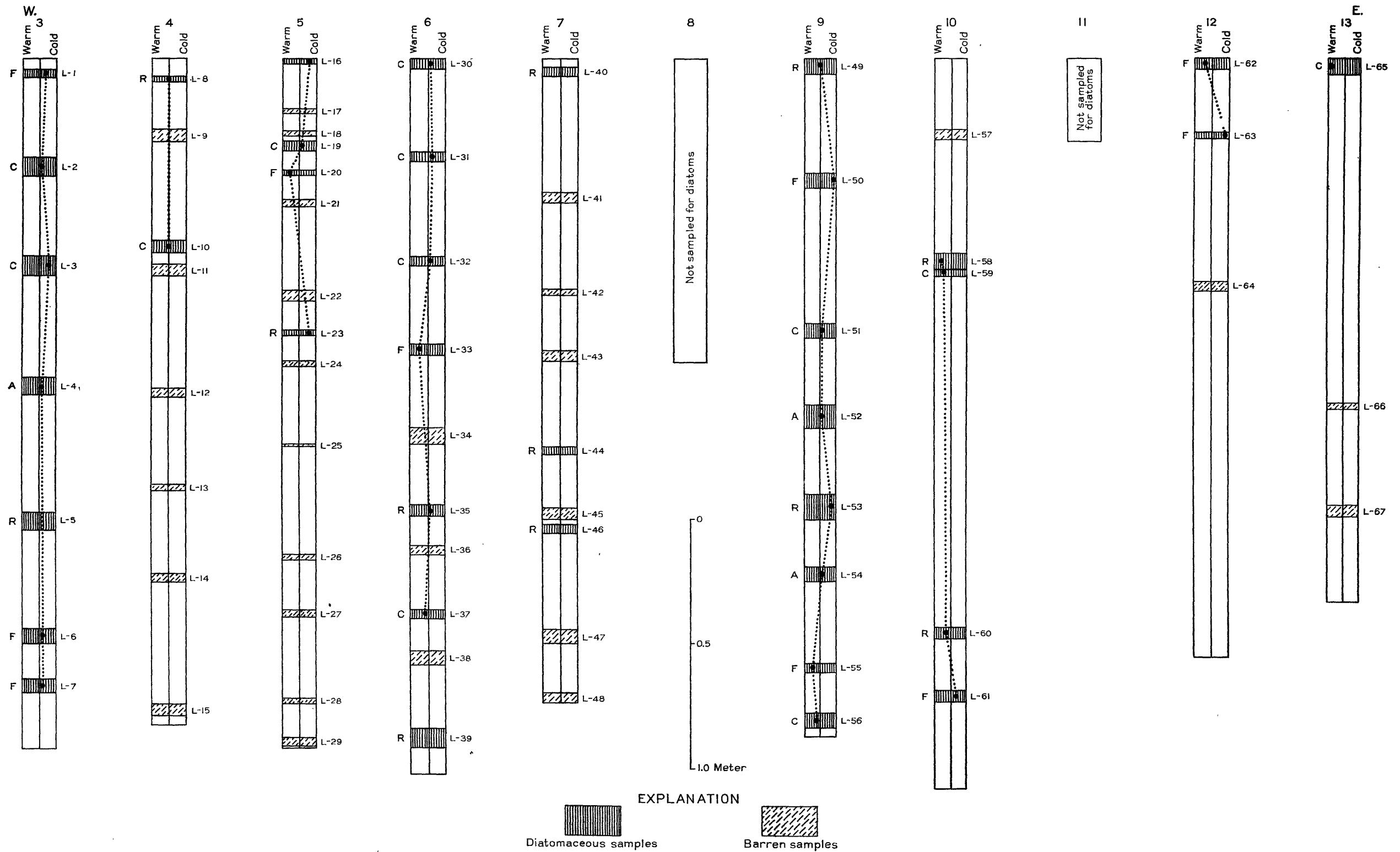


CHART SHOWING DISTRIBUTION AND TEMPERATURE SIGNIFICANCE OF THE DIATOMS IN THE CORES.

Each core is represented by a column whose length is indicated by the meter scale below column 8. The samples are indicated by patterned rectangles. At the right of each rectangle is the sample number, and at the left is a letter indicating the relative abundance of the diatoms: R, rare; F, frequent; C, common; and A, abundant. The mean temperature facies indicated by the diatom flora of each sample is indicated by the position of a dot within the sample rectangle. The distance of the dot from the center line of the column is a measure of the warmth or coldness of the diatom environment indicated by the assemblage of diatoms in the sample. As a visual aid, these dots in the rectangles are connected by dotted lines.

core 8, taken at the top of the mid-Atlantic ridge, the absence of diatoms as well as other fine constituents has been explained by Bramlette and Bradley as due to the winnowing out of the fine material from the top of the ridge during deposition by a bottom current apparently flowing eastward. This idea is strengthened by the unusually high percentage of fine material and diatoms found in core 9, taken at the eastern base of the ridge.

The maximum settling time for the diatoms is probably of the order of magnitude of several hundred years, based on the extrapolation of the laboratory experiments. This is so different from the very large figure of 23,000 years obtained by vertical shifting of the plotted temperature deviations (pl. 11) that the larger figure appears to have little significance. If this is so, the partial agreement in temperature variation between the diatom data on the one hand and the foraminiferal and lithologic data on the other may be entirely fortuitous. This possibility is strengthened by the fact that the agreement was not uniform for all the cores. Dr. Roger Revelle, of the Scripps Institution of Oceanography, has suggested⁸ that the partial agreement between the two lines of evidence may not be fortuitous but may be due to changes in ocean currents caused by the advance and recession of the ice during glacial and interglacial epochs. At present (see fig. 22) the warm Gulf Stream swings in a general northeasterly direction along the line of the cores, particularly in the region from the mid-Atlantic ridge eastward. It seems highly probable that during the maximum southerly advance of the drift ice in a glacial epoch the Gulf Stream would be deflected southward. Presumably the cold Labrador Current would be weaker during a glacial epoch than during an interglacial one. Thus, although the Gulf Stream bringing the tropical forms northward would actually be deflected somewhat to the south, nevertheless the slackening of the Labrador Current might result in the deposition of a higher percentage of warm-water diatoms along the line of the cores in a glacial epoch than in an interglacial epoch. Furthermore, owing to probable lobelike extensions on the southern limit of the glacial ice in the North Atlantic, the difference in phase between diatoms and Foraminifera might be quite different in the different cores.

This idea is included here as a frank speculation, as it cannot be proved with the available data. The results of subsequent comparisons of temperature facies based on diatom and foraminiferal data may corroborate this speculation and form one method of approaching the almost untouched field of paleo-oceanography.

The most definite generalization that has come out of my study of the cores from the North Atlantic is that much more caution is needed in making geologic or ecologic interpretations of diatom floras from very deep ocean basins than from shallow basins where the chances

are much greater that the organism will be deposited in nearly the identical geographic location as the one in which it lived.

SYSTEMATIC DESCRIPTIONS

The classification of diatoms has occupied the attention and exercised the imagination of many students of these organisms during more than a hundred years, and has been based primarily, by different authors, upon the mode of living, the nature and distribution of the endochrome, the presence or absence of a raphe, the external shape of the valves, the type of symmetry developed by the markings on valves, and upon various combinations of the above.

From the point of view of the paleontologist, any system of classification that depends, even in part, upon the soft (and hence usually unfossilized) parts is not satisfactory. Although relatively few of the students of diatoms have been geologists or paleontologists, nevertheless a great many workers have studied fossil diatoms in the eternal search for new and interesting species. As a result, only the classifications based on the shape, structure, and markings of the "indestructible" siliceous shell have survived.

During the last 30 or 40 years the excellent classification proposed by Schütt in Engler and Prantl's *Natürliche Pflanzenfamilien*, which was published in 1896, has been almost universally followed. In Schütt's scheme the diatoms were divided into two suborders, the Centricae, in which the structure and markings were related to a central point, and the Pennatae, in which the structure and markings were related to a longitudinal line. Aside from minor changes in the naming of the suborders and slight rearrangement of families, little real change and almost no improvement have been introduced during the 40 years following the first appearance of Schütt's classification. In 1937 Hendey⁹ proposed a new classification based in part on Schütt's earlier one but eliminating the twofold separation into centric and pennate forms. As Hendey points out, such genera as *Biddulphia*, *Chaetoceros*, *Rhizosolenia*, *Anaulus*, and *Triceratium* do not fall into either of Schütt's major divisions. For convenience Schütt and all who have followed him have included the above genera, as well as others equally unfit, in the Centricae. Hendey considers the diatoms as a class of Algae, Bacillariophyceae, comprising 1 order, Bacillariales, which is divided into 10 suborders. The 10 suborders are again divided into families and subfamilies in the customary manner. The scheme is simple and workable and removes many of the anomalies and ambiguities inherent in the older system. It is unfortunate that Hendey included in his classification only a few genera outside of those he encountered in the material from the southern seas. Although it is

⁸ Personal communication.

⁹ Hendey, N. I., The plankton diatoms of the southern seas: *Discovery Repts.*, vol. 16, p. 199, 1937.

true that other authors will undoubtedly add genera with which they happen to be working, it would seem better if the one who proposed a new classification would make it as complete as possible. In spite of this lack it is a most valuable contribution and is the system followed in this report.

A synonymy is given for each species, arranged according to standard practice in the Geological Survey. The description by the founder of the species is cited first; next, references to the species and genus as at present accepted, in chronologic order; and last, synonyms and misidentifications, also in chronologic order. Complete synonymies have not been attempted, as to do so would have lengthened the report out of all proportion. For the same reason, descriptions have been given only for species that were considered to be new or inadequately described elsewhere. All species are illustrated, however, and references are given either to adequate descriptions or illustrations, or both.

ALGAE

Class **BACILLARIOPHYCEAE**

Order **BACILLARIALES**

Suborder **DISCINEAE**

Family **COSCINODISCACEAE**

Subfamily **MELOSIROIDEAE**

Genus **MELOSIRA** Agardh, 1824

Melosira granulata (Ehrenberg) Ralfs

Plate 12, figure 9

Gaillonella granulata Ehrenberg, K. Akad. Wiss. Berlin Abh., 1841, p. 127, many figures, 1843.

Ehrenberg, Mikrogeologie, pl. 33, group 2, fig. 15, 1854.

Melosira granulata (Ehrenberg) Ralfs, in Pritchard, A., History of the Infusoria, 4th ed., p. 820, 1861.

Van Heurck, Synopsis diatomées Belgique, pl. 87, figs. 10-12, 1882.

Schmidt, Atlas der Diatomaceenkunde, pl. 181, figs. 57, 58, 1893.

Boyer, Acad. Nat. Sci. Philadelphia Proc., vol. 78, supplement, p. 30, 1926.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 248, fig. 104, 1927.

Hustedt, in Pascher, Die Süßwasser-Flora Mitteleuropas, Heft. 10, 2d ed., p. 87, fig. 44, 1930.

This fresh-water diatom was found rarely in sample L-16 from the top of core 5 and in samples L-46 from core 7. It may have been deposited from a melting iceberg or may have been carried out to sea from the mouth of some river. Its presence in the cores indicates the extent of the migration of diatom tests in the open sea. The nearest land is the Azores, some 600 to 700 miles distant.

The spelling of *Gaillonella* is variable, *Gallionella*, *Gaillionella*, and *Gaillonella* often occurring in different parts of the same paper. Hustedt,¹⁰ noting that the word is taken from Gaillon, prefers the form here

¹⁰ Hustedt, Friedrich, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 226, 1930.

given, although in the same work he also used *Gaillionella*.

Dimensions of figured specimen (U. S. G. S. diatom catalog no. 1928-1): Length, 20 μ ; diameter, 7 μ . From sample L-16 (U. S. G. S. diatom locality 2817), 0-2 cm. below the top of core 5.

Found rarely in samples L-16, L-40, and L-46.

Melosira sulcata (Ehrenberg) Kützing

Plate 12, figure 1

Gaillonella sulcata Ehrenberg, Die Infusionsthierchen als vollkommene Organismen, p. 170, pl. 21, fig. 5, 1838.

Melosira sulcata (Ehrenberg) Kützing, Die Kieselalgen Bacillarien oder Diatomeen, p. 55, pl. 2, fig. 7, 1844.

Van Heurck, Synopsis diatomées Belgique, pl. 91, figs. 15, 16, 1882.

Schmidt, Atlas der Diatomaceenkunde, pl. 178, figs. 1-5, 7-19, 22-24, 1893.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 276, figs. 118, 119, 1928.

Hendey, Discovery Reports, vol. 16, p. 235, 1937.

Orthosira marina W. Smith, Synopsis of the British Diatomaceae, vol. 2, p. 59, pl. 53, fig. 338, 1856.

Paralia sulcata Cleve, K. Svenska Akad. Handl., Bihang, Band 1, no. 13, p. 7, 1873.

Schmidt, Atlas der Diatomaceenkunde, pl. 176, figs. 28, 32-39, 42-44, 46, 1893.

Orthosira sulcata O'Meara, Royal Irish Acad. Sci. Proc., vol. 2, ser. 2, p. 252, 1876.

This cosmopolitan species was found in nearly every sample examined, ranging in abundance from rare to frequent. It is fundamentally a littoral form, although sporadically found in plankton. It is fairly uniformly distributed throughout most of the cores. *Melosira sulcata* has a long geologic history. It is known from the Eocene to the Recent, and Schulz¹¹ has recently reported a variety, *siberica* Grunow, from a Cretaceous coral rock in Danzig Bay. In littoral deposits of various ages it is usually common to abundant. Hendey¹² has commented on its rarity in the Antarctic Ocean.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1983-1), 32 μ . From sample L-63 (U. S. G. S. diatom locality 2876), 30.5-33 cm. below the top of core 12.

Found rarely in samples L-1, L-2, L-3, L-4, L-5, L-16, L-19, L-23, L-30, L-31, L-33, L-35, L-49, L-50, L-51, L-53, L-55, L-56, and L-61 and frequently in samples L-6, L-32, L-44, L-60, L-62, L-63, and L-65.

Genus **PODOSIRA** Ehrenberg, 1840

Podosira stelliger (Bailey) Mann

Plate 12, figures 5, 6

Hyalodiscus stelliger Bailey, Smithsonian Contr. Knowledge, vol. 7, p. 10, 1854.

¹¹ Schulz, Paul, Diatomeen aus senonen Schwammgesteinen der Danziger Bucht: Bot. Archiv. Band 37, p. 393, fig. 3, 1935.

¹² Hendey, N. I., The plankton diatoms of the southern seas: Discovery Repts., vol. 16, p. 235, 1937.

Podosira stelliger (Bailey) Mann, Contr. U. S. Nat. Herbarium, vol. 10, part 5, p. 242, 1907.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 286, fig. 128, 1928.

Hyalodiscus stelliger Bailey. Van Heurck, Synopsis diatomées Belgique, p. 213, pl. 84, fig. 1, 2, 1882.

Van Heurck, Treatise on the Diatomaceae, p. 448, fig. 173; pl. 22, fig. 650, 1896.

Wolle, Diatomaceae of North America, pl. 69, figs. 4-5, 1894.

Boyer, Acad. Nat. Sci. Philadelphia Proc., vol. 78, Supplement, p. 34, 1926.

Hendey, Discovery Repts., vol. 16, p. 236, 1937.

Podosira polita Hanna and Grant, California Acad. Sci. Proc., 4th Ser., vol. 15, p. 164, pl. 20, fig. 5, 1926.

The synonymy of this interesting diatom could be continued for some length, but enough is given above for the present purpose. Bailey's original description (first citation above) follows: "Discoid, bases with a broad margin, covered with distinct rectilinear rows of dots, arranged in sectoral groups, so as to produce a stellate appearance." The economy of words and ideas in this description and the absence of a figure may explain some of the misunderstandings that have arisen in regard to it. But the difficulties connected with the species pale into insignificance when compared with the much greater ambiguities surrounding the two genera into which it has been placed by different authors. An excellent review of these difficulties up to 1907 is given by Mann,¹³ who proposed that *Podosira* and *Hyalodiscus* be combined under the older name, *Podosira*. He gave a detailed description of the combined genus, retaining what he considered to be the most important and diagnostic characteristics of each of the former genera. Mann, as well as many of his predecessors, was so obsessed by the fact that both genera possessed an umbilicus that he came to look on this as the most important characteristic of both genera, and hence consistent differences between the two were overlooked. Since individuals belonging to both genera grow singly or in groups of several frustules attached to each other by means of short gelatinous stipes, the relative size and presence or absence of an umbilicus (caused by this method of growth) is of little significance as a specific, and even less as a generic character.

Hustedt¹⁴ has recently separated Mann's *Podosira* back into *Podosira* and *Hyalodiscus*, disregarding the variable and uncertain umbilicus as a generic characteristic. He included in *Podosira* all species in which the markings outside the umbilicus (when present) are arranged in definite radial sectors, and in *Hyalodiscus* those in which the outer markings exhibit no sectorial arrangement. Other minor generic characters separate the two, but the presence or absence of a sectorial arrangement is the most significant. This appears to be

the best solution of the difficulty. Although the number of sectors is variable in *Podosira* and is of little or no value as a characteristic, the presence or absence of sectors appears to be significant and provides a definite ground for separation.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1984-2), 56 μ . From sample L-65 (U. S. G. S. diatom locality 2878), 0-7 cm. below the top of core 13. Two views are given, as it is impossible to obtain sufficient magnification and resolution to show the finer markings and sufficient depth of focus to show the entire diatom sharp at the same time.

Found rarely in samples L-3 and L-46 and frequently in sample L-65.

Subfamily SKELETONEMOIDEAE

Genus ENDICTYA Ehrenberg, 1845

Endictya Ehrenberg, K. Akad. Wiss. Berlin, Ber., p. 76, 1845.

Dictyopyxis Ehrenberg, in part.

Melosira Agardh, in part.

Orthosira Thwaites, in part.

Coscinodiscus Ehrenberg, in part.

The genus *Endictya* Ehrenberg has been in a nomenclatorial tangle for many years. Rattray¹⁵ included *Endictya* in the already large and unwieldy genus *Coscinodiscus* without observing the true nature of the differences between the two. He says, when discussing *Coscinodiscus concavus* (Ehrenberg) Gregory, "Specimens sometimes named *Endictya oceanica* differ from *C. concavus* only in showing the markings somewhat more irregular."¹⁶ Mann¹⁷ doubtfully followed Rattray after clearly stating the differences between the two genera. His remarks are worth repeating here:

The most unsatisfactory member of the above combination to me is *Endictya* Ehrenb. The close resemblance of its members to the evident *Coscinodiscus* forms *C. robustus* Grev. and *C. marginatus* Ehrenb. is responsible for this union. But they are also close to some specimens of *Stephanopyxis* and besides have certain peculiarities found in no other *Coscinodiscus*. The valves are not flat or convex disks, but cups; not bounded by a ring-like margin, but when viewed from the valval side, encircled by a somewhat raised and pointed edge from which the valves turn vertically downward to form a band, ornamented like the face of the valve with a rugged network; so that the two valves if placed together form, without the connecting girdle, a cylindrical pill box.

By 1925 Mann¹⁸ formally accepted Ehrenberg's *Endictya*. Hustedt¹⁹ has also recognized the distinctness of *Endictya* and has published the best description to date.

¹⁵ Rattray, John, A revision of the genus *Coscinodiscus* and some allied genera: Royal Soc. Edinburgh Proc., vol. 16, p. 450, 1889.

¹⁶ Idem, p. 470.

¹⁷ Mann, Albert, Diatoms of the *Albatross* voyages: Contr. U. S. Nat. Herbarium, vol. 10, part 5, p. 246, 1907.

¹⁸ Mann, Albert, Marine diatoms of the Philippine Islands: U. S. Nat. Mus. Bull. 100, vol. 6, part 1, p. 75, 1925.

¹⁹ Hustedt, Friedrich, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 296, 1928.

¹³ Mann, Albert, Diatoms of the *Albatross* voyages: U. S. Nat. Herbarium, vol. 10, part 5, p. 240, 1907.

¹⁴ Hustedt, Friedrich, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 279 (*Podosira*), and p. 290 (*Hyalodiscus*), 1928.

Endictya oceanica Ehrenberg

Plate 12, figure 3

Endictya oceanica Ehrenberg, K. Akad. Wiss. Berlin Ber., p. 76, 1845.

Ehrenberg, Mikrogeologie, pl. 35A, group 18, figs. 6, 7, 1854.
Schmidt, Atlas der Diatomaceenkunde, pl. 65, figs. 10, 12, 13, 1881.

Van Heurck, Treatise on the Diatomaceae, p. 445, fig. 169, 1896.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 297, fig. 136, 1928.

Endictya cribrosa Brébisson, Annals and Mag. Nat. History, ser. 2, vol. 19, p. 11, pl. 2, fig. 15, 1857.

Orthosira oceanica Brightwell, Quart. Jour. Micr. Sci., vol. 8, p. 96, pl. 6, fig. 14, 1860.

Coscinodiscus concavus Gregory, in part.

Individuals from the Atlantic cores assigned to this species have a very narrow mantle, usually about 7μ wide, and do not exhibit the secondary structure shown by Hustedt (fig. 136c, 5th citation above). Only one valve was found that could be photographed, and it is not very good. Some of the areolae in the central part of the valve have air bubbles entrapped, which makes them appear darker than the rest. Parts of the valve show evidences of corrosion, probably of a chemical rather than a mechanical origin. None of the other species present in the sample from which this came (L-52, core 9) showed evidence of chemical corrosion, and this, taken together with the fact that the species was present in no other core, suggests transportation for some considerable distance by ocean currents before deposition. It is found commonly along the coast of southern Europe, in the Black Sea, near the Philippine Islands, and generally in warmer waters than occur in the North Atlantic.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1970-16), 84μ . From sample L-52 (U. S. G. S. diatom locality 2858), 142-151 cm. below the top of core 9.

Found rarely in sample L-52.

Endictya robusta (Greville) Hanna and Grant

Plate 12, figure 4

Coscinodiscus robustus Greville, London Micr. Soc. Trans., new ser., vol. 14, p. 3, pl. 1, fig. 8, 1866.

Endictya robustus (Greville) Hanna and Grant, California Acad. Sci. Proc., 4th ser., vol. 15, no. 2, p. 144, pl. 16, figs. 2, 3, 1926.

Coscinodiscus robustus Greville, Schmidt, Atlas der Diatomaceenkunde, pl. 62, figs. 16, 17, 1878.

Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 511, 1889.
Mann, Contr. U. S. Nat. Herbarium, vol. 10, pt. 5, p. 258, pl. 48, fig. 4, 1907.

Boyer, Synopsis of North American Diatomaceae, p. 54, 1926.

Coscinodiscus subvelatus Grunow, Schmidt, Atlas der Diatomaceenkunde, pl. 65, fig. 9, 1881.

Coscinodiscus kinkarianus Truan and Witt, Die Diatomaceen der Polycystinenkreide von Jérémie in Hayti, p. 13, pl. 3, fig. 1, 1888.

This species is frequently confused with *Coscinodiscus marginatus* Ehrenberg, as both are without central space or rosette and have similar markings. The principal difference between the two is the generic characteristic that defines *Endictya*, namely, that in *Endictya* the areolae do not terminate at the margin as in *Coscinodiscus* but turn abruptly and form the mantle. In valve view, the areolae forming the mantle in *Endictya robusta* have much the same appearance as the marginal striae in *C. marginatus*. In *Endictya* it is possible to focus vertically through several rows of areolae in the mantle (when seen in valve view), whereas in *Coscinodiscus* the limit is the depth of the margin. The remarkable connecting zone or girdle of *E. robusta* is a feature which immediately distinguishes it when present. Rattray's brief description²⁰ of this girdle is worth repeating here:

In a Santa Monica form 0.13 mm. in diameter, discovered by Dr. Rae, the usual striated border was surrounded by a second more sharply defined but narrower band, with a slightly convex surface, and bearing delicate striae, 8 to 10 in 0.01 mm.; at one place this band is interrupted and somewhat more convex on the two sides of the break. This gives it the appearance of an elastic spring enveloping the valve.

Brun²¹ has also found a specimen of *Coscinodiscus crassus* Bailey with a similar girdle, but there is no possibility of confusing *Endictya robusta* with *C. crassus* as they are different in many respects.

This cosmopolitan species was found in many samples from six of the cores and usually occurred most frequently in the upper part of each core. It is a cool-water diatom most abundant today in the northern hemisphere and has had a wide distribution since the middle Tertiary, reaching its heyday in upper Miocene time.

Diameter of figured specimen (U. S. G. S. diatom catalog, no. 1958-2), 108μ . From sample L-52 (U. S. G. S. diatom locality 2858), 142-151 cm. below the top of core 9.

Found rarely in samples L-6, L-10, L-16, L-23, L-32, L-49, L-53, and L-56, and frequently in samples L-2, L-3, L-4, L-19, L-30, L-31, L-50, L-51, and L-59.

Subfamily THALASSIOSIROIDEAE**Genus THALASSIOSIRA Cleve, 1873****Thalassiosira baltica (Grunow) Ostenfeld**

Plate 12, figure 11

Coscinodiscus polyacanthus var. *baltica* Grunow, K. svenska vetensk. akad. Handl., Band 17, No. 2, p. 112, 1880.

Coscinodiscus balticus Cleve, Soc. Fauna Flora Fenn. Acta, Band 8, No. 2, p. 68, 1891.

Thalassiosira baltica (Grunow) Ostenfeld, Nyt mag. naturvidensk., Band 39, Heft. 4, p. 290, 1901.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 328, fig. 164, 1928.

²⁰ Rattray John, A revision of the genus *Coscinodiscus* and some allied genera: Royal Soc. Edinburgh Proc., vol. 16, p. 512, 1889.

²¹ Brun, Jacques, Diatomées marines fossiles ou pelagiques: Genève Soc. Physique Histoire Nat. Mém., Tome 31, pt. 2, no. 1, p. 21, pl. 20, fig. 3, 1891.

The prominent marginal apiculi, which are characteristic of this species, are well exhibited on the specimens from the cores but, unfortunately, are extremely difficult to show in a photomicrograph. The high magnification required to reproduce this tiny specimen on an adequate scale is incompatible with the depth of focus needed to show both apiculi and areolae in focus simultaneously. In the present instance this difficulty was augmented by the fact that the most nearly whole specimen found was slightly tilted in mounting.

Lebour²² gives the following distribution for this brackish-water neritic diatom: "Southern part of North Sea, Danish seas, Cattegat, Great and Little Belts, Gulf of Finland, Gulf of Bothnia, common in the Baltic. Also recorded from Gulf of Maine and California."

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1965-4), 27 μ . From sample L-3 (U. S. G. S. diatom locality 2865), 81-89 cm. below the top of core 3.

Found rarely in samples L-3 and L-4.

Thalassiosira decipiens (Grunow) Joergensen

Plate 12, figure 8

Coscinodiscus decipiens Grunow, in Van Heurck, Synopsis des diatomées Belgique, pl. 91, fig. 10, 1882.

Thalassiosira decipiens (Grunow) Joergensen, Hydrogr. biol. inv. Norwegian fjords, p. 96, pl. 6, fig. 3, 1905.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 322, fig. 158, 1928.

Hendey, Discovery Repts., vol. 16, p. 238, pl. 11, fig. 9, 1937.

Thalassiosira gelatinosa Henson, Komm. Wiss. untersuchung deutschen Meere in Kiel Ber., p. 87, 1887.

This species usually has very prominent marginal apiculi, but many specimens found in the cores have very faint ones. In the specimen photographed, the apiculi are present, but in order to show them it would have been necessary to focus so far down as to obscure the markings over two-thirds of the valve. The small excentric nodule that indicates the point of attachment of the gelatinous stipe that connects the frustules together to form a chain is well shown.

This species is neritic along the coast of Europe and is occasionally found in oceanic waters. It is fairly common in temperate waters in the Northern Hemisphere.

Reinhold²³ has recorded the earliest known geologic occurrence of this species from rocks doubtfully assigned to the lower Eocene near Maastricht, Netherlands.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1970-4), 30 μ . From sample L-52 (U. S. G. S. diatom locality 2858), 142-151 cm. below and top of core 9.

Found rarely in samples L-1, L-2, and L-19 and frequently in samples L-31 and L-52.

Subfamily COSCINODISCOIDEAE

Genus STEPHANODISCUS Ehrenberg, 1845

Stephanodiscus astraea (Ehrenberg) Grunow

Plate 12, figure 2

Discoplea astraea Ehrenberg, Berlin Akad. Wiss. Ber., 1844, p. 267, 1844.

Stephanodiscus astraea (Ehrenberg) Grunow, K. Svenska vetensk. akad. Handl., Band 17, no. 2, p. 114, 1880.

Schmidt, Atlas der Diatomaceenkunde, pl. 226, figs. 1-5, 1901.

Boyer Acad. Nat. Sci. Philadelphia Proc., vol. 78, Supplement, p. 61, 1927.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 368, fig. 193, 1928.

The wide distribution of this fresh-water and brackish-water species and its rare occurrence in a marine environment suggest that its occurrence in only one sample (L-56), near the bottom of core 9, is the result of transportation from shore. Fricke²⁴ has reported it from Flensburg as Recent marine, but it appears possible that his specimen was also introduced into the sea from some stream. It has not been observed actually living in a marine environment. Only one specimen was found in the core and it was badly worn.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1962-1), 38 μ . From sample L-56 (U. S. G. S. diatom locality 2862), 267-272 cm. below the top of core 9.

Found rarely in sample L-56.

Genus COSCINODISCUS Ehrenberg, 1838

Section EXCENTRICAE Rattray

Coscinodiscus excentricus Ehrenberg

Plate 12, figure 7; plate 13, figure 8

Coscinodiscus excentricus Ehrenberg, Berlin K. Akad. Wiss., Physical Abh., 1839, p. 146, 1841.

Smith, Synopsis of the British Diatomaceae, vol. 1, p. 23, pl. 3, fig. 38, 1853.

Ehrenberg, Mikrogeologie, pl. 18, fig. 32; pl. 21, fig. 6, 1854.

Schmidt, Atlas der Diatomaceenkunde, pl. 58, figs. 46-49, 1878.

Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 461, 1889.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 388, fig. 201, 1928.

Hendey, Discovery Repts., vol. 16, p. 242, 1937.

Coscinodiscus minor Schmidt, Atlas der Diatomaceenkunde, pl. 113, fig. 9, 1888.

Coscinodiscus labyrinthus Roper, Quart. Jour. Micr. Sci., vol. 6, p. 21, pl. 3, fig. 2a-b, 1858.

It is frequently difficult to separate this species from *Planktoniella sol* (Wallich) Schütt,²⁵ particularly when individuals like that shown on plate 13, figure 8 are found. This particular individual (U. S. G. S. diatom

²² Lebour, M. V., The planktonic diatoms of northern seas, p. 61, 1930.

²³ Reinhold, Th., Diatoms from rocks, possibly belonging to the Danian (or Lower Eocene), near Maastricht, The Netherlands: Nederland Jaarv. geologisch Bureau Jaarv., 1930, p. 17, pl. 1, fig. 12, 1931.

²⁴ Fricke, Friedrich, in Schmidt, Atlas der Diatomaceenkunde, pl. 226, fig. 5, 1901.

²⁵ Hustedt, Friedrich, Die Kieselalgen Deutschlands, Österreichs und der Schweiz, Teil 1, p. 465, fig. 259, 1929.

catalog no. 2000-3) has very faint apiculi, which do not show in the photograph and might easily be taken for the center of *Planktoniella sol*, the slightly silicified outer portion of which is rarely found preserved in fossils. The normal form with prominent apiculi is shown on plate 12, figure 7.

Coscinodiscus excentricus ranges all through the Tertiary, and Schultz²⁶ has recently reported it from a coral rock of probable Cretaceous age in Danzig Bay.

Diameter of figured specimens: U. S. G. S. diatom catalog no. 1968-8, from sample L-51 (U. S. G. S. diatom locality 2857), core 9, 108-114 cm. below top, 45 μ ; U. S. G. S. diatom catalog no. 2000-3, from sample L-52 (U. S. G. S. diatom locality 2858), core 9, 142-151 cm. below top, 39 μ .

Found rarely in samples L-1, L-2, L-3, L-4, L-6, L-31, L-32, L-40, L-49, L-50, L-53, L-58, L-60, and L-61, frequently in L-10, L-20, L-33, L-51, L-52, L-54, L-56, and L-65, and commonly in L-37.

Coscinodiscus circumdatus Schmidt

Plate 12, figure 12

Coscinodiscus circumdatus Schmidt, Atlas der Diatomaceenkunde, pl. 59, fig. 3, 1878.

Van Heurck, Synopsis diatomées Belgique, pl. 131, fig. 4, 1883.

Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 466, 1889.

Valve usually flat but occasionally slightly domed; without rosette or central space; diameter, 60-70 μ ; covered with polygonal areolae, 7 to 8 in 10 μ over center three-fourths of valve, 10 to 11 in 10 μ near margin; arranged in nearly straight to slightly sigmoid decussating rows. Border complex, consisting of narrow zone, 2 μ wide, filled with fine decussate markings, 14-16 in 10 μ and crossed by very narrow radial apiculi having a length equal to the width of the marginal zone and an average spacing of 3 μ and with a very narrow margin having short radial striae, 11 to 13 in 10 μ .

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1941-2), 62 μ . From sample L-30 (U. S. G. S. diatom locality 2838), 0-4.5 cm. below top of core 6.

Rattray's description (last citation above) of this diatom was apparently written from Schmidt's figure (first citation above) and not from an actual specimen and as a result is very misleading. The border appears hyaline under a dry objective but clearly shows the decussate markings when viewed under an oil immersion objective. The valve might be mistaken for *C. excentricus* Ehrenberg, as the markings on *C. circumdatus* are frequently (but not always) arranged so as to resemble *C. excentricus*. The distinctive border at once sets this species apart. A sort of pseudo rosette occurs frequently, consisting of a somewhat indefinite circlet of areolae surrounding a central one, all of which are the same size.

Although this species has been known for 50 years, it has been reported previously only from the original occurrence at Yokohama. No information is available as to the source of Schmidt's original specimen, which was collected by Gründler. Its second occurrence in the North Atlantic core is very interesting, particularly so in view of the fact that it was found frequently in one sample (L-30) from the top of core 6, and not even a recognizable fragment was found in any other sample studied.

Section LINEATAE Rattray

Coscinodiscus lineatus Ehrenberg

Plate 12, figure 10

Coscinodiscus lineatus Ehrenberg, Berlin K. Akad. Wiss., Physikal. Abh., 1838, p. 129, 1839.

Ehrenberg, Mikrogeologie, pl. 18, fig. 33; pl. 22, fig. 6; pl. 35A, group 16, fig. 3; group 17, fig. 7, 1856.

Schmidt, Atlas der Diatomaceenkunde, pl. 59, figs. 26-32, 1878; pl. 114, fig. 13, 1888.

Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 472, 1889.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 392, fig. 204, 1928.

Hendey, Discovery Repts., vol. 16, p. 242, 1937.

Coscinodiscus ehrenbergii O'Meara, Royal Irish Acad. Proc., 2d ser., vol. 2, p. 264, pl. 26, fig. 24, 1875.

This cosmopolitan species has a world-wide distribution in the oceanic and neritic plankton of temperate and subtropical seas. Its known geological range is from Cretaceous²⁷ to Recent.

Most of the cores contained this diatom at various depths and in amounts ranging from rare to common.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1967-5), 89 μ . From sample L-51 (U. S. G. S. diatom locality 2857), core 9, 108-114 cm. below top.

Found rarely in samples L-1, L-2, L-19, L-32, L-49, L-50, L-54, and L-60, frequently in L-4, L-10, L-20, L-31, L-33, L-51, L-52, L-55, L-56, L-59, and L-62, and commonly in L-30, L-37, and L-65.

Section STELLATAE Rattray

Coscinodiscus stellaris Roper

Plate 13, figure 2

Coscinodiscus stellaris Roper, Quart. Jour. Micr. Sci., vol. 6, p. 21, pl. 3, fig. 3, 1858.

Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 493, 1889.

Schmidt, Atlas der Diatomaceenkunde, pl. 164, fig. 4, 1891.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 396, fig. 207, 1928.

Lebour, Planktonic diatoms of northern seas, p. 49, pl. 1, fig. 4, 1930.

Grunow's *Coscinodiscus symbolophorus*²⁸ differs from *C. stellaris* in having much coarser structure. I agree with the following statement by Mann:²⁹

²⁷ Schulz, Paul, Diatomeen aus senonen Schwammgesteinen der Danziger Bucht: Bot. Archiv, Band 37, p. 390, 1935.

²⁸ Grunow, Albert, Die Diatomeen von Franz Josefs-Land: Akad. Wiss. Wien, Math.-naturwiss. Kl., Denkschr., Band 48, p. 82, pl. D, figs. 3-6, 1884.

²⁹ Mann, Albert, Diatoms of the *Albatross* voyages: Contr. U. S. Nat. Herbarium, vol. 10, part 5, p. 257, 1907.

²⁶ Schulz, Paul, Diatomeen aus senonen Schwammgesteinen der Danziger Bucht: Bot. Archiv., Band 37, p. 387, 1935.

I am convinced that there is no reasonable ground for Grunow's *C. symbolophorus* as distinguished from Roper's older name *C. stellaris*. Grunow admits that the difference is one of relative fineness of marking—too slight a character for creating a new species, especially when this difference is by no means striking and many intermediate forms are obtainable.

Mann, however, in his early zeal for strict priority, tried to throw the two well-known species, *C. stellaris* and *C. symbolophorus*, into obscurity by reviving Ehrenberg's old name *pentas*. Apparently his reasoning was as follows: Starting with the defensible contention that there was less than specific difference between *C. stellaris* and *C. symbolophorus*, he lumped both into Grunow's species *symbolophorus*. Grunow, however, had taken his specific name from Ehrenberg's old genus *Symbolophora*, which had as its principal differentiating characteristic the central stellate cluster of irregular markings. Grunow was in considerable doubt as to the validity of his species, for he said, "Diese Art ist so nahe mit *C. subtilis* verwandt, dass es vielleicht besser wäre, sie als Varietät derselben zu betrachten."

Mann then selected Ehrenberg's specific name *pentas* (from *Symbolophora pentas*) and combined both *C. stellaris* and *C. symbolophorus* into *Coscinodiscus pentas* (Ehrenberg) Mann. Although it might be possible to justify this obscuring of two well-known names on the ground of strict priority, common sense dictates otherwise. He completely ignored Jörgensen's very satisfactory disposition of Grunow's doubtful species, which appeared in 1905, 2 years before Mann's paper was published. Jörgensen³⁰ made *C. symbolophorus* a variety of *C. stellaris*, thus preserving two useful names that have appeared in a great deal of diatom literature for over half a century. Boyer,³¹ in 1927, ignored the whole dispute and retained *C. stellaris* and *C. symbolophorus* as separate species. Hustedt³² followed Jörgensen in retaining Roper's specific name *stellaris* and making *symbolophora* a variety of it.

Although an oceanic, cool-water species common in both southern and northern seas, it occurred in only two samples in one core and then rarely.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1970-14), 62 μ . From sample L-52 (U. S. G. S. diatom locality 2858), core 9, 142-151 cm. below top. Unfortunately the specimen was badly damaged in mounting, the central portion being broken and pushed below the rest of the valve.

Found rarely in samples L-51 and L-52, core 9.

³⁰ Jörgensen, E., The protist plankton and the diatoms in bottom samples, Hydrographical and biological investigations in Norwegian fjords; Bergens Mus. Skrifter, vol. 7, p. 196, 1905.

³¹ Boyer, C. S., Synopsis of North American Diatomaceae: Acad. Nat. Sci. Philadelphia Proc., vol. 78, suppl., pp. 49-50, 1927.

³² Hustedt, Friedrich, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 396, 1928.

Section RADIATAE Rattray

Coscinodiscus africanus Janisch

Plate 13, figures 4, 7, 10

Coscinodiscus africanus Janisch, in Schmidt, Atlas der Diatomaceenkunde, pl. 59, figs. 24, 25, 1878.

Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 534, 1889.

Mann, Contr. U. S. Nat. Herbarium, vol. 10, pt. 5, p. 247, 1907.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 428, fig. 231, 1928.

Heiden and Kolbe, Deutsche Südpolar-Expedition, Band 8, Botanik, Heft 5, p. 496, 1928.

Mann's explanation (see 3d citation above) of the spiral border markings in this species is open to considerable question. The spiral markings (see pl. 13, fig. 10) are distinctly visible with a 2-mm. oil-immersion apochromat (Mann says they are not visible with a 1/12-in. objective). He thought that the markings were illusory and were only seen when both valves of a frustule were in contact, and then only under low powers. Schmidt's original figure (4th citation above) is the best one published insofar as the border is concerned and closely approaches an accurate representation of this peculiar diatom. The actual structure appears to be as follows: The areolae terminate along an abrupt, irregular edge, which is the inner (toward the center) edge of an irregular space between the areolae and the radial marginal striae. This space appears hyaline, but careful focusing with a 2-mm. oil-immersion apochromat reveals tiny dots in no regular arrangement. The marginal striae are short, about 16 μ in 10 μ , and rounded, usually followed by another annular row of short, rounded striae offset from the first, the whole giving the appearance of a single ring of bifurcated striae. At intervals of 4 μ to 5 μ along the margin are short apiculi, which project outward from the margin into a narrow hyaline ring surrounding the valve. The apiculi turn abruptly at an angle of about 90° in the hyaline ring and bend downwards at an acute angle to the surface of the valve, giving the spiral appearance. Mann's idea of their illusory nature was probably due to the difficulty experienced in focusing these sloping (toward or away from the observer in valve view) apiculi. The sloping apiculi also account for the great difficulty experienced in photographing them at high magnifications. The term "apiculi" is here used loosely, as they are not apiculi in the ordinary sense but apparently markings in the hyaline outer ring.

C. africanus is a warm-water marine species and probably neritic. Its occurrence in the cores again suggests transportation for a considerable distance before deposition.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1972-1), 41 μ . From sample L-4 (U. S. G. S. diatom locality 2866), 130.5-137 cm. below the top of core 3.

Found rarely in samples L-4, L-51, and L-54.

Coscinodiscus argus Ehrenberg

Plate 13, figures 1, 3

- Coscinodiscus argus* Ehrenberg, K. Akad. Wiss. Berlin, Physikal. Abh. 1838, p. 129, 1839.
 Ehrenberg, Mikrogeologie, pl. 21, fig. 2, 1854.
 Grunow, Akad. Wiss. Wien, Math.-naturwiss. Kl., Denkschr., Band 48, p. 72, 1884.
 Schmidt, Atlas der Diatomaceenkunde, pl. 113, fig. 7, 1888.
 Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 527, 1889.
 Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 422, fig. 226, 1928.
 Reinhold, Nederland. Geol. Bur. Jaarv. 1930, p. 15, pl. 1, figs. 9, 10 (?), and 11, 1931.
Coscinodiscus irradiatus Harting, K. Akad. Wetensch. Amsterdam Verh., No. 2, p. 8, pl. 1, fig. 1, 1864.
Coscinodiscus heteroporus Ehrenberg, K. Akad. Wiss. Berlin Ber., 1844, p. 265, 1845.
 Schmidt, Atlas der Diatomaceenkunde, pl. 61, figs. 1, 4, 1878.
Coscinodiscus woodwardii Schmidt, Atlas der Diatomaceenkunde, pl. 61, figs. 2, 3, 1878.

Specimens with polygonal areolae (pl. 13, fig. 3) and with rounded areolae (pl. 13, fig. 1) that differed in no other particular were found in the same sample. Hustedt's figure (see 6th citation above) shows the rounded areolae; other authors have usually illustrated the form with polygonal areolae. Reinhold's figure 10 (see 7th citation above) is here questioned; as the markings are definitely fasciculate, there is apparently a central space, and what appear to be apiculi can be seen on the upper margin. These features definitely remove the specimen in question from *C. argus* and place it nearer to *C. fimbriatus* Ehrenberg. His figure 11 appears satisfactory, as does his later figure³³ from the upper Miocene of Java.

This is another species with a long geologic range. It has been found in beds of various ages from lower Eocene to the Recent, but the fossil species are much more numerous than the Recent. The evidence is at least suggestive that the heyday of this species has been reached and passed and that it is now declining toward extinction. The few Recent occurrences listed in the literature indicate that this is a distinctly warm-water marine species, although Hustedt³⁴ says, regarding its occurrence and distribution: "In allen Meeren verbreitet, aber vielleicht nur litoral unter anderen Diatomeen."

Diameter of figured specimens, plate 13, figure 3 (U. S. G. S. diatom catalog no. 1968-3), 77 μ ; plate 13, figure 1 (U. S. G. S. diatom catalog no. 1968-2), 71 μ . Both from sample L-51 (U. S. G. S. diatom locality 2857), 108-114 cm. below the top of core 9.

Found rarely in samples L-31 and L-51.

³³ Reinhold, Th., Fossil diatoms of the Neogene of Java and their zonal distribution: Nederland en Koloniën Geol.-Mijnbouw. Genootschap Verh., Geol. ser., Deel 12, p. 93, pl. 10, fig. 11, 1937.

³⁴ Hustedt, Friedrich, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 422, 1928.

Coscinodiscus asteromphalus Ehrenberg

Plate 13, figure 11

- Coscinodiscus asteromphalus* Ehrenberg, K. Akad. Wiss. Berlin Ber. 1844, p. 77, 1845.
 Ehrenberg, Mikrogeologie, pl. 18, fig. 45; pl. 33, group 15, fig. 7, 1854.
 Grunow, Akad. Wiss. Wien, Math.-naturwiss. Kl., Denkschr., Band 48, p. 78, pl. 3 (C), fig. 9, 1884.
 Schmidt, Atlas der Diatomaceenkunde, pl. 63, fig. 12, 1878; pl. 113, figs. 22, 23, 1888.
 Van Heurck, Synopsis diatomées Belgique, pl. 128, figs. 1-3, 5, 1883.
 Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 549, 1889.
 Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 452, fig. 250, 1928.
 Hendey, Discovery Repts., vol. 16, p. 243, 1937.
Coscinodiscus asteromphalus var. *conspicua* Grunow, in Van Heurck, Synopsis diatomées Belgique, pl. 130, figs. 1, 2, 5, 6, 1883.

The distribution in the cores of this large and ornate diatom was very peculiar. It occurred commonly to rarely in the upper half of core 3, rarely in the lower third of core 9, and nowhere else. The geologic distribution of this species is equally erratic. It occurs commonly in the Calvert formation, of middle Miocene age, in Maryland and Virginia, but has not been found in the Temblor formation, of the same age, in the Coast Ranges in California, although a very large percentage of the species in each are common to the two formations.³⁵ By upper Miocene time it had become rare on the Atlantic Coast³⁶ and common on the coast of southern California.³⁷ It is also a common species in upper Pliocene rocks in the Kettleman Hills, Calif.³⁸ Diatoms have not been recorded from definitely dated Pliocene rocks along the Atlantic Coastal Plain. During the Pleistocene, however, *C. asteromphalus* appears to have become more widely distributed, and at present it is practically world-wide, although rarely abundant at any one locality. According to Hendey,³⁹ it is "a neritic diatom, favoring a fairly high salinity."

Diameter of figured specimen (U. S. G. S. diatom catalog no. 2004-2), 198 μ . From sample L-2 (U. S. G. S. diatom locality 2864), 40-48 cm. below top of core 3.

Found rarely in samples L-4, L-54, L-55, and L-56, frequently in sample L-3, and commonly in sample L-2.

³⁵ Lohman, K. E., Comparison of the diatom floras from the Calvert formation (middle Miocene) of Maryland and Virginia with those from the Temblor formation (middle Miocene) of California. (In preparation.)

³⁶ Henbest, L. G., Lohman, K. E., and Mansfield, W. C., Foraminifera, diatoms, and mollusks from test wells near Elizabeth City, N. C.: U. S. Geol. Survey Prof. Paper 189-G, p. 222, 1939.

³⁷ Lohman, K. E., in Hoots, H. W., Geology of the eastern part of the Santa Monica Mountains, Los Angeles County, California: U. S. Geol. Survey Prof. Paper 165-C, p. 114, 1931.

³⁸ Lohman, K. E., Pliocene diatoms from the Kettleman Hills, California: U. S. Geol. Survey Prof. Paper 189-C, p. 82, pl. 21, fig. 3, 1938.

³⁹ Hendey, N. I., The plankton diatoms of the southern seas: Discovery Repts., vol. 16, p. 244, 1937.

Coscinodiscus convexus Schmidt

Plate 13, figure 9

Coscinodiscus convexus Schmidt, Atlas der Diatomaceenkunde, pl. 60, fig. 15, 1878.

Rattray, Royal Soc. Edinburgh Proc. vol. 16, p. 552, 1889.

Heiden and Kolbe, deutsche Südpolar-Expedition 1901-1903, Band 8, Botanik, Heft 5, p. 497, 1928.

Hanna, California Acad. Sci. Proc., 4th ser., vol. 20, No. 6, p. 179, pl. 6, figs. 2, 3; pl. 7, fig. 1, 1931.

The specimens found in the cores have coarser areolation than Schmidt's specimens, but the difference is too slight to warrant making a new species. The areolation ranged from $1\frac{1}{2}$ to 4 in 10μ in two individuals otherwise identical. The size and degree of convexity ranged between wide limits also, but, with the large number of specimens available, many of which formed gradational series, it appears wiser to refer them all to this species. One of the least convex specimens was chosen for the photomicrograph, as the more convex individuals are extremely difficult to focus all over simultaneously.

Schmidt's type came from the Springfield deposit, Barbados (probably Eocene in age), and Hanna's material (last citation above) came from the middle Miocene Temblor formation, Sharktooth Hill, Kern County, Calif. Heiden and Kolbe (3d citation above) reported this species from Observatory Bay, Kerguelen, but did not give its abundance nor state whether or not it was in the living state when found. It is entirely possible and certainly not improbable that this is another extinct species, which may have been redeposited from beds of Miocene age. It is an exceedingly robust, highly silicified species and would be able to withstand transportation over great distances.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1970-6), 178μ . From sample L-52 (U. S. G. S. diatom locality 2858), 142-151 cm. below the top of core 9.

Found rarely in samples L-4, L-5, L-49, L-54, and L-56, frequently in samples L-50, L-51, L-59, and L-62, and commonly in sample L-52.

Coscinodiscus decrescens Grunow

Plate 13, figure 6

Coscinodiscus decrescens Grunow, in Schmidt, Atlas der Diatomaceenkunde, pl. 61, figs. 8, 9, 10 (?), 1878.

Grunow, Akad. Wiss. Wien, Math.-naturwiss. Kl., Denkschr., Band 48, p. 80, 1884.

Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 525, 1889.

De Toni, Sylloge algarum omnium hucusque cognitarum, vol. 2, p. 1252, 1894.

Van Heurck, Expédition Antarctique Belge, Botanique, p. 47, 1909.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 430, fig. 233, 1928.

Hendey, Discovery Repts., vol. 16, p. 245, 1937.

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Reinhold⁴⁰ has reported this species from rocks of middle Miocene age in Java. The original type (see 1st citation above) came from Eocene rocks in Barbados, and I⁴¹ have found it in the Modelo formation, of upper Miocene age, in the Santa Monica mountains, Los Angeles County, Calif. It is frequently found in European waters both in plankton and in littoral floras. Hendey (see last citation above) found it only in the plankton off south Georgia at water temperatures averaging 0° C. Although it has not been reported from the North Atlantic, it might be indigenous in that region.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1947-1), 39μ . From sample L-33 (U. S. G. S. diatom locality 2841), 118-122 cm. below the top of core 6.

Found rarely in samples L-33 and L-50.

Coscinodiscus kurzii Grunow

Plate 13, figure 5

Coscinodiscus kurzii Grunow, in Schmidt, Atlas der Diatomaceenkunde, pl. 11, fig. 17, 1888.

Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 564, 1889.

Lohman, U. S. Geol. Survey Prof. Paper 189-C, pl. 20, fig. 1; pl. 21, fig. 2, 1938.

This species has not been reported living. Grunow's original specimen (see 1st citation above) came from Elephant Point, and I have found it occurring commonly in the Etchegoin and San Joaquin formations, of upper Pliocene age, in the Kettleman Hills, Calif. (see last citation above). All of the specimens found in the cores were broken, and this, together with the fact that this species has never been reported definitely as living, invites the speculation that the forms found in the cores had been reworked from some fossil outcrop and redeposited on the ocean floor.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1951-1), 62μ . From sample L-10 (U. S. G. S. diatom locality 2854), 74-79 cm. below the top of core 4.

Found rarely in sample L-52 and frequently in sample L-10.

Coscinodiscus marginatus Ehrenberg

Plate 14, figures 1, 6

Coscinodiscus marginatus Ehrenberg, K. Akad. Wiss. Berlin, Physikal. Abh. 1841, p. 142, 1843.

Ehrenberg, Mikrogeologie, pl. 18, fig. 44; pl. 33, group 12, fig. 13; pl. 38B, group 22, fig. 8, 1854.

Schmidt, Atlas der Diatomaceenkunde, pl. 62, figs. 1-5, 9, 11, 12, 1878.

⁴⁰ Reinhold, Th., Fossil diatoms of the Neogene of Java and their zonal distribution: Nederland en Koloniën Geol.-Mijnbouw. Genootschap Verh., Geol. ser., Deel 12, p. 94, pl. 10, fig. 9, 1937.

⁴¹ Lohman, K. E., in Hoots, H. W., Geology of the eastern part of the Santa Monica Mountains, Los Angeles County, California: U. S. Geol. Surv. Prof. Paper 165-C, p. 114, pl. 28, fig. 5, 1931.

Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 509, 1889.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 416, fig. 223, 1928.

Hendey, Discovery Repts., vol. 16, p. 248, 1937.

Coscinodiscus limbatus Ehrenberg, K. Akad. Wiss. Berlin, Monatsber., 1840, p. 206, 1841.

Coscinodiscus fimbriatus-limbatus Ehrenberg, Mikrogeologie, pl. 19, fig. 4, 1854.

Coscinodiscus radiatus forma *heterosticta* Grunow, in Pantocsek, Beiträge zur Kenntnis der fossilen Bacillarien Ungarns, Teil 1, p. 70, pl. 20, fig. 184, 1886.

Coscinodiscus subconcausus forma *major* Schmidt, Atlas der Diatomaceenkunde, pl. 62, fig. 7, 1878.

For the differences between this species and *Endictya robusta* (Greville) Hanna and Grant, see discussion under the latter on p. 66 of this report. It is also sometimes confused with *C. radiatus* Ehrenberg, from which it differs in having coarser areolation, longer and coarser marginal striae, and much greater convexity. *C. radiatus* is usually quite flat. The convexity of *C. marginatus* is not so evident in plate 14, figure 1 (taken with a 16-mm. apochromat) but is very well shown in plate 14, figure 6 (taken with an 8-mm. apochromat).

This species has had a widespread distribution since early Miocene time and occurs today in all warm to temperate seas. According to Hendey ⁴² it is "probably a bottom form, meroplanktonic, but sometimes observed a considerable distance from land." It is one of the most common species found in the cores.

Measurements of figured specimens

U. S. G. S. diatom catalog no.	Diameter	Areolae near center	Areolae near margin	Marginal striae
1967-17----	115 μ	1½-2 in 10 μ	3 in 10 μ	5½ in 10 μ
1967-19----	97 μ	2 in 10 μ	3½ in 10 μ	5 in 10 μ

Both from sample L-3 (U. S. G. S. diatom locality 2857, 81-89 cm. below the top of core 3).

Found rarely in samples L-1, L-7, L-8, L-10, L-20, L-58, and L-60, frequently in samples L-2, L-3, L-4, L-31, L-33, L-51, L-52, L-54, L-55, and L-56, and commonly in samples L-19, L-32, and L-59.

Coscinodiscus nodulifer Schmidt

Plate 14, figures 3, 5

Coscinodiscus nodulifer Schmidt, Atlas der Diatomaceenkunde, pl. 59, figs. 21-23, 1878.

Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 520, 1889.

De Toni, Sylloge algarum omnium hucusque cognitarum, vol. 2, p. 1249, 1894.

Boyer, Acad. Nat. Sci. Philadelphia Proc., vol. 78, supplement, p. 55, 1926.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 426, fig. 229, 1928.

Schmidt in his original illustration of this distinctive species included a form with prominent marginal

apiculi,⁴³ which Rattray ⁴⁴ subsequently described as var. *apiculata*. Mann ⁴⁵ casually and Hustedt ⁴⁶ definitely disregarded Rattray's variety and included it with the species. This does not appear to have been the wisest choice for the following reasons: The apiculi are shown quite definitely on Schmidt's figure and are good morphological characters used without question elsewhere; the variety *apiculata* has been recorded from only two localities,⁴⁷ both in warm tropical waters, and both occurrences were presumably in a living state. The type species has never been recorded from the same localities but has been found widely scattered over the globe, both living and from fossil deposits as old as middle Miocene. It seems possible, therefore, that var. *apiculata* may represent a particular ecologic condition, such as that found in Campeche Bay, and may prove useful as an ecologic indicator when and if found in sediments.

C. nodulifer has been reported from neritic zones of tropical and subtropical seas by various oceanographic expeditions but never in latitudes as high as those of the cores (lat. 46° to 49° N.), and it may, therefore, be regarded as a warm-water or warm-temperate-water species. Hendey ⁴⁸ found it in only one sample, at latitude 38°27'30" S. at a water temperature of 14.8° C. The presence of this species in the cores at higher latitude and in much colder water suggests transportation by the Gulf Stream.

Diameter of figured specimens, plate 14, figure 5 (U. S. G. S. diatom catalog no. 1967-6), 83 μ ; plate 14, figure 3 (U. S. G. S. diatom catalog no. 1967-9), 51 μ . Both from sample L-51 (U. S. G. S. diatom locality 2857), 108-114 cm. below top of core 9.

Found rarely in samples L-6, L-31, L-52, L-55, L-59, and L-65 and frequently in samples L-2, L-4, and L-51.

Coscinodiscus oculus-iridis var. *borealis* (Bailey) Cleve

Plate 14, figure 2

Coscinodiscus borealis Bailey, Am. Jour. Sci., ser. 2, vol. 22, p. 3, 1856.

Schmidt, Atlas der Diatomaceenkunde, pl. 63, fig. 11, 1878.

Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 558, 1889.

Coscinodiscus oculus-iridis var. *borealis* (Bailey) Cleve, Vega-Exped. vetensk. Iakttagelser, Bandet 3, p. 488, 1883.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 456, fig. 253, 1928.

The large robust areolae and the raised zone about one-fifth the radius in from the margin distinguish this variety from *C. oculus-iridis* Ehrenberg. In the early

⁴³ Schmidt, Adolf, Atlas der Diatomaceenkunde, pl. 59, fig. 20, 1878.

⁴⁴ Rattray, John, A revision of the genus *Coscinodiscus* and some allied genera: Royal Soc. Edinburgh Proc., vol. 16, p. 520, 1889.

⁴⁵ Mann, Albert, Diatoms of the *Albatross* voyages: Contr. U. S. Nat. Herbarium, vol. 10, part 5, p. 255, 1907.

⁴⁶ Hustedt, Friedrich, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 427, 1928.

⁴⁷ Rattray, op. cit., p. 520.

⁴⁸ Hendey, N. I., The plankton diatoms of the southern seas: *Discovery Repts.*, vol. 16, p. 248, 1937.

⁴⁸ Hendey, N. I., The plankton diatoms of the southern seas: *Discovery Repts.*, vol. 16, p. 248, 1937.

stages of the present investigation many individuals were tentatively identified as *C. oculus-iridis*, but, when large numbers of the variety *borealis* were found, the ones previously identified as typical were re-examined more critically, and all were assigned to the variety. Although this variety is very distinct, its close affinity to the type make specific separation unwise. Hustedt (last citation above) says, "Für die spezifische Abtrennung dieser Form liegt kein Grund vor."

It occurred in greater abundance than any other diatom in cores 3 and 9. Three other cores contained it rarely to frequently.

This is a definitely cold-water form and is common in most diatom floras from Arctic waters.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1965-1), 214 μ . From sample L-3 (U. S. G. S. diatom locality 2865), 81-89 cm. below the top of core 3.

Found rarely in samples L-16, L-31, L-33, L-49, L-58, L-60, and L-62, frequently in samples L-1, L-7, L-10, L-19, L-32, L-37, L-51, and L-59, commonly in sample L-6, and abundantly in samples L-2, L-3, L-4, L-52, and L-54.

Coscinodiscus radiatus Ehrenberg

Plate 14, figures 7, 8

Coscinodiscus radiatus Ehrenberg, K. Akad. Wiss. Berlin, Physikal. Abh. 1839, p. 148, pl. 3, figs. 1a-c, 1841.

Schmidt, Atlas der Diatomaceenkunde, pl. 60, figs. 5, 6, 9, 10, 1878.

Van Heurck, Synopsis diatomées Belgique, pl. 129, fig. 1, 1883.

Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 514, 1889.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 420, fig. 225, 1928.

Hendey, Discovery Repts., vol. 16, p. 250, 1937.

Coscinodiscus caspius Ehrenberg, K. Akad. Wiss. Berlin, Physikal. Abh. 1872, p. 394, pl. 12, group 1, fig. 14, 1873.

Coscinodiscus borealis Ehrenberg, K. Akad. Wiss. Berlin, Monatsber. 1861, p. 294, 1862.

Coscinodiscus fallax Schumann, Königsberg K. physikal.-ökonomischen Gesell., Schr., Jahrg. 8, p. 62, pl. 3, fig. 76, 1867.

Hustedt⁴⁹ has recently included a great many varieties of *C. radiatus* with the species, and it appears to have been a wise course. Most of the varieties have been based on minor differences in areolation and size. In a variable species such as this, minor differences quickly lead to absurdities if new varieties are erected for each departure from the norm. In the material studied for this report, many variations of this species were found, with practically infinitesimal gradations between. The two extremes of such a series are here illustrated, one (pl. 14, fig. 7) a large form with areolae 2 to 2½ in 10 μ , outer quarter of valve convex, and the other a smaller form (pl. 14, fig. 8) less than half the diameter of the former, with areolae 4 to 5 in 10 μ , and flat from center to margin. In general the smaller

forms are flat, and many of those with diameters greater than 100 μ are convex. Although a great many individuals were found, nearly every one was damaged in some way.

This species has a world-wide distribution in warm to temperate seas and is probably encountered as often as any marine diatom. It is one of the species found most frequently in the cores. It has a long geologic history and has been found in many marine diatomites of Eocene and later ages.

Diameters of figured specimens: Plate 14, figure 7 (U. S. G. S. diatom catalog no. 1967-2), 158 μ ; plate 14, figure 8 (U. S. G. S. diatom catalog no. 1967-10), 71 μ . Both from sample L-51 (U. S. G. S. diatom locality 2857), 108-114 cm. below top of core 9.

Found rarely in samples L-2, L-3, L-5, L-16, L-23, L-44, L-49, L-55, and L-58, frequently in samples L-4, L-6, L-7, L-10, L-19, L-30, L-31, L-32, L-33, L-37, L-52, L-56, L-62, and L-65, and commonly in samples L-54 and L-59.

Section FASCICULATAE Rattray

Coscinodiscus bicurvulatus Lohman, n. sp.

Plate 15, figure 5

Valve circular, flat, without rosette or central space; hexagonal areolae in indefinite fasciculi, occasionally straight but usually curved in either clockwise or counterclockwise direction; areolae near center, 7 to 8 in 10 μ ; at semi radius, 6 in 10 μ ; near margin, 8 to 9 in 10 μ . Margin narrow with short radial striae, 18 in 10 μ ; stout rounded marginal apiculi, 10 μ apart. Diameter 60-80 μ .

Holotype: U. S. G. S. diatom catalog no. 1967-12, diameter, 67 μ . U. S. G. S. diatom locality 2857. Sample L-52, from 108-114 cm. below the top of core 9, taken at a depth of 2,050 fathoms in lat. 49°40'00" N., and long. 28°29'00" W., by C. S. Piggot, 1936.

Reinhold⁵⁰ has recently published a figure of this species and confused it with *C. normani* Gregory. He published two figures (pl. 11, figs. 4 and 9), which he called *C. normani*. Figure 4 is not entirely clear, but appears to be *C. normani*, but figure 9, which is an excellent photomicrograph, is clearly not *C. normani* but identical with the present species. In *C. normani* the fasciculi are straight, with the rows of areolae parallel to the center row in each fasciculus, and the narrow zone between the apiculi and the margin is covered with very fine decussate markings. Both these features are exhibited in Reinhold's figure 4 but not in his figure 9.

This species is somewhat similar to *C. curvulatus* var. *odontodiscus* (Grunow) Hustedt,⁵¹ from which it differs in having smaller areolae, particularly near the center and margin, and in not having the irregular hyaline

⁴⁹ Hustedt, Friedrich, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 420, 1928.

⁵⁰ Reinhold, Th., Fossil diatoms of the Neogene of Java and their zonal distribution: Nederland en Koloniën Geol.-Mijnbouw. Genootschap Verh., Geol. ser., Deel 12, pl. 11, fig. 9, 1937.

⁵¹ Hustedt, Friedrich, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 408, fig. 215, 1928.

ring at the center. This ring is well shown in Grunow's original figure.⁵²

More than a dozen individuals were found in the cores, all of which were consistent with the description and figure here given. No perfect individual was found; the holotype has the margin broken away from half of the valve but is otherwise intact. In view of the fact that many perfect specimens of more fragile diatoms were found, it is entirely possible that this species has been reworked from older material.

Found rarely in samples L-2, L-4, L-30, L-51, L-52, L-54, L-59, and L-60.

***Coscinodiscus crenulatus* Grunow var. *nodulifer* Lohman, n. var.**

Plate 14, figure 4; plate 15, figure 1

Valve circular, flat, without rosette but occasionally with a small, irregular central space; polygonal areolae, 7 to 8 in 10μ at the semiradius, usually constant over the entire valve, but occasionally somewhat closer toward the margin; areolae arranged in definite fasciculi; initial and longest row of areolae in each fasciculus sometimes radial but more often tangent to an imaginary circle at the center of the valve and one-tenth to one-twelfth its diameter; initial row usually straight but occasionally slightly curved; remaining rows in each fasciculus parallel to the initial one. A single nodule 1μ to 1.5μ in diameter is always present, although not always obvious, and is always slightly excentric and usually surrounded by a narrow irregular space. Marginal apiculi 6μ to 9μ apart with indentation at each apiculus giving a crenulate appearance to the margin. Marginal striae, short and robust, 14 to 16 in 10μ . Diameter of valve, 30μ to 40μ .

Holotype: U. S. G. S. diatom catalog no. 1970-3 (pl. 15, fig. 1); paratype: U. S. G. S. diatom catalog 1957-11 (pl. 14, fig. 4). U. S. G. S. diatom locality 2858. Sample L-52, from 142-151 cm. below the top of core 9, taken at a depth of 2,050 fathoms in lat. $49^{\circ}40'00''$ N. and long. $28^{\circ}29'00''$ W., by C. S. Piggot, 1936.

Measurements of figured specimens

Specimen	Diameter	Areolae in 10μ	Marginal striae in 10μ	Apiculi, distance apart
Holotype, 1970-3----	μ 40	7-8	15-16	μ 9
Paratype, 1957-11----	37	7-8	14	6

This variety differs from *C. crenulatus* Grunow⁵³ principally in the presence of the small excentric nodule. This nodule is not present in any published figures or descriptions of *C. crenulatus*. In the type,

⁵² Grunow, Albert, Die Diatomeen von Franz Josefs-Land: Akad. Wiss. Wien, Math.-naturwiss. Kl., Denkschr., Band 48, p. 81, pl. 3 (C), fig. 23, 1884.

⁵³ Idem, p. 83, pl. 4 (D), fig. 17.

the fasciculi are more definitely curved than in the variety, and, according to Hustedt,⁵⁴ who has given the best description of the species, the marginal striae are more closely spaced (20 in 10μ) in the type than in the variety. Rattray's description⁵⁵ of *C. crenulatus* is very confusing, as, according to Hustedt,⁵⁶ he made his measurements on Schmidt's figure⁵⁷ rather than on an actual specimen and failed to notice that this particular figure was drawn at a magnification of 990 diameters, whereas the magnification for the balance of the plate was 660 diameters. Rattray used the smaller enlargement in computing his measurements.

The type is a littoral form from southern seas, and it is possible that the habitat of the variety was similar. Found rarely in samples L-30, L-51, and L-52.

***Coscinodiscus curvatus* Grunow**

Plate 15, figure 8

Coscinodiscus curvatus Grunow, in Schmidt, Atlas der diatomaceenkunde, pl. 57, fig. 33, 1878.

Grunow, Akad. Wiss. Wien, Math.-naturwiss. Kl., Denkschr., Band 48, p. 82, pl. D, figs. 11-15, 1884.

Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 486, 1889.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 406, fig. 214, 1928.

In the figured specimen the extreme margin is lacking, and the marginal apiculi so well illustrated by Hustedt in the figure cited above are not prominent, but careful focusing on the margin reveals them. Schmidt's original figure⁵⁸ shows the apiculi about as strongly developed as those in Hustedt's figure. Rattray⁵⁹ on the other hand, says, "apiculi absent." It is obvious that the apiculi represent a variable feature and one not to be taken too seriously, at least as far as this species is concerned. Another variable feature is the degree of curvature of the fasciculi. In most published figures of this species a pronounced curvature of the fasciculi is shown. In the specimens found in the cores, the curvature is real and constant as to direction but very slight. Mann⁶⁰ observed the same lack of pronounced curvature in his specimens from Bering Sea.

This species is known from the whole Tertiary, the earliest occurrence being recorded by Reinhold,⁶¹ who found it in rocks of probable lower Eocene age near Maastricht, Netherlands.

Its present distribution is widespread in oceanic plankton, but is more abundant in cold northern waters.

⁵⁴ Hustedt, Friedrich, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 411, fig. 219, 1928.

⁵⁵ Rattray, John, A revision of the genus *Coscinodiscus* and some allied genera: Royal Soc. Edinburgh Proc., vol. 16, p. 489, 1889.

⁵⁶ Hustedt, Friedrich, op. cit., p. 412.

⁵⁷ Schmidt, Adolf, Atlas der Diatomaceenkunde, pl. 57, fig. 38, 1878.

⁵⁸ Idem, fig. 33.

⁵⁹ Rattray, John, op. cit., p. 486.

⁶⁰ Mann, Albert, Diatoms of the *Albatross* voyages: Contr. U. S. Nat. Herbarium, vol. 10, part 5, p. 250, 1907.

⁶¹ Reinhold, Th., Diatoms from rocks, possibly belonging to the Danian (or Lower Eocene), near Maastricht, Netherlands: Nederland. Geol. Bur. Jaarv., 1930, p. 15, pl. 1, figs. 2, 4-8, 1931.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1960-3), 91 μ . From sample L-54 (U. S. G. S. diatom locality 2860), 206-213 cm. below top of core 9.

Found rarely in samples L-2 and L-31 and frequently in samples L-52 and L-54.

***Coscinodiscus curvatus* var. *minor* (Ehrenberg) Grunow**

Plate 15, figure 3

Coscinodiscus minor Ehrenberg, K. Akad. Wiss. Berlin, Physikal. Abh. 1838, p. 129, pl. 4, fig. 12e, 1840.

Coscinodiscus curvatus var. ? *minor* (Ehrenberg) Grunow, Akad. Wiss. Wien. Math.-naturwiss. Kl., Denkschr., Band 48, p. 83, pl. 4 (D), figs. 8-10, 1884.

Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 487, 1889.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 409, fig. 217, 1928.

The curved fascicles immediately distinguish this small variety from small forms of *Coscinodiscus excentricus*, with which it is frequently confused. Ehrenberg's earliest figure of this diatom (see first citation above) left much to be desired. Many subsequent authors have combined Ehrenberg's *C. minor* with *C. excentricus*, whereas Grunow saw the curved fasciculate arrangement of the markings and hence realized its relationship to *C. curvatus*. The doubtful accuracy of the original figure (now 100 years old) and the various interpretations that have been placed on it by other authors have confused the true position of this tiny diatom. Grunow entertained and recorded a doubt as to whether or not *C. minor* should be made a variety of *C. curvatus* or combined with it. I agree with Rattray and Hustedt (see above synonymy) that the forms Grunow figured were certainly related to *C. curvatus*. The specimens from the cores are more finely marked than the one figured by Hustedt (see last citation above) and approach *C. divisus* Grunow, which, however, is larger and has a zone of very fine decussate markings between the apiculi and the margin.

This variety is frequently found with small forms of *C. excentricus*, pelagic in all seas, but is more abundant in colder waters.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1957-1), 29 μ . From sample L-52 (U. S. G. S. diatom locality 2858), 142-151 cm. below top of core 9.

Found rarely in sample L-4, and frequently in sample L-52.

***Coscinodiscus denarius* Schmidt**

Plate 15, figure 6.

Coscinodiscus denarius Schmidt, Atlas der Diatomaceenkunde, pl. 57, figs. 19-21, 1878.

Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 504, 1889.

Boyer, Acad. Nat. Sci. Philadelphia Proc., vol. 78, supplement, p. 51, 1926.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 399, fig. 210, 1928.

Specimens assigned to this species have polygonal areolae, 8 in 10 μ , which decrease in size very slightly toward the margin. In the photomicrograph the reduc-

tion in size of the areolae toward the margin is exaggerated on account of the change in focus from center to margin caused by the convexity of the valve. The number of rows of areolae in each fasciculus is greater than that usually given by various authors, but the difference does not appear to warrant specific separation, as the size of the fasciculi differs between different valves and even in a single valve.

This species is frequently confused with *C. subtilis* Ehrenberg, from which it differs in having coarser areolation and more definite fasciculi.

Schmidt's original specimens came from Eocene rocks on the island of Barbados,⁶² and it has since been reported from Campeche Bay in the Gulf of Mexico,⁶³ and from the Antarctic Ocean.⁶⁴ Hustedt⁶⁵ states that except for a report by Peragallo of its occurrence living in the Bay of Villefranche, it is not known in European waters. It occurred in nearly half the samples from the cores but never in large numbers. As far as can be determined from available data it is not at all critical regarding temperature.

Measurements of figured specimen (U. S. G. S. diatom catalog no. 1968-4): Diameter, 76 μ ; areolae, 8 in 10 μ ; marginal striae, 13 in 10 μ . From sample L-51 (U. S. G. S. diatom locality 2857), 108-114 cm. below the top of core 9.

Found rarely in samples L-2, L-3, L-7, L-16, L-19, L-20, L-31, L-32, L-51, L-54, and L-61, and frequently in samples L-4, L-33, and L-37.

***Coscinodiscus divisus* Grunow**

Plate 15, figure 7

Coscinodiscus divisus Grunow, in Schneider, Naturwiss. Beitr. zur Kenntniss der Kaukasusländer, p. 125, 1878.

Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 499, 1889.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 410, fig. 218, 1928.

Coscinodiscus (curvatus var. ?) *divisus* Grunow, Akad. Wiss. Wien, Math.-naturwiss. Kl., Denkschr., Band 48, p. 83, pl. 4 (D), fig. 16, 1884.

On purely morphologic grounds this species is closely related to both *C. curvatus* Grunow and *C. rothii* (Ehrenberg) Grunow, having the curved fascicles (with rows of areolae parallel to a marginal row in each fascicle) of the former, and the band of fine, decussate markings between the apiculi and the margin of the latter. If the phylogenies of all three species were better known, it seems probable that *C. divisus* might be the intermediate form. On ecologic grounds the relationship is, perhaps, less evident but at least

⁶² Schmidt, Adolf, Atlas der Diatomaceenkunde, pl. 57, figs. 19-21, 1878.

⁶³ Rattray, John, A revision of the genus *Coscinodiscus* and some allied genera: Royal Soc. Edinburgh Proc., vol. 16, p. 504, 1889.

⁶⁴ Heiden, Heinrich, and Kolbe, R. W., Die marinen Diatomeen, in Von Drygalski, E., Die deutschen Südpolar-Expedition, 1901-1903, Band 8, Botanik, Heft 5, p. 490, 1928.

⁶⁵ Hustedt, Friedrich, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 400, 1928.

not contradictory. According to Hendey,⁶⁶ *C. curvatulus* is "an oceanic species having a wide distribution in temperate seas." *C. divisus* is, according to Hustedt,⁶⁷ "Wahrscheinlich neritisch oder litoral." Regarding the occurrence of *C. rothii* and its varieties, the same author⁶⁸ states: "Die Art ist in allen Meeren verbreitet und meist häufig. Die Varietäten finden sich besonders im Brackwasser der Flussmündungen, zum Teil auch in Binnenseen mit reinem Süßwasser." Thus, assuming for the moment that the oceanic *C. curvatulus* was the earlier form, the neritic or litoral *C. divisus* the intermediate form and *C. rothii* var. *normani* the end product, we have a gradual transition from oceanic through littoral to brackish-water and even fresh-water conditions. The geologic evidence, as far as known, does not bear this out. Both *C. curvatulus* and *C. rothii* are known from the Eocene, whereas the oldest recorded occurrence for *C. divisus* is from the upper Pliocene of Java.⁶⁹ It is entirely possible, however, that some of the diatoms identified as *C. curvatulus* in earlier rocks were really *C. divisus*.

This species was well represented in the cores and occurred in nearly half of the samples studied.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1970-11), 57 μ . From sample L-52 (U. S. G. S. diatom locality 2858), 142-151 cm. below top of core 9.

Found rarely in samples L-6, L-20, L-49, L-52, L-56, and L-60, and frequently in samples L-4, L-10, L-30, L-31, L-33, L-37, L-51, L-54, L-59, and L-65.

Coscinodiscus subtilis Ehrenberg

plate 15, figure 4

Coscinodiscus subtilis Ehrenberg, K. Akad. Wiss. Berlin, Physikal. Abh. 1841, p. 412, pl. 1, group 3, fig. 18; pl. 3, group 7, fig. 4, 1843.

Schmidt, Atlas der Diatomaceenkunde, pl. 57, figs. 11-16, 1878.

Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 494, 1889.

Mann, Contr. U. S. Nat. Herbarium, vol. 10, pt. 5, p. 259, 1907.

Boyer, Acad. Nat. Sci. Philadelphia Proc., vol. 78, suppl., p. 50, 1926.

Hendey, Discovery Repts., vol. 16, p. 254, 1937.

The diatoms referred to this species agree more closely with Ehrenberg's original description than with some descriptions published in later years. Most authors give from 6 to 10 areolae per 10 μ , whereas these have 12 in 10 μ , as did Ehrenberg's. The marginal striae, 16 in 10 μ , are finer than usual and are of unequal length, giving the appearance of apiculi when viewed under me-

dium magnifications, but none of the specimens found exhibit true apiculi.

C. subtilis has become somewhat of a catch-all for finely marked coscinodiscoid forms having fasciculi of varying degrees of distinctness and, undoubtedly, has been most frequently confused with *C. denarius* Schmidt and *C. rothii* (Ehrenberg) Grunow. Hustedt⁷⁰ has recently reviewed the situation and concluded that the name *C. subtilis* Ehrenberg should be abandoned and that forms referred to this species should be included in the "Formenkreis" of *C. rothii*. Although Hustedt's conclusion has much in its favor, it appears best to continue to recognize the species *C. subtilis* until a definite and thorough revision is made of the whole group.

This species has an almost universal distribution, occurring in marine, brackish, and fresh waters, and most abundantly today in cold subpolar waters, but also along the shores of most continents, in the mud of estuaries and in fresh water. Boyer⁷¹ reports it as, "Very common in the water supply of Philadelphia and Camden, where the diameter seldom exceeds 40 μ and the markings on the semiradius are 10 in 10 μ ." It occurs in many marine fossil deposits from Miocene to Recent,⁷² and it is abundant in some Miocene fresh-water diatomites in the Otis Basin, Harney County, Oreg.⁷³

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1972-8), 48 μ . From sample L-4 (U. S. G. S. diatom locality 2866), 130.5-137 cm. below the top of core 3.

Found rarely in samples L-3 and L-6, and frequently in sample L-54.

Genus *ACTINOCYCLUS* Ehrenberg, 1838

Actinocyclus curvatulus Janisch

Plate 15, figure 2

Actinocyclus curvatulus Janisch, in Schmidt, Atlas der Diatomaceenkunde, pl. 57, fig. 31, 1878.

Mann, Contr. U. S. Nat. Herbarium, vol. 10, pt. 5, p. 261, 1907.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 538, 1929.

Coscinodiscus curvatulus var. *subocellatus* Grunow, Akad. Wiss. Wien, Math.-naturwiss. Kl., Denkschr., Band 48, p. 83, pl. 4 (D), fig. 15, 1884.

Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 488, 1889.

Actinocyclus subocellatus (Grunow) Rattray, Quekett Micr. Club. Jour., ser. 2, vol. 4, p. 145, 1890.

Boyer, Acad. Nat. Sci. Philadelphia Proc., vol. 78, supplement, p. 81, 1926.

The indefiniteness of the pseudonodule on this diatom has resulted in much confusion. In view of the fact that the most fundamental difference between the gen-

⁶⁶ Hendey, N. I., The plankton diatoms from the south seas: *Discovery Repts.*, vol. 16, p. 252, 1937.

⁶⁷ Hustedt, Friedrich, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 411, 1928.

⁶⁸ Idem, p. 404.

⁶⁹ Reinhold, Th., Fossil diatoms of the Neogene of Java and their zonal distribution: *Nederland en Koloniën Geol.-Mijnbouw. Genootschap, Verh.*, Geol. ser., Deel 12, p. 94, 1937.

⁷⁰ Hustedt, Friedrich, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 404, 1928.

⁷¹ Boyer, C. S., The diatomaceae of Philadelphia and vicinity, p. 22, 1916.

⁷² Rattray, John, op. cit., p. 495.

⁷³ Lohman, K. E., in Moore, B. N., Nonmetallic mineral resources of eastern Oregon: U. S. Geol. Survey Bull. 875, p. 105, 1937.

era *Coscinodiscus* and *Actinocyclus* is the presence of a pseudonodule on the latter, the present species must go into *Actinocyclus*, even though the pseudonodule is not always obvious. The distinctness of the pseudonodule among the members of this species found in the cores ranged through wide limits. Most of the individuals were damaged, and the one figured represents the only whole specimen found. The dark radial streak near the top of the figure is due to a fragment of a diatom girdle that is firmly attached. The pseudonodule in this particular specimen (shown near the margin at the bottom of the figure) is rather faint, but may be seen clearly by proper focusing. It has exactly the same appearance as the one in the excellent drawing of *A. curvatus* by Hustedt (3d citation above).

The distribution of this species is very imperfectly known, but appears to be fairly widespread, although Hustedt⁷⁴ notes that it has not been found in European seas. Doubtless it has been confused frequently with *Coscinodiscus curvatus*.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1957-2), 66 μ . From sample L-52 (U. S. G. S. diatom locality 2858), 142-151 cm. below the top of core 9.

Found rarely in samples L-30, L-49, L-50, L-52, L-58, L-60 and L-65 and frequently in sample L-51.

Actinocyclus octonarius Ehrenberg

Plate 16, figure 4

Actinocyclus octonarius Ehrenberg, Die Infusionsthierehen als vollkommene Organismen, p. 172, pl. 21, fig. 7, 1838.

Hendey, Discovery Repts., vol. 16, p. 262, 1937.

Actinocyclus ehrenbergii Ralfs, in Pritchard, A history of Infusoria, 4th ed. p. 834, 1861.

Van Heurck, Synopsis diatomées Belgique, pl. 123, fig. 7, 1883; p. 215, 1885.

Rattray, Quekett Micr. Club Jour., ser. 2, vol. 4, p. 171, 1890.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 525, fig. 298, 1929.

Hanna, California Acad. Sci. Proc., 4th ser., vol. 20, p. 168, pl. 2, figs. 1, 2, 3, 1932.

Lohman, U. S. Geol. Survey Prof. Paper 189-C, p. 83, pl. 22, fig. 1, 1938.

The synonymy of this well-known species could be extended almost indefinitely, but this has already been done so often that nothing would be gained here by repeating it.

Hendey (see 2d citation above), has invoked the rule of strict priority and thus revived Ehrenberg's hundred-year-old original name from oblivion. Although Ralfs' name has been hallowed by long usage, it is, as Hendey has ably demonstrated, invalid. Ralfs, possibly thinking to appease Ehrenberg's displeasure, caused by throwing 118 of his names into synonymy, named the whole group *Actinocyclus ehrenbergii* instead of using *octonarius*, the earliest name. It is with some misgiving

that I agree with Hendey in this matter, as common sense would appear to dictate that Ralfs name be retained, even though invalid, on the grounds of long and universal usage. However, the plea of "common-sense usage" might better be reserved for doubtful cases and not be applied in such clearly unequivocal ones as the present. It seems necessary, therefore, to follow Hendey and return to Ehrenberg's original name, although those who are inclined to use the common-sense plea in all cases may call it sheer pedantry.

The specimens found in the cores are all smaller than typical ones but differ in no other respect. They range from 34 μ to 50 μ in diameter, but the radial beads on each specimen are but 7 in 10 μ , the mean for the type.

At the present time this neritic diatom has a world-wide distribution in temperate seas. Its known geologic range is middle Miocene⁷⁵ to Recent.

Measurements of figured specimen (U. S. G. S. diatom catalog no. 1971-1): diameter, 35 μ ; radial beads, 7 in 10 μ . From sample L-3 (U. S. G. S. diatom locality 2865), 81-89 cm. below the top of core 3.

Found rarely in samples L-54 and L-66, frequently in L-2, L-3, L-10, and L-51, and commonly in L-4.

Genus *ROPERIA* Grunow, 1883

Roperia tessellata (Roper) Grunow

Plate 16, figure 3

Eupodiscus tessellatus Roper, Quart. Jour. Micr. Sci., vol. 6, p. 19, pl. 3, fig. 1, 1858.

Roperia tessallata (Roper) Grunow, in Van Heurck, Synopsis diatomées Belgique, pl. 118, figs. 6, 7, 1883.

Rattray, Royal Micr. Soc. Jour., vol. 8, p. 917, 1888.

Boyer, Acad. Nat. Sci. Philadelphia Proc., vol. 78, supplement, p. 88, 1926.

Heiden and Kolbe, Deutsche Südpolar Expedition 1901-1903, Band 8, Botanik, Heft 5, p. 507, 1928.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 523, fig. 297, 1929.

Actinocyclus tessellatus Ralfs, in Pritchard, History of the Infusoria, 4th Ed., p. 835, 1861.

Mann, U. S. Nat. Herbarium Contr., vol. 10, pt. 5, p. 264, 1907.

This pelagic diatom is found frequently in the central Pacific Ocean, off Rio de Janeiro, and along the coast of Europe. It is apparently a temperate to warm water form and may have been brought to the North Atlantic by the Gulf Stream. Lebour⁷⁶ has recorded it from (presumably) the North Atlantic but gives no information regarding locality or relative abundance.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1967-7), 62 μ . From sample L-51 (U. S. G. S. diatom locality 2857), 108-114 cm. below the top of core 9.

Found rarely in samples L-2, L-6, L-10, L-51, and L-52 and frequently in samples L-4, L-30, and L-65.

⁷⁵ Hanna, G. D., The diatoms of Sharktooth Hill, Kern County, California: California Acad. Sci. Proc., 4th ser., vol. 20, No. 6, p. 168, 1932.

⁷⁶ Lebour, M. V., The planktonic diatoms of northern seas, p. 55, 1930.

⁷⁴ Hustedt, Friedrich, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 539, 1929.

Family **HEMIDISCACEAE**
 Subfamily **HEMIDISCOIDEAE**
 Genus **HEMIDISCUS** Wallich, 1860

Hemidiscus cuneiformis Wallich, s. l.

Plate 16, figures 1, 2, 5

- Hemidiscus cuneiformis* Wallich, London Micr. Soc. Trans., new ser., vol. 8, p. 42, pl. 2, figs. 3, 4, 1860.
 Ralfs, in Pritchard, History of the Infusoria, 4th ed., p. 853, pl. 6, fig. 14, 1861.
 Mann, Contr. U. S. Nat. Herbarium, vol. 10, pt. 5, p. 316, 1907.
 Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 904, fig. 542, 1930.
 Hendey, Discovery Repts., vol. 16, p. 264, 1937.
Euodia gibba Bailey. Ralfs, in Pritchard, History of the Infusoria, 4th ed., p. 852, pl. 8, fig. 22, 1861.
 Boyer, Acad. Nat. Sci. Philadelphia Proc., vol. 78, supplement, p. 87, 1926.
Euodia cuneiformis (Wallich) Schütt, in Engler and Prantl, Natürliche Pflanzenfamilien, Teil 1, Abteilung 16, p. 100, 1896.
 Gran, Nordisches Plankton, Lief. 3, p. 45, 1905.
Euodia inornata Castracane, Challenger Repts., Botany, vol. 2, p. 149, pl. 12, fig. 1, 1886.

Different authors have expressed very decided and diverse views regarding the disposition of this species and its varieties. Mann (3d citation above) could see no reason for making certain "species" such as *Hemidiscus rectus* (Castracane) Mann and *H. ventricosa* (Castracane) Mann varieties of *H. cuneiformis*. With considerable justification he says, "On the other hand, it should be here noted that the striking build of the members of this genus leads to the too easy conclusion that all cuneiform frustules bearing a reasonably close resemblance to the original species, *Hemidiscus cuneiformis* Wall, must be mere varieties of it." Hustedt (4th citation above), on the other hand, after a careful study of the situation, recognized four varieties of *H. cuneiformis*, namely, *gibba*, *recta*, *ventricosa*, and *orbicularis*, all as members of a closely related group or "formenkreis."

Hendey (5th citation above), finding himself unable to accept either of these alternatives, referred all his forms to *H. cuneiformis*. He says:

Much variation in outline has been observed, and many species and varieties have been created upon such variable characters as the ratio between the apical and transapical axes, the degree of gibbosity displayed upon the ventral side, the convexity of the dorsal side, and the development of the marginal spinulae and pseudo-ocellus. From the vast amount of material examined from such widespread areas as the waters around the Cape of Good Hope, the west coast of Africa, the mid-Atlantic, and the Humbolt current in the Pacific, specimens were obtained forming a series of intermediate forms that made it impossible to recognize the value of the nomenclatorial species and varieties. All of the specimens observed have been referred to *H. cuneiformis* Wallich.

My own experience in dealing with a fairly large number of forms from the cores has caused me to agree with Hendey, although I believe it safer to add *sensu lato* to the name when so used.

The forms found in the cores and referred to this species were quite variable in size and shape, but the two figured forms were the most common. My figures 1 and 5 would be Hustedt's variety *ventricosa*, and figure 2 would be near his variety *orbicularis*.

This is an oceanic species with a wide distribution in tropical and subtropical seas, although it is occasionally found in the North Atlantic as an introduced species.⁷⁷

Dimensions of figured specimens

Figure	U. S. G. S. diatom catalog number	U. S. G. S. diatom locality number	Sample number	Length	Width
1-----	1970-2	2858	L-52	114	74
2-----	1967-15	2857	L-51	49	43
5-----	1970-13	2858	L-52	69	51

Found rarely in samples L-1, L-49, L-52, and L-54, frequently in samples L-2, L-6, L-30, L-51, and L-59, and commonly in samples L-4 and L-65.

Family **ACTINODISCEAE**
 Subfamily **ASTEROLAMPROIDEAE**
 Genus **ASTEROMPHALUS** Ehrenberg, 1844

Asteromphalus roperianus var. **atlanticus** Castracane

Plate 16, figure 6

- Asteromphalus roperianus* var. *atlanticus* Castracane, Challenger Repts., Botany, vol. 2, p. 133, pl. 5, fig. 3, 1886.
 De Toni, Sylloge algarum omnium hucusque cognitarum, vol. 2, p. 1411, 1894.

Castracane's original figure of this diatom is drawn with more geometric precision than similitude; otherwise the specimen found in the core agrees perfectly. The two characteristics which Castracane used in his description to differentiate his variety from the species, the straight inner edge of the sectors and the failure of the hyaline rays to reach the margin, are well exhibited in the present specimen. Unfortunately, the convexity of the valve is so great that the margin is out of focus in my photomicrograph and the latter characteristic is not shown clearly. The validity of the variety depends on the constancy of these characteristics, but this could not be tested in the present case, as only one specimen was found. Rattray⁷⁸ says in his description of *A. roperianus*, " * * * the intervals broad, their edges parallel, the outer ends sometimes slightly expanded, not reaching the border." On the other hand, Hendey,⁷⁹ who had a great many specimens of *A. roperianus* at his disposal says in his excellent description, "Hyaline rays proceed from the central area to the periphery." If Hendey's diagnosis of the species is correct, and I feel sure that it is, then Castracane's variety is a

⁷⁷ Lebour, M. V., The planktonic diatoms of northern seas, p. 56, 1930.

⁷⁸ Rattray, John, A revision of the genus *Coscinodiscus* and some allied genera: Royal Soc. Edinburgh Proc., vol. 16, p. 657, 1889.

⁷⁹ Hendey, N. L., The plankton diatoms of the southern seas: Discovery Repts., vol. 16, p. 270, 1937.

valid one. In my specimen the margin is very narrow and the hyaline rays stop 2 to 3μ from the periphery. Hexagonal areolae continuous with those on each sector fill the space between the end of the ray and the periphery.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1960-1), 71μ . From sample L-54 (U. S. G. S. diatom locality 2860), 206-213 cm. below the top of core 9.

Found rarely in sample L-54.

Subfamily ACTINOPTYCHOIDEAE

Genus ACTINOPTYCHUS Ehrenberg, 1843

***Actinoptychus bipunctatus* Lohman n. sp.**

Plate 16, figures 7, 10-12

Valve discoid, divided into 10 sectors, alternately raised or depressed. Central area indefinite in outline, sometimes hyaline, but usually covered with fine, scattered punctae in no definite arrangement. Raised⁸⁰ sectors covered with large rounded polygonal markings, 7 to 8 in 10μ , which appear round under medium or low magnification. Depressed sectors covered with similar markings overlain by fine puncta, 19 to 20 in 10μ , arranged in rows parallel to the center, radial row in each sector. Narrow, hyaline space occasionally across outer ends of raised sectors only. Marginal apiculi usually opposite the center of all sectors, occasionally only in depressed (bipunctate) sectors. Occasional valves have one to three apiculi perpendicular to the plane of the valve and in the sectors about one-fifth to one-fourth of the radius away from the margin. Margin narrow, 0.7 to 1.0μ wide, covered with fine decussate puncta, 20 to 22 in 10μ . Diameter, 25 to 35μ .

Holotype: U. S. G. S. diatom catalog no. 2000-1 (figs. 10-12), diameter, 34μ . Paratype: U. S. G. S. diatom catalog no. 1970-10 (fig. 7), diameter 26μ . Both from U. S. G. S. diatom locality 2858. Sample L-52 from 142-151 cm. below the top of core 9, taken at a depth of 2,050 fathoms in lat. $49^{\circ}40'00''$ N. and long. $28^{\circ}29'00''$ W. by C. S. Piggot, 1936.

The fine puncta on the depressed sectors can be seen with difficulty with a 4-mm. apochromat used at nearly full aperture and are quite obvious under a 2-mm. oil immersion apochromat. When a dry objective is used with an effective numerical aperture of around 0.50, the fine puncta on the depressed sectors are not visible, and the diatom somewhat resembles *A. parvus* Mann.⁸¹ Mann's species, however, in addition to having identical markings on all sectors, is much less undulate and never has a hyaline space across the outer ends of any sectors. In the present species, the narrow hyaline space across the outer ends of the raised sectors is definitely seen with some difficulty and is never present across the ends of the

depressed bipunctate sectors. The fine puncta in the bipunctate depressed sectors extend into and become continuous with the marginal puncta, but the coarser markings in the same sectors stop about 1μ short of the margin, giving the appearance of a hyaline space when viewed with objectives of insufficient aperture to resolve the finer puncta. These obviously illusory spaces in the depressed sectors are more visible under low and medium magnifications than the real spaces in the raised sectors.

Hanna and Grant⁸² have figured a 10-sectored specimen of *A. maculatus* Grove and Sturt, of about the same size as the present species which might be confused with it. *A. bipunctatus* has a narrower margin with the same type of markings throughout, whereas *A. maculatus*⁸³ has the symmetrical group of coarse marginal puncta opposite each bipunctate sector, has coarse markings (maculations) in alternate sectors and fine markings throughout (the reverse is true in the present species), and has a prominent hyaline space opposite the sectors with fine markings only.

A large number of individuals of this species were found in the cores, and the characters as given above were remarkably constant, with the following exceptions: The scattered puncta in the central area ranged from prominent in most specimens to absent in a few; the marginal apiculi were present on all sectors in most cases and on alternate sectors in a few specimens. The number of sectors, usually considered to be a feature of minor importance in this genus, was uniformly 10 in all specimens observed.

Found rarely in samples L-30, L-50, L-51, and L-59, and frequently in samples L-31, L-52, and L-54.

***Actinoptychus campanulifer* Schmidt**

Plate 16, figure 8

Actinoptychus campanulifer Schmidt, Atlas der Diatomaceenkunde, pl. 29, figs. 13-15, 1875.

The occurrence of this diatom in the cores is the first known to me since its original discovery by Schmidt from Rio Brasil in 1875. The broad hyaline submarginal space on alternate sectors, with pronounced marginal apiculi on intervening sectors, are distinguishing features that are constant among the specimens studied.

The specimen figured is the best one found, and unfortunately it was tilted somewhat in mounting, so that only half of the valve is in focus.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1984-5), 33μ . From sample L-65 (U. S. G. S. diatom locality 2878), 0-7 cm. below the top of core 13.

Found rarely in samples L-62 and L-65.

⁸⁰ The terms "raised" and "depressed" may be interchanged if the valve is viewed from the opposite side.

⁸¹ Mann, Albert, Marine diatoms of the Philippine Islands: U. S. Nat. Mus. Bull. 100, vol. 6, part 1, p. 15, pl. 1, fig. 8, 1925.

⁸² Hanna, G. D., and Grant, W. M., Miocene marine diatoms from Maria Madre Island, Mexico: California Acad. Sci., 4th ser., vol. 15, no. 2, p. 122, pl. 11, figs. 8, 9, 1926.

⁸³ Grove, Edmund, and Sturt, Gerald, On a fossil marine diatomaceous deposit from Oamaru, Otago, New Zealand: Quekett Micr. Club Jour., ser. 2, vol. 3, p. 64, pl. 5, fig. 5, 1887.

Actinoptychus senarius (Ehrenberg) Ehrenberg

Plate 16, figure 9

- Actinocyclus senarius* Ehrenberg, Die Infusionsthierchen als vollkommene Organismen, p. 172, pl. 21, fig. 6, 1838.
- Actinoptychus senarius* (Ehrenberg) Ehrenberg, Berlin K. Akad. Wiss. Physikal. abh., 1841, p. 400, pl. 1, fig. 27, 1843.
- Hendey, Discovery Repts., vol. 16, p. 271, 1937.
- Actinocyclus* sp. Bailey, Am. Jour. Sci., 1st ser. vol. 42, pl. 2, fig. 11, 1842.
- Actinocyclus undulatus* Kützing, Die kieselchaligen Bacillarien oder Diatomeen, p. 132, pl. 1, fig. 44, 1844.
- Omphalopelta areolata* Ehrenberg, K. akad. Wiss. Berlin, Ber. 1844, p. 270, 1845.
- Ehrenberg, Mikrogeologie, pl. 33, group 13, fig. 17; pl. 35A, group 18, fig. 2, 1854.
- Actinoptychus undulatus* (Kützing) Ralfs, in Pritchard, A history of Infusoria, 4th ed., p. 839, pl. 5, fig. 88, 1861.
- Actinoptychus omphalopelta* Grunow, in Fenzl, Reise der Österreichischen Fregatte Novara um die Erde in Jahren 1857, 1858, 1859, Bot. Theil, Band 1, p. 25, 1870.
- Actinoptychus undulatus* Kützing, Grunow, idem, p. 25, 1870.
- Actinoptychus undulatus* var. *senarius* Grunow, idem, p. 25, 1870.
- Actinoptychus undulatus* Ehrenberg, Schmidt, Komm. zur Untersuchung der deutschen Meer in Kiel, p. 94, pl. 3, figs. 29, 30, 1874.
- Schmidt, Atlas der Diatomaceenkunde, pl. 1, figs. 1-4, 1875; pl. 109, fig. 1, 1886; pl. 132, fig. 16, 1888.
- Van Heurck, Synopsis diatomées Belgique, pl. 22B, fig. 14, 1880; pl. 122, figs. 1, 3, 1883; p. 210, 1885.
- Actinoptychus undulatus* var. *microsticta* Grunow, in Van Heurck, Synopsis diatomées Belgique, pl. 122, figs. 2, 4, 1883.
- Actinoptychus undulatus* Ehrenberg, Van Heurck, Treatise on the Diatomaceae, p. 493, fig. 232; p. 494, fig. 234; p. 496, pl. 22, fig. 648, 1896.
- Actinoptychus undulatus* (Bailey) Ralfs, Mann, Contr. U. S. Nat. Herbarium, vol. 10, pt. 5, p. 272, 1907.
- Actinoptychus undulatus* (Kützing) Ralfs, Boyer, The Diatomaceae of Philadelphia and vicinity, p. 24, pl. 4, figs. 1, 2, 4, 6, 1916.
- Actinoptychus undulatus* (Bailey?) Ralfs, Boyer, Acad. Nat. Sci. Philadelphia Proc., vol. 78, supplement, p. 64, 1926.
- Actinoptychus undulatus* (Bailey), Hanna and Grant, California Acad. Sci. Proc., 4th ser., vol. 15, no. 2, p. 124, pl. 12, fig. 4, 1926.
- Actinoptychus undulatus* Ehrenberg, Hanna, Jour. Paleontology, vol. 1, no. 2, p. 108, 1927.
- Actinoptychus undulatus* Ralfs, Karsten, in Engler, Die natürlichen Pflanzenfamilien, Band 2, Bacillariophyta, p. 219, fig. 236, a, b, 1928.
- Coupin, Album général des Diatomées, pl. 294, fig. H, 1930.
- Actinoptychus undulatus* (Bailey) Ralfs, Hustedt, Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 475, fig. 264, 1929.
- Hanna, California Acad. Sci. Proc. 4th ser., vol. 20, No. 6, p. 172, 1932.
- Mills, An Index to the Genera and Species of the Diatomaceae, vol. 1, p. 117, 1933.
- Actinoptychus undulatus* Ehrenberg, Lohman, U. S. Geol. Survey Prof. Paper 189-C, p. 82, pl. 20, fig. 8; pl. 22, fig. 3, 1938.

Although the above list may seem unnecessarily long and detailed, it is only a fragment of the available synonymy of this species. The present synonymy has been given in considerable detail to show the uncertainty with which the name *Actinoptychus undulatus*

has been used in the past by different authors, and to justify Hendey's action⁸⁴ in invoking the rule of strict priority by returning to Ehrenberg's original name, *Actinoptychus senarius*. In each of the citations the authorship of the species is given, exactly as it appears in the paper cited. The synonymy itself presents such a graphic picture of the uncertainty with which the name *Actinoptychus undulatus* has been used by different authors (occasionally even by the same author in different works) that the point hardly needs elaboration here.

As Hendey's excellent volume on the planktonic diatoms of the southern seas may not be available to many, his argument for changing the name of this well-known diatom deserves to be repeated here. He says:⁸⁵

It has been often said that there existed in the minds of early diatomists a confusion between *Actinoptychus* and *Actinocyclus*. Although this has now been settled, the following notes are included in order to make clear the reasons which have led to changes being made in the names of some well-known species. Ehrenberg (1838, p. 171)⁸⁶ established the genus *Actinocyclus*. Two species were described and figured, *A. senarius* and *A. octonarius*. Later, other forms were added, and Ehrenberg, realizing that the genus contained more than one group, desired to make a separation. Ehrenberg (1840a)⁸⁷ introduced a subgenus in the following manner:

"*Actinocyclus* (*Actinoptychus*) *senarius*, synonym *Actinocyclus senarius* 1838." Later Ehrenberg ((1841) 1843, p. 400)⁸⁸ established the genus *Actinoptychus*. On a previous page (p. 328), and in the description of the plates, the combination *Actinoptychus senarius* was used, and there is reason to believe from the similarity of the figures provided that *Actinoptychus senarius* Ehrenberg was based on *Actinocyclus senarius* (1838). Ehrenberg (1843, p. 400) explained that the separation was necessary on account of structural differences that existed in *Actinocyclus* (1838) and continued at some length to explain the differences upon which the separation was made. *Actinocyclus octonarius* (1838) was retained as the type species of *Actinocyclus*. The species *Actinoptychus senarius* is often attributed to Bailey in the following manner: "*Actinoptychus undulatus* Bailey," but there appear to be no grounds for this. Bailey (1842)⁸⁹ mentioned the occurrence of a number of species of *Actinocyclus* in fossil material from Richmond, Virginia, and provided figures which undoubtedly represented the species under consideration here, but the figures were unnamed. Ehrenberg (1843, p. 328) accepted Bailey's figure as being equal to his *Actinoptychus senarius*. Kützing (1844)⁹⁰ took Bailey's illustration as a type illustration and described *Actinocyclus undulatus*. Ralfs (1861)⁹¹ placed this species in

⁸⁴ Hendey, N. I., The plankton diatoms of the southern seas: *Discovery* Repts., vol. 16, p. 271, 1937.

⁸⁵ Hendey, N. I., idem., p. 271.

⁸⁶ Ehrenberg, C. G., Die Infusionsthierchen als vollkommene Organismen, p. 171, 1838.

⁸⁷ Ehrenberg, C. G., Über noch jetzt zahlreich lebende Thierarten der Kreidebildung und den Organismus der Polythalamien: K. Akad. Wiss. Berlin. Physikal. Abh. 1839, p. 137, pl. 4, fig. 1a-e, 1841.

⁸⁸ Ehrenberg, C. G., Verbreitung und Einfluss des mikroskopischen Lebens in Süd- und Nord-Amerika: Berlin K. Akad. Wiss. Physikal. Abh., 1841, p. 400, 1843.

⁸⁹ Bailey, J. W., A sketch of the infusoria of the family Bacillaria, with some account of the most interesting species which have been found in a recent or fossil state in the United States: Am. Jour. Sci., vol. 42, p. 93, pl. 2, fig. 11, 1842.

⁹⁰ Kützing, F. T., Die kieselchaligen Bacillarien oder Diatomeen, p. 132, pl. 1, fig. 44, 1844.

⁹¹ Ralfs, John, in Pritchard, Andrew, A history of Infusoria, 4th ed., p. 839, pl. 5, fig. 88, 1861.

the genus *Actinoptychus*, but accepted Kützing's epithet. Ehrenberg's epithet is used here to satisfy claims of priority.

This is another case (see *Actinocyclus octonarius* Ehrenberg, p. 77) where there is no choice between the claims of strict priority and the "common sense" view of allowing a well-established name to stand.

This neritic species is common in subtropical seas, and Lebour⁹² has reported it from "all parts of the North Sea, Norwegian Seas, Danish Seas, Skaggerak, Baltic, North Atlantic, Finland, English Channel, West Coast of France, Mediterranean, Atlantic and Pacific American coasts." Its geologic range is Eocene⁹³ to Recent.

Diameter of figured specimen (U. S. G. S. diatom catalog no. 1958-1): 39 μ . From sample L-52 (U. S. G. S. diatom locality 2858), 142-151 cm. below the top of core 9.

Found rarely in samples L-23, L-31, L-32, L-37, and L-52 and frequently in sample L-10.

Suborder BIDDULPHINEAE

Family CHAETOCERACEAE

Subfamily CHAETOCEROIDEAE

Genus CHAETOCEROS Ehrenberg, 1844

Subgenus PHAEOCEROS Gran, 1897

Chaetoceros atlanticum Cleve

Plate 17, figure 1

Chaetoceros atlanticum Cleve, K. svenska vetensk. akad. Handl., Band 1, no. 13, p. 11, pl. 2, fig. 8, 1873.

Gran, Nordisches Plankton, Lief. 3, p. 64, fig. 74, 1905.

Hustedt, in Schmidt, Atlas der Diatomaceenkunde, pl. 337, fig. 1, 2, 1921.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 641, fig. 363, 1930.

Hendey, Discovery Repts., vol. 16, p. 290, 1937.

Chaetoceros dispar Castracane, Challenger Repts., Botany, vol. 2, p. 76, pl. 8, fig. 6, 1886.

Chaetoceros audax Schütt, Deutsche bot. Gesell. Ber., Band 13, p. 47, pl. 5, fig. 25, 1895.

Chaetoceros polygonum Schütt, Deutsche bot. Gesell. Ber., Band 13, p. 46, pl. 5, fig. 24, 1895.

This oceanic species is common in north polar and North Atlantic waters and is frequently found in European seas farther south. Hendey (5th citation above) notes that it prefers a high salinity and although common in south temperature seas is seldom found in Antarctic waters.

Major axis of valve in specimen figured (U. S. G. S. diatom catalog no. 1957-4), 27 μ . From sample L-52 (U. S. G. S. diatom locality 2858), 142-151 cm. below the top of core 9.

Found rarely in sample L-30 and frequently in sample L-52.

⁹² Lebour, M. V., The planktonic diatoms of northern seas, p. 51, fig. 27, 1930.

⁹³ Hanna, G. D., The lowest known tertiary diatoms in California: Jour. Paleontology, vol. 1, no. 2, p. 108, 1927. (From Kreyenhagen shale in Phoenix Canyon, Fresno County, California, then considered by Hanna to be Lower Miocene in age, but now thought to be Upper Eocene.)

Suborder SOLENIINEAE

Family RHIZOSOLENIACEAE

Subfamily RHIZOSOLENIOIDEAE

Genus RHIZOSOLENIA Ehrenberg, 1843, emend. Brightwell, 1858

Rhizosolenia bergonii H. Peragallo

Plate 17, figure 2

Rhizosolenia bergonii H. Peragallo, Le Diatomiste, vol. 1, p. 110, pl. 15, fig. 5, 1892.

Gran, Nordisches Plankton, Lief. 3, p. 51, fig. 60, 1905.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 575, fig. 327, 1929.

Lebour, The planktonic diatoms of northern seas, p. 102, fig. 74b, 1930.

Rhizosolenia amputata Ostenfeld, in Schmidt, Bot. Tidsskrift., Band 25, p. 227, fig. 4, 1902.

Hustedt, in Schmidt, Atlas der Diatomaceenkunde, pl. 318, fig. 1-3, 1920.

Only the spines of this oceanic species were found and these rarely. The characteristic canal, cup-shaped at the apex and inflated at the base, and the fine markings on the shoulder serve to identify these fragments.

It is usually found in tropical and subtropical seas. Lebour (4th citation above) gives the northerly limit of this species as lat. 48° N.

Length of fragment figured (U. S. G. S. diatom catalog no. 1961-1), 88 μ . From sample L-55 (U. S. G. S. diatom locality 2861), 246-250 cm. below the top of core 9.

Found rarely in sample L-55.

Rhizosolenia styliiformis Brightwell

Plate 17, figures 3, 4

Rhizosolenia styliiformis Brightwell, Quart. Jour. Micr. Sci., vol. 6, p. 95, pl. 5, fig. 5, 1858.

Peragallo, H., Le Diatomiste, vol. 1, p. 111, pl. 17, fig. 5, 1892.

Van Heurck, Treatise on the Diatomaceae, p. 415, fig. 133; pl. 17, fig. 601, 1896.

Gran, Nordisches Plankton, Lief. 3, p. 54, 1905.

Hustedt, in Schmidt, Atlas der Diatomaceenkunde, pl. 316, figs. 1-4, 8-11, 1914.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 584, fig. 333, 1929.

Hendey, Discovery Repts., vol. 16, p. 320, pl. 11, figs. 15-17, 1937.

Kain and Schultze⁹⁴ have reported this species from beds that are probably equivalent to the Calvert formation (middle Miocene) of Maryland, from a depth of 387-638 feet in a well at Atlantic City, N. J. Brun and Tempère⁹⁵ also reported this species as abundant in a calcareous shale of probable upper Miocene age in Sendai, Japan. Its occurrence in these older rocks is particularly interesting, as the cell wall in this species is usually much less highly silicified than in other diatoms. Many specimens were found in the cores, but

⁹⁴ Kain, C. H., and Schultze, E. A., On a fossil marine diatomaceous deposit from Atlantic City, N. J.: Torrey Bot. Club Bull., vol. 16, p. 76, 1889.

⁹⁵ Brun, J., and Tempère, J., Diatomées fossiles du Japon: Genève Soc. Phys. Hist. Nat. Mém., tome 30, No. 9, p. 73, 1889.

in each case only the apical spines and small portions of the valve were preserved. The winglike projections near the base of the spine are clearly shown in figure 3.

This is an oceanic species of world-wide distribution, common in both tropical seas and in the colder sub-Arctic and sub-Antarctic waters.

Over-all lengths of fragments figured

Figure	U. S. G. S. diatom catalog number	U. S. G. S. diatom locality number	Sample number	Length in μ
4-----	1960-2	2860	L-54	92
3-----	1964-5	2864	L-2	75

Found rarely in samples L-3, L-6, L-31, and L-54 and frequently in samples L-2, L-4, L-30, and L-37.

Suborder ARAPHIDINEAE

Family FRAGILARIACEAE

Subfamily FRAGILARIOIDEAE

Genus RHAPHONEIS Ehrenberg, 1844

Rhaphoneis surirella (Ehrenberg) Grunow

Plate 17, figure 6

Zygoceros surirella Ehrenberg, K. Akad. Wiss. Berlin Abh., pl. 4, fig. 12, 1840.⁹⁶

Ralfs, in Pritchard, History of the Infusoria, 4th ed., p. 850, pl. 11, figs. 50, 51, 1861.

Rhaphoneis surirella (Ehrenberg) Grunow, in Van Heurck, Synopsi diatomées Belgique, pl. 36, fig. 26, 27a, 1881.

De Toni, Sylloge algarum omnium hucusque cognitarum, vol. 2, p. 712, 1892.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 2, p. 173, fig. 679 a-c, 1931.

Dimcrogramma surirella Grunow, K. svenska vetensk. akad. Handl., Band 5, no. 8, p. 11, 1878.

Fragilaria surirella Schönfeldt, Die deutschen Diatomeen des Süßwassers und des Brackwassers, p. 103, 1907.

Rhaphoneis surirella Ehrenberg, Hustedt, in Schmidt, Atlas der Diatomaceenkunde, pl. 267, figs. 47-49, 1911.

The pseudoraphe in this species is frequently expanded near the apices. In the specimen found in the core, the pseudoraphe was parallel-sided throughout its length. Hustedt (5th citation above) has figured both forms.

This species lives in brackish and salt water and is frequently found in brackish estuaries and along the coast of southern Europe.

Length of figured specimen (U. S. G. S. diatom catalog no. 1984-4), 36 μ . From sample L-66 (U. S. G. S. diatom locality 2878), 0-7 cm. below the top of core 13.

Found rarely in sample L-66.

Genus THALASSIOTHRIX Cleve and Grunow, 1880

Thalassiothrix longissima Cleve and Grunow

Plate 17, figure 5

Synedra thalassiothrix Cleve, K. svenska vetensk. akad. Handl., Bihang, Band 1, no. 13, p. 22, pl. 4, fig. 24, 1873.

⁹⁶ This citation is doubtful, as I have been unable to find the original. Reference here taken from Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 2, p. 173, 1931.

Thalassiothrix longissima Cleve and Grunow, K. svenska vetensk. akad. Handl., Band 17, no. 2, p. 108, 1880.

Heiden and Kolbe, Deutsche Südpolar-Expedition, Band 8, Botanik, Heft 5, p. 565, pl. 6, fig. 123, 1928.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 2, p. 247, fig. 726, 1932.

Hendey, Discovery Repts., vol. 16, p. 336, 1937.

This diatom, the longest known, attains a length of 4 mm. with an average width of only 3 to 4 μ . As only fragments of varying length are found in anything but recent material, it is easily confused with *Thalassionema nitzschioides* (Grunow) Hustedt, which has somewhat similar markings. The latter species, however, grows in stellate or zigzag clusters, and individual frustules rarely attain a length of 100 μ .

It occurs commonly to frequently in middle Miocene⁹⁷ and later rocks in California. In general the forms assigned to this species from the cores are somewhat heavier-walled than the California forms; otherwise they are identical. In the Upper Miocene Monterey formation in California, concentrations of this diatom occur in the form of thin partings in shale up to beds several inches thick, in which it forms a very large percentage of the material present. No such concentrations were observed in the cores.

Brun and Tempère⁹⁸ found it in considerable abundance in Japan in what are now considered to be upper Miocene rocks. In my report on the Pliocene diatoms from the Kettleman Hills, Calif.,⁹⁹ I erroneously assigned this diatom to *Thalassionema nitzschioides* Grunow.

It is a true pelagic marine cold-water diatom and is very common in the Arctic seas, the North Atlantic, along the European coasts, and in the South Atlantic and South Pacific.

Although one of the most abundant species found in the cores, no whole specimens were found. The fragments ranged from 3 μ to 6 μ in width, and 30 μ to 165 μ in length.

Dimensions of figured specimen (fragment) (U. S. G. S. diatom catalog no. 1957-9): Length, 165 μ ; maximum width, 6 μ . From sample L-52 (U. S. G. S. diatom locality 2858), 142-151 cm. below the top of core 9.

Found rarely in sample L-6, L-7, L-8, L-16, L-49, L-53, L-59, and L-61, frequently in samples L-1, L-2, L-3, L-20, L-23, L-33, L-50, and L-55, commonly in samples L-10, L-19, L-32, L-37, L-51, L-52, L-54, and L-56, and abundantly in samples L-4, L-30 and L-31.

⁹⁷ Lohman, K. E., Comparison of the diatom floras from the Temblor formation (middle Miocene) in California with those from the Calvert (middle Miocene) in Maryland and Virginia: MS. (Report in preparation).

⁹⁸ Brun, Jacques and Tempère, J., Diatomées fossiles du Japon. Espèces marines et nouvelles des calcaires argileux de Sendai et de Yedo: Genève Soc. Physique Hist. Nat. Mém., tome 30, no. 9, p. 74, 1889.

⁹⁹ Lohman, K. E., Pliocene diatoms from the Kettleman Hills, California: U. S. Geol. Survey Prof. Paper 189-C, p. 83, 1937.

Suborder **RAPHIDIOIDINEAE**
 Family **EUNOTIACEAE**
 Genus **EUNOTIA** Ehrenberg, 1837

Eunotia praerupta Ehrenberg var. **bidens** (W. Smith) Grunow

Plate 17, figure 7

Himantidium bidens Ehrenberg. W. Smith, Synopsis of the British Diatomaceae, vol. 2, p. 13, pl. 33, fig. 284, 1854.

Eunotia praerupta Ehrenberg var. *bidens* (W. Smith) Grunow, in Van Heurck, Synopsis diatomées Belgique, pl. 34, figs. 20, 21, 1881.

Grunow, Akad. Wiss. Wien, Math.-naturwiss. Kl., Denkschr., Band 48, p. 48, pl. 2 (B), fig. 12, 1884.

Hustedt, in Schmidt, Atlas der Diatomaceenkunde, pl. 273, figs. 26-28, 32, 33, 1911.

Hustedt, in Pascher, Die Süßwasser-flora Mitteleuropas, Heft 10, p. 174, fig. 213, 1930.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 2, p. 281, figs. 747A, i-m, 1932.

Eunotia bigibba Gregory (not Kützing), Quart. Jour. Micr. Sci., 1854, p. 95, pl. 4, fig. 3.

William Smith, in his original (?) description of *Himantidium bidens* cited Ehrenberg as the author, but no one has since been able to discover where or when Ehrenberg described it. The authority is, therefore, attributed to Smith.

This is another fresh-water diatom that must have been transported many miles to be deposited on a mid-Atlantic sea bottom.

Length of figured specimen (U. S. G. S. diatom catalog no. 1987-1), 69 μ . From sample L-39 (U. S. G. S. diatom locality 2894), 275-281 cm. below the top of core 6.

Found rarely in sample no. L-39.

Genus **PSEUDOEUNOTIA** Grunow, 1881

Pseudoeunotia doliolus (Wallich) Grunow

Plate 17, figure 12, 13

Synedra doliolus Wallich, Micr. Soc. London Trans., new ser., vol. 8, p. 48, pl. 2, fig. 19, 1860.

Pseudoeunotia doliolus (Wallich) Grunow, in Van Heurck, Synopsis diatomées Belgique, pl. 35, fig. 22, 1881.

Mann, U. S. Nat. Mus. Bull. 100, vol. 6, pt. 1, p. 140, pl. 30, figs. 7-8, 1925.

Heiden and Kolbe, Deutsche Südpolar-Expedition 1901-1903, Band 8, Botanik, Heft 5, p. 558, 1928.

Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 2, p. 259, fig. 737, 1932.

Himantidium? *doliolus* Grunow, Zool.-bot. Gesell. Wien Verh., Band 12, p. 342, 1862.

Hustedt's figure (5th citation above) is somewhat misleading, as he does not show the heavy, double-beaded margin that is clearly shown in Grunow's figures (2d citation above) and in Mann's figures (3d citation above). It is very prominent on the forms found in the cores. My specimens have the same slender, produced apices shown in Mann's figures, and not the broader apices shown by Hustedt.

This is a littoral, warm-water species found along the coast of southern Europe and around the Philippine

Islands. It has never been reported from the North or West Atlantic, and its presence in the cores suggests long travel before deposition.

Dimensions of figured specimen (U. S. G. S. diatom catalog no. 2000-2): Length, 75 μ ; width, 8 μ . From sample L-52 (U. S. G. S. diatom locality 2858), 142-151 cm. below top of core 9.

Found rarely in samples L-10, L-37, L-51, and L-52.

Suborder **MONORAPHIDINEAE**

Family **ACHNANTHACEAE**

Subfamily **ACHNANTHOIDEAE**

Genus **RHOICOSPHENIA** Grunow, 1860

Rhoicosphenia curvata (Kützing) Grunow

Plate 17, figure 8

Gomphonema curvatum Kützing, Linnaea, vol. 8, p. 567, pl. 16, fig. 51, 1833.

Rhoicosphenia curvata (Kützing) Grunow, in Fenzl, Reise der Österreichischen Fregatte Novara um die Erde, Bot. Theil, Band 1, Algen, p. 8, 1870.

Van Heurck, Synopsis diatomées Belgique, p. 127 (1885), pl. 26, fig. 1-3, 1880.

Schmidt, Atlas der Diatomaceenkunde, pl. 213, figs. 1-5, 1899.

Pantocsek, Die Kieselalgen oder Bacillarien des Balaton, p. 60, pl. 7, figs. 155, 156, 1901.

Boyer, Diatomaceae of Philadelphia and vicinity, p. 56, pl. 19, figs. 25-27, 1916.

Hustedt, in Pascher, Die Süßwasser-flora Mitteleuropas, Heft 10, p. 211, fig. 311, 1930.

Hustedt, Die Kieselalgen, Deutschlands, Österreichs, und der Schweiz, Teil 2, p. 431, fig. 879, 1933.

Gomphonema fractum Schumann, Königsberg physikal.-ökonomische Gesell. Schr., Band 3, p. 187, pl. 9, fig. 32, 1863.

Rhoicosphenia fracta Rabenhorst, Flora Europaea algarum, p. 292, 1864.

Rhoicosphenia curvata var. *fracta* Cleve, K. svenska vetensk. akad. Handl., Band 27, no. 3, p. 166, 1895.

Rhoicosphenia linearis Östrup, Danske Diatomeer, p. 120, pl. 3, fig. 74, 1910.

This widely distributed fresh-water and brackish-water form was probably introduced into the basin of deposition by currents.

Dimensions of specimen figured (U. S. G. S. diatom catalog no. 1951-2): Length (as shown), 68 μ ; maximum width, 14 μ . From sample L-10 (U. S. G. S. diatom locality 2854), 74-79 cm. below the top of core 4.

Found rarely in sample L-10.

Suborder **BIRAPHIDINEAE**

Family **NAVICULACEAE**

Subfamily **NAVICULOIDEAE**

Genus **NAVICULA** Bory, 1822

Navicula pennata Schmidt

Plate 17, figure 14

Navicula pennata Schmidt, Atlas der Diatomaceenkunde, pl. 48, fig. 41-43, 1876.

Cleve, K. svenska vetensk. akad. Handl., Band 27, no. 3, p. 32, 1895.

Mann, Contr. U. S. Nat. Herbarium, vol. 10, pt. 5, p. 349, 1907.

Boyer, Diatomaceae of Philadelphia and vicinity, p. 96, pl. 27, fig. 22, 1916.

Lohman, U. S. Geol. Survey Prof. Paper 189-C, p. 84, pl. 22, fig. 16, 1938.

Mann (see 3d citation above) has listed as synonyms of this species, *N. kinkeri* Pantocsek,¹ *N. pinnata* Pantocsek,² and *Scoliopleura szakalensis* Pantocsek,³ which for several reasons does not appear to have been a wise choice. The type of *N. pennata* Schmidt came from the Mediterranean Sea and has since been found living in several other localities. Neither *N. kinkeri* or *N. pinnata* have been found living and hence may be of value in stratigraphy if kept separate from *N. pennata*. Cleve⁴ combined *Scoliopleura szakalensis* and *Navicula kinkeri* as *Navicula pennata* var. *kinkeri*, which appears to be a satisfactory solution of the difficulty. Cleve retained *N. pinnata* Pantocsek as a separate species, and several other authors have followed.⁵

This is a warm-water species of wide distribution at present and is known from the Pliocene⁶ to the Recent.

Dimensions of figured specimen (fragment) (U. S. G. S. diatom catalog no. 1964-1): Length, 75 μ ; width, 17 μ ; costae, 4-5 in 10 μ . From sample L-2 (U. S. G. S. diatom locality 2864), 40-48 cm. below the top of core 3.

Found rarely in samples L-2 and L-66.

Genus *DIPLONEIS* Ehrenberg, 1844

Diploneis interrupta (Kützinger) Cleve

Plate 17, figure 15

Navicula interrupta Kützinger, Die kieselschaligen Bacillarien oder Diatomeen, p. 100, pl. 29, fig. 93, 1844.

Diploneis interrupta (Kützinger) Cleve, K. svenska vetensk. akad. Handl., Band 26, no. 2, p. 84, 1894.

Boyer, Acad. Nat. Sci. Philadelphia Proc., vol. 79, supplement, p. 348, 1927.

Hustedt, in Pascher, Süßwasser-flora Mitteleuropas, Heft 10, p. 252, fig. 400, 1930.

Navicula interrupta Kützinger. Donkin, The natural history of the British Diatomaceae, pt. 1, p. 47, pl. 7, fig. 2, 1870.

Schmidt, Atlas der Diatomaceenkunde, pl. 12, figs. 3-11, 1875; pl. 69, fig. 24, 1881.

Van Heurck, Synopsis diatomées Belgique, p. 89, 1885; pl. 9, figs. 7, 8, 1880.

Navicula interrupta var. *novae-seelandiae* Schmidt, Atlas der Diatomaceenkunde, pl. 12, fig. 12, 1875.

Diploneis didyma Ehrenberg, K. Akad. Wiss. Berlin, Physikal. Abh., 1870, pl. 2, fig. 13, 1871.

Navicula puella Schmidt, Atlas der Diatomaceenkunde, pl. 69, fig. 25, 1881.

This brackish-water and marine species is one of the most tolerant diatoms known. It occurs in brack-

ish to almost fresh water, under truly marine conditions, and under an equally wide variety of temperatures. Cleve⁷ listed the following habitats for this diatom:

Spitzbergen, Beeren Eiland (Lagst.), Kara, Finmark, North Sea, Baltic (Tornea to Rügen), Mediterranean Sea, Red Sea (Grun.), Java, Samoa, Australia, Auckland (Grun.), Cape Good Hope (Atl.), Atlantic Coast of America, Greenland, Arctic America, Franzenbad, Halle, Great Salt Lake.

The reference to Great Salt Lake above is misleading, as it implies that *Diploneis interrupta* is living in the highly saline water of the Great Salt Lake. In 1870 Ehrenberg⁸ published a paper on diatoms from California in which he lists *D. didyma* (= *D. interrupta*) from three samples of "Sehr weisse, mehlartige, leichte Erde" cataloged as "Salt Lake Nr. 6550, Nr. 6551, and Nr. 6559," on pages 14, 15, and 16 respectively. In his checklist, facing page 68, the same samples are again listed by "Salt Lake Nr. 6550" etc., but without the lithologic description given in the text. It appears that Cleve, in making his list of habitats, used the checklist and thought that Ehrenberg's material from Salt Lake was living in the lake water. Patrick,⁹ who studied the diatoms in mud samples around the shores of the Great Salt Lake, says, "No diatom flora is found living in the lake proper today."

Dimensions of figured specimen (U. S. G. S. diatom catalog no. 1986-1): Length, 33 μ ; maximum width, 13 μ ; width at constriction, 7 μ ; costae, 11 in 10 μ . From sample L-37 (U. S. G. S. diatom locality 2893), 226-230 cm. below the top of core 6.

Found rarely in sample L-37.

Diploneis smithii (Brébisson) Cleve

Plate 17, figure 18

Navicula smithii Brébisson, in Smith, Wm., Synopsis of the British Diatomaceae, vol. 2, p. 92, 1856.

Diploneis smithii (Brébisson) Cleve, K. svenska vetensk. akad. Handl., Band 26, No. 2, p. 96, 1894.

Boyer, Acad. Nat. Sci. Philadelphia Proc., vol. 79, supplement, p. 354, 1927.

Hustedt, in Pascher, Die Süßwasser-flora Mitteleuropas, Heft 10, p. 253, fig. 402, 1930.

Lohman, U. S. Geol. Survey Prof. Paper 189-C, p. 84, pl. 23, fig. 10, 1938.

Navicula smithii Brébisson. Schmidt, Atlas der Diatomaceenkunde, pl. 7, figs. 14-20, 1875.

Van Heurck, Synopsis diatomées Belgique, p. 91, 1885; pl. 9, fig. 12, 1880; supplement, pl. B, fig. 23, 1884.

Mann, Contr. U. S. Nat. Herbarium, vol. 10, pt. 5, p. 354, 1907.

Hanna and Grant, California Acad. Sci. Proc., ser. 4, vol. 15, No. 2, p. 155, pl. 19, fig. 1, 1926.

¹ Pantocsek, Josef, Beiträge zur Kenntnis der fossilen Bacillarien Ungarns, Teil 2, p. 50, pl. 9, fig. 169, 1889.

² Idem, Teil 2, p. 54, pl. 20, fig. 308.

³ Idem, Teil 2, p. 57, pl. 8, fig. 154.

⁴ Cleve, P. T., A synopsis of the naviculoid diatoms, part 2: K. svenska vetensk. akad. Handl., Band 27, no. 3, p. 33, 1895.

⁵ Mills, F. W., An index to the genera and species of the Diatomaceae, part 15, p. 1120, 1934.

⁶ Lohman, K. E., Pliocene diatoms from Kettleman Hills, California: U. S. Geol. Survey Prof. Paper 189-C, p. 84, pl. 22, fig. 16, 1938.

⁷ Cleve, P. T., Synopsis of the naviculoid diatoms: K. svenska. vetensk. akad. Handl., Band 26, no. 2, p. 84, 1894.

⁸ Ehrenberg, C. G., Über die wachsende Kenntniss des unsichtbaren Lebens als felsbildende Bacillarien in Californien: K. Akad. Wiss. Berlin Physikal. Abh. 1870, No. 1, pp. 1-74, pls. 1-3, 1871.

⁹ Patrick, Ruth, Some diatoms of Great Salt Lake: Torrey Bot. Club Bull., vol. 63, p. 165, 1936.

Hanna and Grant, Jour. Paleontology, vol. 3, no. 1, p. 98, pl. 13, fig. 5, 1929.

Navicula elliptica W. Smith, Synopsis of the British Diatomaceae, vol. 1, p. 48, pl. 17, fig. 152a, 1853.

Navicula doczyi Pantocsek, Beiträge zur Kenntniss der fossilen Bacillarien Ungarns, Teil 2, p. 45, pl. 14, fig. 247, 1889.

Navicula (Diploneis) smithii (Brébisson) Cleve. Reinhold, Nederland en Koloniën Geol.-Mijnbouw. Genootschap, Verh., geol. ser., Deel 12, p. 112, pl. 14, fig. 11, 1937.

This diatom has a world-wide distribution in marine and brackish waters in warm, temperate, and cold zones. The specimen figured is an elongate, elliptical form, but others in the same sample were somewhat more angular, approaching the one illustrated in plate 7, figure 18, of Schmidt's Atlas.

Dimensions of figured specimen (U. S. G. S. diatom catalog no. 1981-1): Length, 81μ ; width, 39μ . From sample L-60 (U. S. G. S. diatom locality 2873), 233-237 cm. below the top of core 10.

Found rarely in samples L-51 and L-60.

***Diploneis weissflogii* (Schmidt) Cleve**

Plate 17, figure 16

Navicula weissflogii Schmidt, Gesell. Naturwiss. Zeitschr., Band 41, p. 406, pl. 6, figs. 3, 4, 1873.

Diploneis weissflogii (Schmidt) Cleve, K. svenska vetensk. akad. Handl., Band 26, No. 2, p. 91, 1894.

Boyer, Acad. Nat. Sci. Philadelphia Proc., vol. 79, supplement, p. 351, 1927.

Navicula weissflogii Schmidt. Van Heurck, Synopsis diatomées Belgique, p. 90, supplement, pl. A, fig. 21, 1885.

Van Heurck, Treatise on the Diatomaceae, p. 194, pl. 3, fig. 148, 1896.

Reinhold, Nederland en Koloniën, Geol.-Mijnbouw, Genootschap, Verh., geol. ser., Deel 12, p. 112, pl. 13, fig. 7, 1937.

Cleve¹⁰ has included *Navicula diversa* Greville¹¹ in the synonymy of this species with a query. If Greville's description and figure are accurate, the query should stand, as his species is much less constricted, the central transverse bars have the small nodules at the outer ends rather than towards the center, and the markings are much finer, with a stauriform central space. Greville's species should, therefore, not be combined with *Diploneis weissflogii*, although Peragallo¹² and Mills¹³ (possibly ignoring Cleve's query) have done so.

This is a temperate to warm water species with a known geologic range of upper Miocene¹⁴ to Recent.

Dimensions of figured specimen (U. S. G. S. diatom catalog no. 1972-3): Length, 36μ ; maximum width, 16μ ; width at constriction, 11μ . From sample L-4

(U. S. G. S. diatom locality 2866), 130-137 cm. below top of core 3.

Found rarely in sample L-4.

Genus PLEUROSIGMA Wm. Smith, 1852

***Pleurosigma naviculaceum* Brébisson**

Plate 17, figure 17

Pleurosigma naviculaceum Brébisson, Cherbourg Soc. Sci. Nat. Mém., tome 2, p. 17, fig. 7, 1854.

Cleve and Grunow, K. svenska vetensk. akad. Handl., Band 17, no. 2, p. 51, 1880.

Van Heurck, Synopsis diatomées Belgique, p. 116, supplement, pl. C, fig. 35, 1885.

Peragallo, Le Diatomiste, vol. 1, p. 11, pl. 4, figs. 19, 23, 1891.

Cleve, K. svenska vetensk. akad. Handl., Band 26, No. 2, p. 36, 1894.

Boyer, Diatomaceae of Philadelphia and vicinity, p. 74, pl. 22, fig. 6, 1916.

Pleurosigma transversale W. Smith, Synopsis of the British Diatomaceae, vol. 2, p. 96, 1856.

Pleurosigma japonicum Castracane, Challenger Repts., Botany, vol. 2, p. 38, pl. 29, fig. 14, 1886.

This species is most frequently found in tropical waters, although Cleve¹⁵ has reported it from the North Sea and Boyer¹⁶ has reported it from Long Island Sound. In the material studied for this report it was found only in the two easternmost cores.

Dimensions of figured specimen (U. S. G. S. diatom catalog no. 1984-1): Length, 87μ ; width, 21μ . From sample L-66 (U. S. G. S. diatom locality 2878), 0-7 cm. below the top of core 13.

Found rarely in sample L-62 and frequently in sample L-66.

Family BACILLARIACEAE

Subfamily NITZSCHIOIDEAE

Genus NITZSCHIA Hassall, 1845

***Nitzschia marina* Grunow**

Plate 17, figure 10, 11

Nitzschia marina Grunow, in Cleve and Grunow, K. svenska vetensk. akad. Handl., Band 17, No. 2, p. 70, 1880.

Grunow, in Van Heurck, Synopsis diatomées Belgique, pl. 57, fig. 26-27, 1881.

De Toni, Sylloge algarum omnium hucusque cognitarum, vol. 2, Bacillarieae, p. 500, 1891.

Mann¹⁷ erroneously combined this species with *Nitzschia angustata* (Wm. Smith) Grunow. The differences between the two are as follows:

	<i>N. angustata</i>	<i>N. marina</i>
Length-----	25-110 μ	95-165 μ
Width-----	5-10 μ	8-9.5 μ
Length-width ratio----	5-11	12-17
Longitudinal fold-----	Usually present	Never present
Transverse striae-----	8-13 in 10 μ	12 in 10 μ
Puncta in transverse striae.	18-20 in 10 μ	19 in 10 μ
Arrangement of puncta in transverse striae.	Single rows	Double, staggered rows.

¹⁰ Cleve, P. T., Synopsis of the naviculoid diatoms, part 1: K. svenska vetensk. akad. Handl., Band 26, no. 2, p. 91, 1894.

¹¹ Greville, R. K., Descriptions of new genera and species of diatoms from the South Pacific: Edinburgh New Philos. Jour., new ser., vol. 18, p. 186, pl. 4, fig. 14, 1863.

¹² Peragallo, M., Catalogue général des Diatomées, p. 313, 1897.

¹³ Mills, F. W., An index to the genera and species of the Diatomaceae, part 9, p. 628, 1934.

¹⁴ Reinhold, Th., Nederland en Koloniën, Geol.-Mijnbouw. Genootschap, Verh., geol. ser., Deel 12, p. 72, 1937.

¹⁵ Cleve, P. T., Synopsis of the naviculoid diatoms, part 1: K. svenska vetensk. akad. Handl., Band 26, no. 2, p. 36, 1894.

¹⁶ Boyer, C. S., The Diatomaceae of Philadelphia and vicinity, p. 74, 1916.

¹⁷ Mann, Albert, Diatoms of the *Albatross* voyages: Contr. U. S. Nat. Herbarium, vol. 10, part 5, p. 379, 1907.

The most significant difference is the last one in the table, namely the arrangement of the puncta in the transverse striae. In *N. angustata* the puncta are arranged in single rows; in *N. marina* the puncta are arranged in double rows, with the puncta in any one row opposite the space between puncta in the adjacent row. Furthermore, the puncta in each pair are closer together than those in adjacent pairs, which is very well shown on the lower part of plate 17, figure 11. When viewed with a high-power dry objective the doubling is extremely difficult to see, and the transverse striae appear to be composed of a single row of puncta. Under the increased resolving power of an oil-immersion objective of N. A. 1.30, however, the staggered double rows are very easily observed. The much greater length-width ratio of *N. marina* is another consistent difference.

This species has a wide geographic distribution, from the Mediterranean Sea to the North Atlantic, off Lower California, and in the Arctic Ocean. It has not been reported as abundant in any locality, and the ecologic data in the literature is very sketchy. After a careful review of the literature the most reasonable conclusion appears to be that it is a marine neritic species inhabiting cold to warm waters, with a preference for cold waters. For the purpose of computing the distribution of the temperature facies of the diatoms from the cores (see table 13 and plate 11) this species has been considered to be a cold-water, neritic one.

Dimensions of figured specimen (U. S. G. S. diatom catalog no. 1942-1): Length, 139 μ ; maximum width, 9.5 μ ; transverse striae, 12 in 10 μ ; puncta, 19 in 10 μ . From sample L-30 (U. S. G. S. diatom locality 2838), 0-4.5 cm. below the top of core 6.

Found rarely in samples L-51, L-54, L-59, and L-65 and frequently in samples L-10, L-30, L-31, and L-37.

Nitzschia panduriformis Gregory

Plate 17, figure 9

Nitzschia panduriformis Gregory, Royal Soc. Edinburg Trans., vol. 21, p. 529, pl. 14, fig. 102, 1857.

Van Heurck, Synopsis diatomées Belgique, p. 172, 1885; pl. 58, figs. 1-4, 1881.

Wolle, Diatomaceae of North America, pl. 44, figs. 3, 4, 9, 1894.

Mann, Contr. U. S. Nat. Herbarium, vol. 10, pt. 5, p. 380, 1907.

Hustedt, in Schmidt, Atlas der Diatomaceenkunde, pl. 331, figs. 19-21, 1921.

Boyer, Acad. Nat. Sci. Philadelphia Proc., vol. 79, supplement, p. 497, 1927.

Nitzschia latestriata var. *panduriformis* Rabenhorst, Flora Europaea algarum, Sectio I, p. 154, 1864.

Tryblionella panduriformis (Gregory) Pelletan, Les diatomées, histoire naturelle, p. 29, fig. 284, 1891.

My specimens agree in shape and structure with the form figured by Hustedt in Schmidt's Atlas, plate 331, figure 20, but are somewhat smaller. Hustedt's specimen is 126 μ long and 31 μ wide, whereas the one here figured is 89 μ long and 20 μ wide; in both the transverse rows of dots are 15 in 10 μ , and the other features are similar. Hustedt labeled his figure *Nitzschia panduriformis* Gregory, which is here considered correct. Mills¹⁸ has referred Hustedt's figure 20 (only) to *N. panduriformis* var. *lata* (Witt) Grunow, which must have been a mistake. Grunow¹⁹ in defining his variety *lata*, says:

Schale breiter mit mehr abgerundeten Enden, sonst ganz ähnlich und durch zahlreiche Mittelformen welche grösser oder kleiner und in der Mitte mehr oder weniger eingeschnürt sind, mit der Hauptart zusammenhängend. Querstreifen 13-18 in 0.01 mm. (*Tryblionella lata* O. Witt).

Grunow's description, obviously does not agree with Hustedt's figure 20, which differs from the type only in having a slightly higher length-width ratio. This ratio is not constant in *N. panduriformis* and varies materially in the specimens from the core. I have referred my specimens to Gregory's species as interpreted by Hustedt.

This marine and brackish-water species is found along both the Atlantic and Pacific coasts, usually in temperate waters.

Dimensions of figured specimen (U. S. G. S. diatom catalog no. 1982-3): Length, 89 μ ; maximum width, 20 μ ; width at constriction, 17 μ ; transverse and oblique rows of dots, 15 in 10 μ ; keel puncta, 6 in 10 μ . From sample L-61 (U. S. G. S. diatom locality 2874), 258-263 cm. below the top of core no. 10.

Found rarely in sample L-61.

¹⁸ Mills, F. W., An index to the genera and species of the Diatomaceae, part 16, p. 1225, 1934.

¹⁹ Grunow, Albert, in Cleve, P. T., and Grunow, Albert, Beiträge zur Kenntniss der arctischen Diatomeen: K. svenska vetensk. akad. Handl., Band 17, no. 2, p. 71, 1880.

PLATES 12-17

PLATE 12

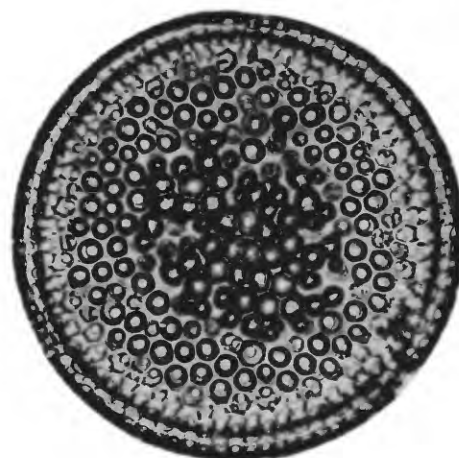
- FIGURE 1. *Melosira sulcata* (Ehrenberg) Kützing. U. S. G. S. diatom catalog no. 1983-1, locality 2876. Diameter, 32μ . $\times 1600$.
2. *Stephanodiscus astraea* (Ehrenberg) Grunow. U. S. G. S. diatom catalog no. 1962-1, locality 2862. Diameter, 38μ . $\times 1000$.
3. *Endictya oceanica* Ehrenberg. U. S. G. S. diatom catalog no. 1970-16, locality 2858. Diameter, 84μ . $\times 700$.
4. *Endictya robusta* (Greville) Hanna and Grant. U. S. G. S. diatom catalog no. 1958-2, locality 2858. Diameter, 108μ . $\times 475$.
5. *Podosira stelliger* (Bailey) Mann. U. S. G. S. diatom catalog no. 1984-2, locality 2878. Diameter, 56μ . $\times 770$. Focused on margin.
6. *Podosira stelliger* (Bailey) Mann. U. S. G. S. diatom catalog no. 1984-2, locality 2878. Diameter, 56μ . $\times 770$. Focused on central portion.
7. *Coscinodiscus excentricus* Ehrenberg. U. S. G. S. diatom catalog no. 1968-8, locality 2857. Diameter, 45μ . $\times 980$.
8. *Thalassiosira decipiens* (Grunow) Joergensen. U. S. G. S. diatom catalog no. 1970-4, locality 2858. Diameter, 30μ . $\times 1370$.
9. *Melosira granulata* (Ehrenberg) Ralfs. U. S. G. S. diatom catalog no. 1928-1, locality 2817. Length, 20μ ; diameter, 7μ . $\times 1280$.
10. *Coscinodiscus lineatus* Ehrenberg. U. S. G. S. diatom catalog no. 1967-5, locality 2857. Diameter, 89μ . $\times 670$.
11. *Thalassiosira baltica* (Grunow) Ostfeld. U. S. G. S. diatom catalog no. 1965-4, locality 2865. Diameter, 27μ . $\times 1000$.
12. *Coscinodiscus circumdatus* Schmidt. U. S. G. S. diatom catalog no. 1941-2, locality 2838. Diameter, 62μ . $\times 970$.



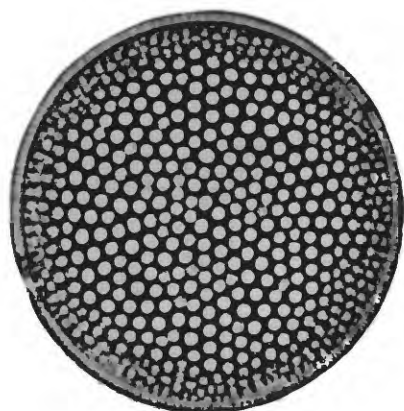
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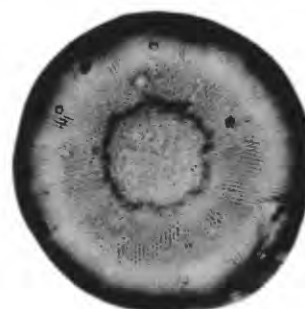
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4



5



6



7



11



8



10

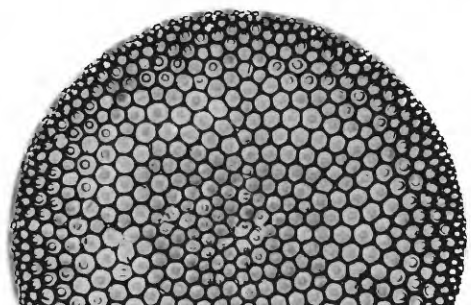


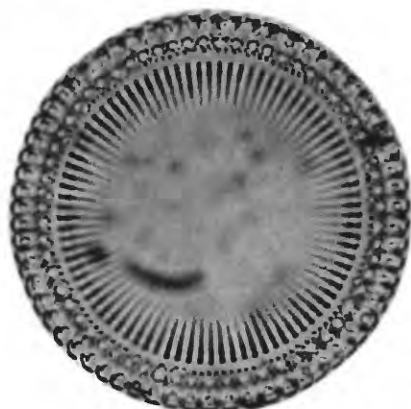
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12

DIATOMS FROM THE NORTH ATLANTIC DEEP SEA CORES.

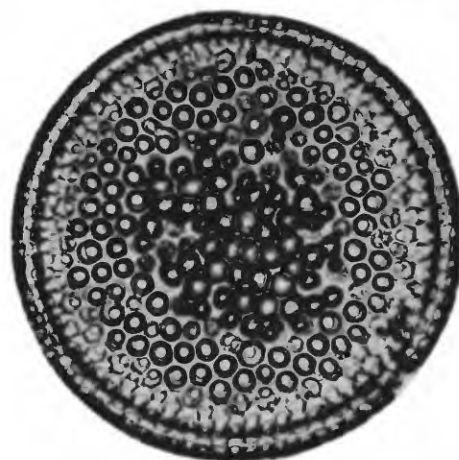




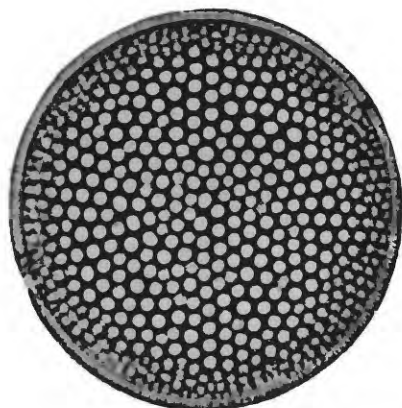
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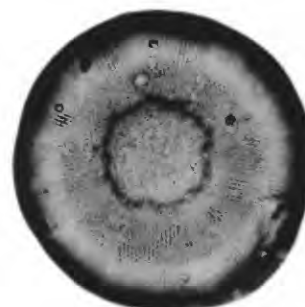
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4



5



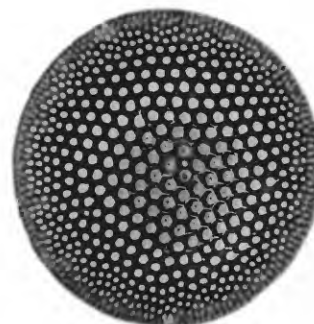
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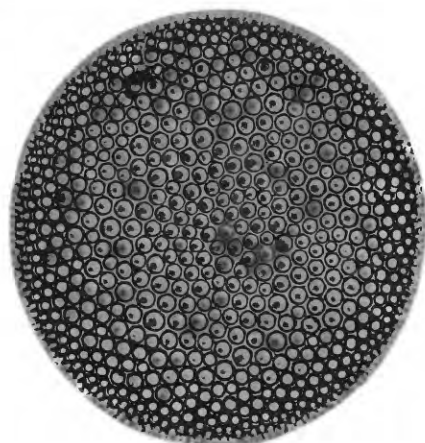


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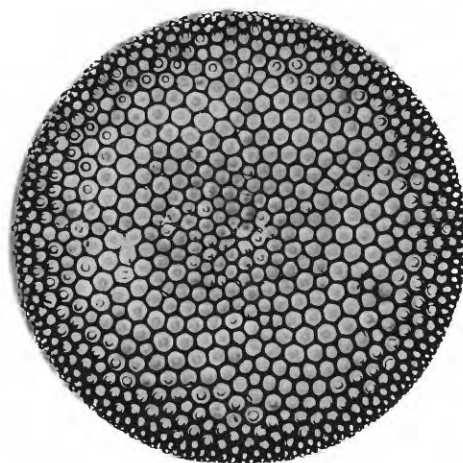
DIATOMS FROM THE NORTH ATLANTIC DEEP SEA CORES.



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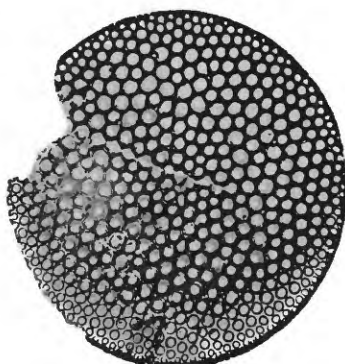
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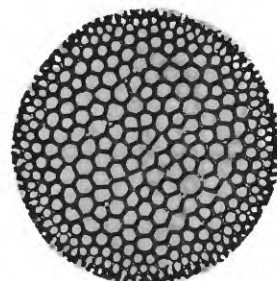
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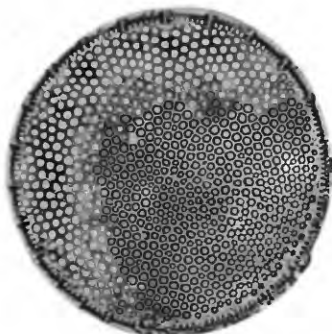
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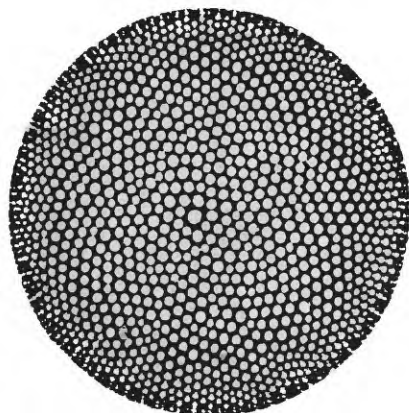
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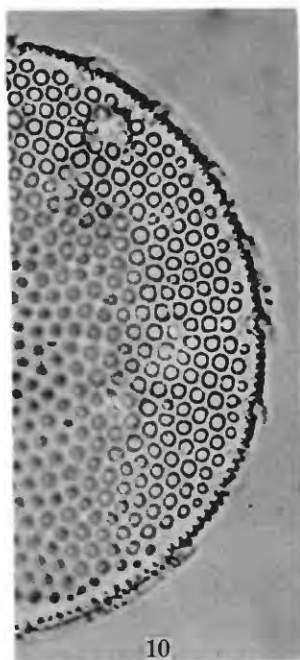
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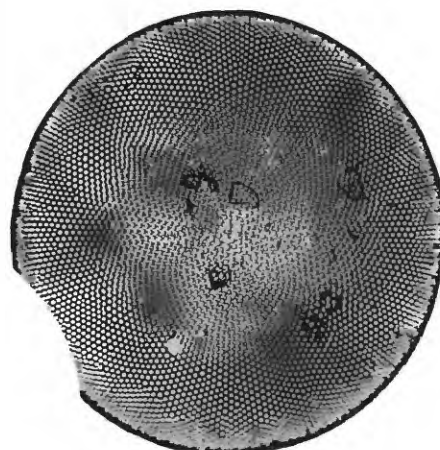
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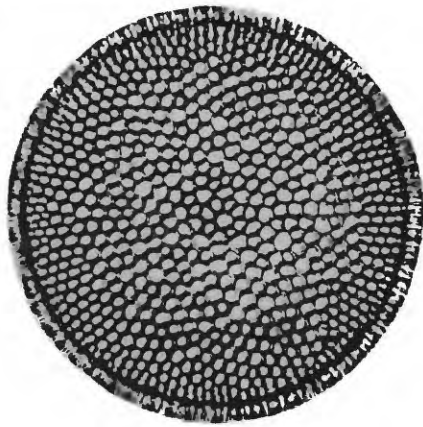
DIATOMS FROM THE NORTH ATLANTIC DEEP SEA CORES.

PLATE 13

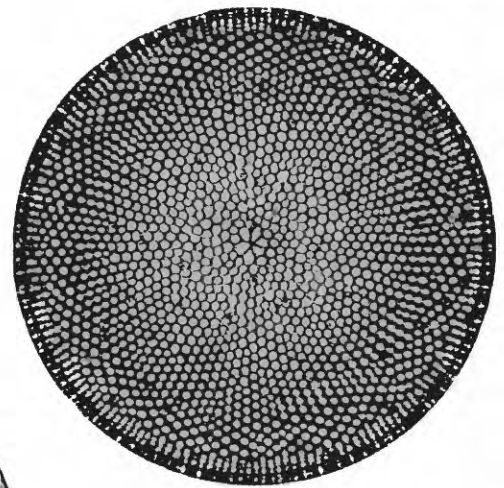
- FIGURE 1. *Coscinodiscus argus* Ehrenberg. U. S. G. S. diatom catalog no. 1968-2, locality 2857. Diameter, 71μ . $\times 780$.
2. *Coscinodiscus stellaris* Roper. U. S. G. S. diatom catalog no. 1970-14, locality 2858. Diameter, 62μ . $\times 640$.
3. *Coscinodiscus argus* Ehrenberg. U. S. G. S. diatom catalog no. 1968-3, locality 2857. Diameter, 77μ . $\times 760$.
4. *Coscinodiscus africanus* Janisch. U. S. G. S. diatom catalog no. 1972-1, locality 2866. Diameter, 41μ . $\times 1230$.
5. *Coscinodiscus kurzii* Grunow. U. S. G. S. diatom catalog no. 1951-1, locality 2854. Diameter, 62μ . $\times 750$.
6. *Coscinodiscus decrescens* Grunow. U. S. G. S. diatom catalog no. 1947-1, locality 2841. Diameter, 39μ . $\times 930$.
7. *Coscinodiscus africanus* Janisch. U. S. G. S. diatom catalog no. 1972-1, locality 2866. Diameter, 41μ . $\times 1050$.
8. *Coscinodiscus excentricus* Ehrenberg. U. S. G. S. diatom catalog no. 2000-3, locality 2858. Diameter, 39μ . $\times 900$.
9. *Coscinodiscus convexus* Schmidt. U. S. G. S. diatom catalog no. 1970-6, locality 2858. Diameter, 178μ . $\times 295$.
10. *Coscinodiscus africanus* Janisch. U. S. G. S. diatom catalog no. 1972-1, locality 2866. Diameter, 41μ . $\times 1900$.
11. *Coscinodiscus asteromphalus* Ehrenberg. U. S. G. S. diatom catalog no. 2004-2, locality 2864. Diameter, 198μ . $\times 293$.

PLATE 14

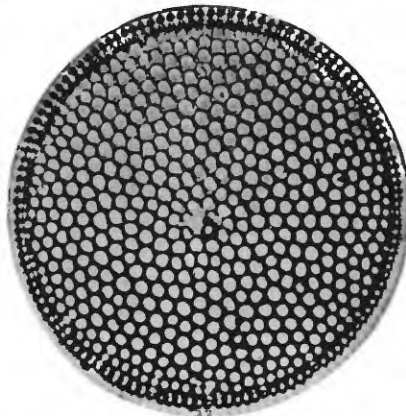
- FIGURE 1. *Coscinodiscus marginatus* Ehrenberg. U. S. G. S. diatom catalog no. 1967-17, locality 2857. Diameter, 115 μ . \times 474.
2. *Coscinodiscus oculus-iridis* Ehrenberg var. *borealis* (Bailey) Cleve. U. S. G. S. diatom catalog no. 1965-1, locality 2865. Diameter, 214. \times 295.
3. *Coscinodiscus nodulifer* Schmidt. U. S. G. S. diatom catalog no. 1967-9, locality 2857. Diameter, 51 μ . \times 1050.
4. *Coscinodiscus crenulatus* Grunow var. *nodulifer* Lohman, n. var. Paratype. U. S. G. S. diatom catalog no. 1957-11, locality 2858. Diameter, 37 μ . \times 1320.
5. *Coscinodiscus nodulifer* Schmidt. U. S. G. S. diatom catalog no. 1967-6, locality 2857. Diameter, 83 μ . \times 660.
6. *Coscinodiscus marginatus* Ehrenberg. U. S. G. S. diatom catalog no. 1967-19, locality 2857. Diameter, 97 μ . \times 485.
7. *Coscinodiscus radiatus* Ehrenberg. U. S. G. S. diatom catalog no. 1967-2, locality 2857. Diameter, 158 μ . \times 425.
8. *Coscinodiscus radiatus* Ehrenberg. U. S. G. S. diatom catalog no. 1967-10, locality 2857. Diameter, 71 μ . \times 880.



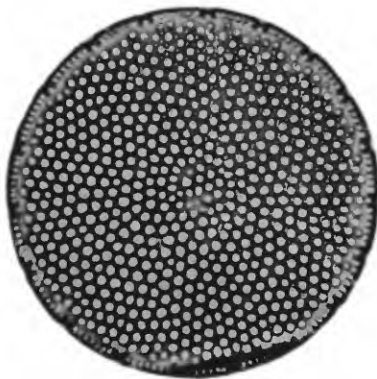
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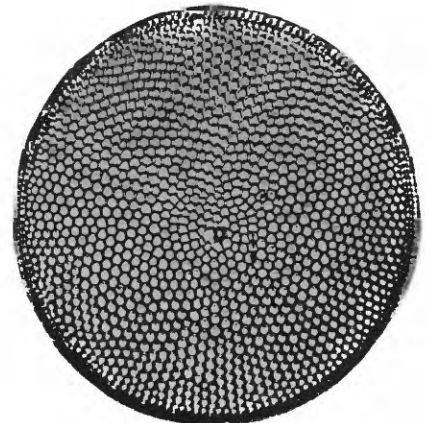
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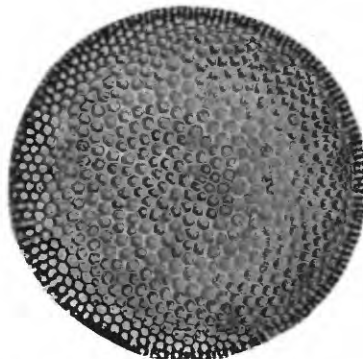
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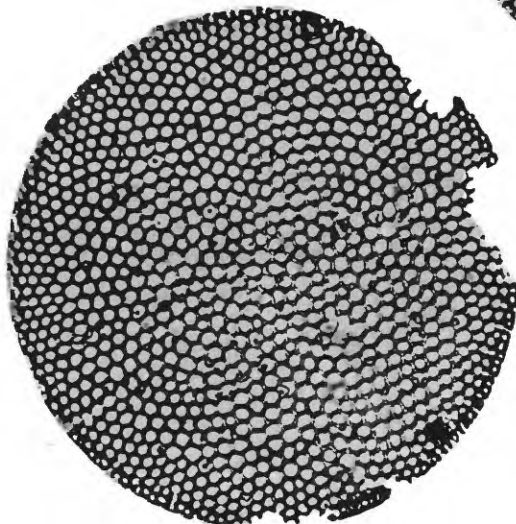
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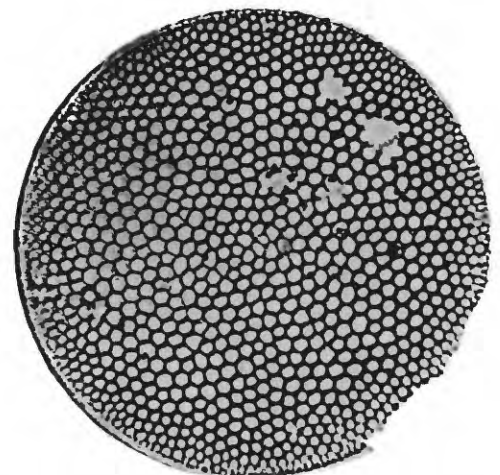
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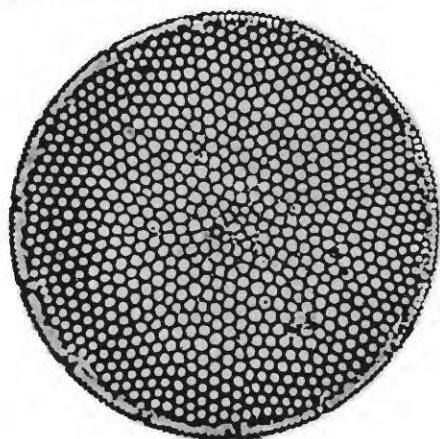


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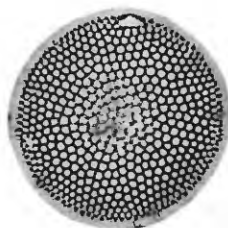
DIATOMS FROM THE NORTH ATLANTIC DEEP SEA CORES.



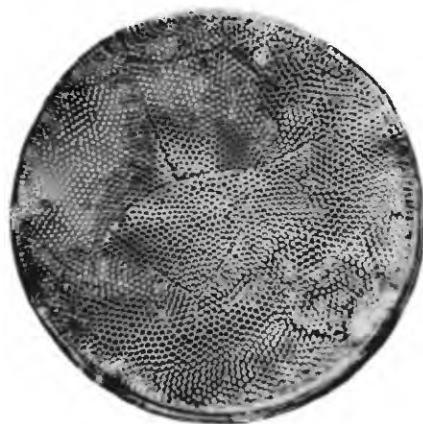
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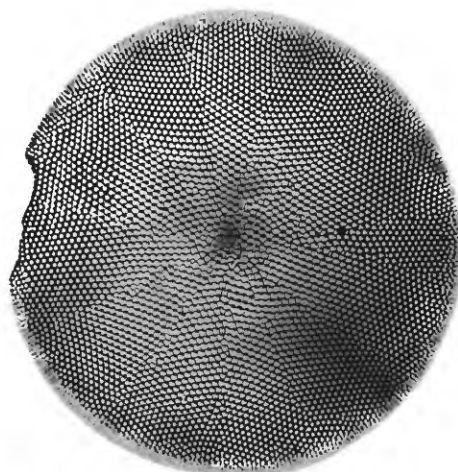
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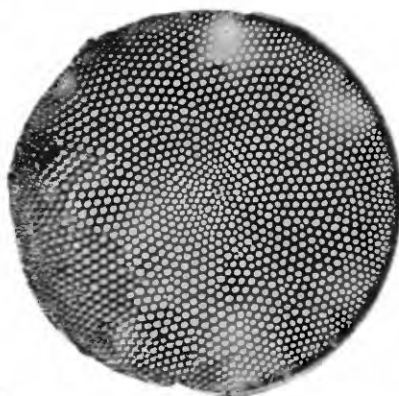
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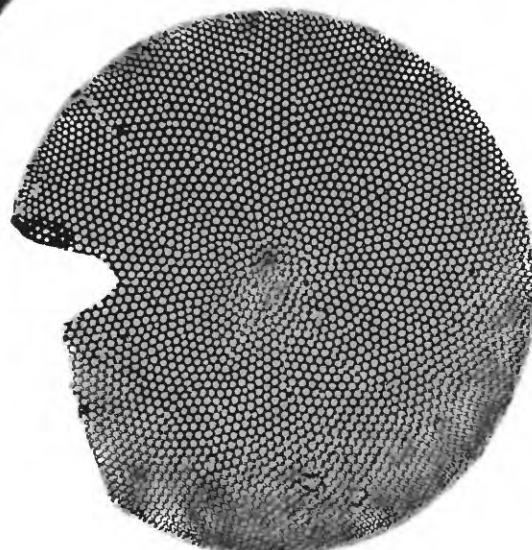
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DIATOMS FROM THE NORTH ATLANTIC DEEP SEA CORES.

PLATE 15

- FIGURE 1. *Coscinodiscus crenulatus* Grunow var. *nodulifer* Lohman, n. var. Holotype. U. S. G. S. diatom catalog no. 1970-3, locality 2858. Diameter, 40μ . $\times 1410$.
2. *Actinocyclus curvatulus* Janisch. U. S. G. S. diatom catalog no. 1957-2, locality 2858. Diameter, 66μ . $\times 930$.
3. *Coscinodiscus curvatulus* Grunow var. *minor* (Ehrenberg) Grunow. U. S. G. S. diatom catalog no. 1957-1, locality 2858. Diameter, 29μ . $\times 1000$.
4. *Coscinodiscus subtilis* Ehrenberg. U. S. G. S. diatom catalog no. 1972-8, locality 2866. Diameter, 48μ . $\times 1110$.
5. *Coscinodiscus bicurvatulus* Lohman, n. sp. Holotype. U. S. G. S. diatom catalog no. 1967-12, locality 2857. Diameter, 67μ . $\times 780$.
6. *Coscinodiscus denarius* Schmidt. U. S. G. S. diatom catalog no. 1968-4, locality 2857. Diameter, 76μ . $\times 790$.
7. *Coscinodiscus divisus* Grunow. U. S. G. S. diatom catalog no. 1970-11, locality 2858. Diameter, 57μ . $\times 1150$.
8. *Coscinodiscus curvatulus* Grunow. U. S. G. S. diatom catalog no. 1960-3, locality 2860. Diameter, 91μ . $\times 780$.

PLATE 16

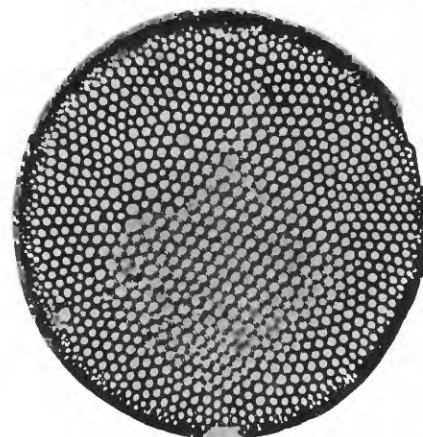
- FIGURE 1. *Hemidiscus cuneiformis* Wallich, s. l. U. S. G. S. diatom catalog no. 1970-2, locality 2858. Length, 114 μ ; width, 74 μ . \times 635.
2. *Hemidiscus cuneiformis* Wallich, s. l. U. S. G. S. diatom catalog no. 1967-15, locality 2857. Length, 49 μ ; width, 43 μ . \times 1000.
3. *Roperia tessellata* (Roper) Grunow. U. S. G. S. diatom catalog no. 1967-7, locality 2857. Diameter, 62 μ . \times 940.
4. *Actinocyclus octonarius* Ehrenberg (= *A. ehrenbergii* Ralfs). U. S. G. S. diatom catalog no. 1971-1, locality 2865. Diameter, 35 μ . \times 915.
5. *Hemidiscus cuneiformis* Wallich, s. l. U. S. G. S. diatom catalog no. 1970-13, locality 2858. Length, 69 μ ; width, 51 μ . \times 697.
6. *Asteromphalus roperianus* var. *atlanticus* Castracane. U. S. G. S. diatom catalog no. 1960-1, locality 2860. Diameter, 71 μ . \times 715.
7. *Actinoptychus bipunctatus* Lohman, n. sp. Paratype. U. S. G. S. diatom catalog no. 1970-10, locality 2858. Diameter 26 μ . \times 1770.
8. *Actinoptychus campanulifer* Schmidt. U. S. G. S. diatom catalog no. 1984-5, locality 2878. Diameter, 33 μ . \times 1030.
9. *Actinoptychus senarius* Ehrenberg (= *A. undulatus* of authors). U. S. G. S. diatom catalog no. 1958-1, locality 2858. Diameter, 39 μ . \times 1020.
10. *Actinoptychus bipunctatus* Lohman, n. sp. Holotype. U. S. G. S. diatom catalog no. 2000-1, locality 2858. Diameter, 34 μ . \times 1530.
11. *Actinoptychus bipunctatus* Lohman, n. sp. Holotype. U. S. G. S. diatom catalog no. 2000-1, locality 2858. Diameter, 34 μ . \times 1530.
12. *Actinoptychus bipunctatus* Lohman, n. sp. Holotype. U. S. G. S. diatom catalog no. 2000-1, locality 2858. Diameter, 34 μ . \times 1530.



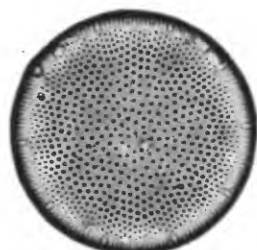
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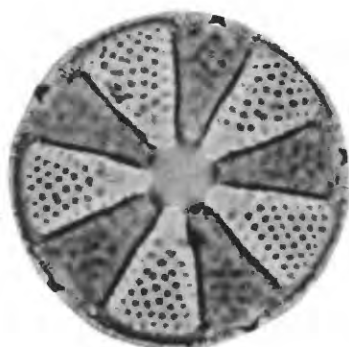
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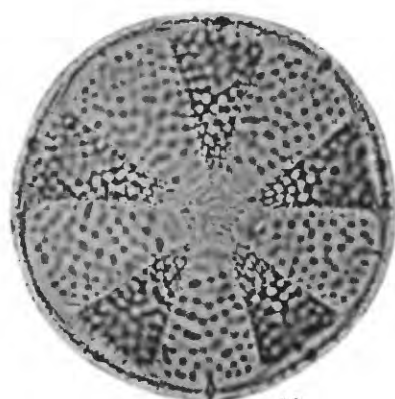
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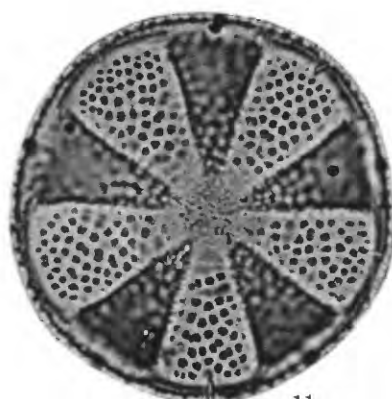
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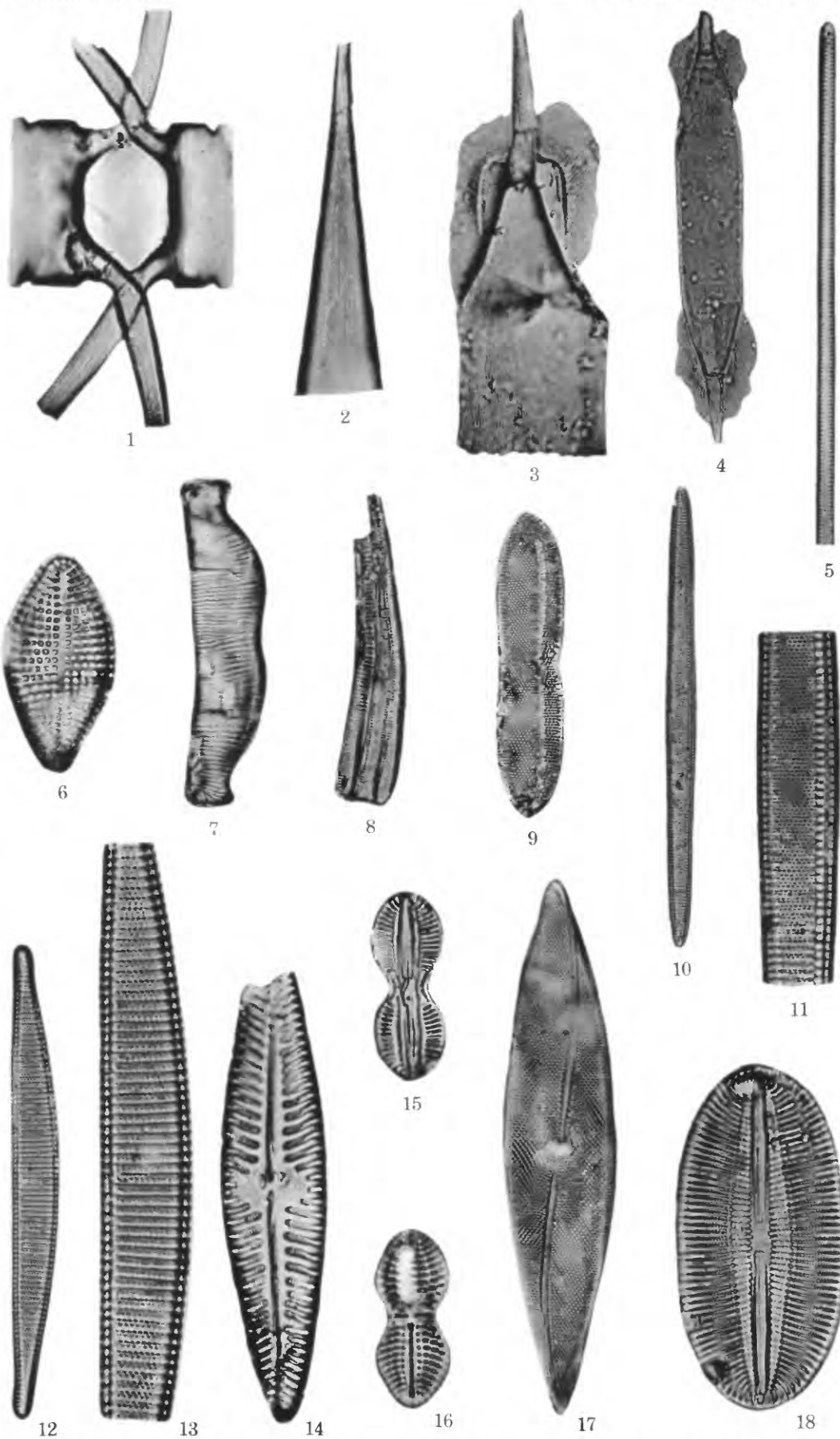


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12

DIATOMS FROM THE NORTH ATLANTIC DEEP SEA CORES.



DIATOMS FROM THE NORTH ATLANTIC DEEP SEA CORES.

PLATE 17

- FIGURE 1. *Chaetoceros atlanticum* Cleve. U. S. G. S. diatom catalog no. 1957-4, locality 2858. Major axis, 27μ . $\times 1000$.
2. *Rhizosolenia bergonii* H. Peragallo. U. S. G. S. diatom catalog no. 1961-1, locality 2861. Length of fragment, 88μ . $\times 670$.
 3. *Rhizosolenia styliformis* Brightwell. U. S. G. S. diatom catalog no. 1964-5, locality 2864. Length of fragment, 75μ . $\times 1000$.
 4. *Rhizosolenia styliformis* Brightwell. U. S. G. S. diatom catalog no. 1960-2, locality 2860. Length of fragment, 92μ . $\times 784$.
 5. *Thalassiothrix longissima* Cleve and Grunow. U. S. G. S. diatom catalog no. 1957-9, locality 2858. Length of fragment, 165μ . $\times 520$.
 6. *Rhaphoneis surirella* (Ehrenberg) Grunow. U. S. G. S. diatom catalog no. 1984-4, locality 2878. Length, 36μ . $\times 1020$.
 7. *Eunotia praeurupta* Ehrenberg var. *bidens* (W. Smith) Grunow. U. S. G. S. diatom catalog no. 1987-1, locality 2894. Length, 69μ . $\times 790$.
 8. *Rhoicosphenia curvata* (Kützing) Grunow. U. S. G. S. diatom catalog no. 1951-2, locality 2854. Length of fragment, 68μ ; width (max.), 14μ . $\times 760$.
 9. *Nitzschia panduriformis* Gregory. U. S. G. S. diatom catalog no. 1982-3, locality 2874. Length, 89μ . $\times 590$.
 10. *Nitzschia marina* Grunow. U. S. G. S. diatom catalog no. 1942-1, locality 2838. Length, 139μ ; width, 9.5μ . $\times 545$.
 11. *Nitzschia marina* Grunow. U. S. G. S. diatom catalog no. 1942-1, locality 2838. Central portion only. $\times 1480$.
 12. *Pseudoeunotia doliolus* (Wallich) Grunow. U. S. G. S. diatom catalog no. 2000-2, locality 2858. Length, 75μ . $\times 1060$.
 13. *Pseudoeunotia doliolus* (Wallich) Grunow. U. S. G. S. diatom catalog no. 2000-2, locality 2858. Enlarged to show structure. $\times 1830$.
 14. *Navicula pennata* Schmidt. U. S. G. S. diatom catalog no. 1964-1, locality 2864. Length of fragment, 75μ . $\times 1000$.
 15. *Diploneis interrupta* (Kützing) Cleve. U. S. G. S. diatom catalog no. 1986-1, locality 2893. Length, 33μ . $\times 970$.
 16. *Diploneis weissflogii* (Schmidt) Cleve. U. S. G. S. diatom catalog no. 1972-3, locality 2866. Length, 36μ . $\times 850$.
 17. *Pleurosigma naviculaceum* Brébisson. U. S. G. S. diatom catalog no. 1984-1, locality 2878. Length, 87μ . $\times 1030$.
 18. *Diploneis smithii* (Brébisson) Cleve. U. S. G. S. diatom catalog no. 1981-1, locality 2873. Length, 81μ . $\times 716$.

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