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Fresh-Water Diatoms from Atlantic Deep-Sea Sediments

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Nine years ago the Swedish Deep-Sea Expedition 1947–48, under the leadership of H. Pettersson, completed its cruise around the world. The object of the expedition was to make investigations mainly in the tropical belt of the Pacific, Indian, and Atlantic oceans. One of the most important aims of the expedition was the investigation of deep-sea sediments in cores reaching as deep as modern coring technique would allow.

It is well known that the mere securing of ooze and mud from great depths requires a complicated technique. The difficulties increase if it is necessary to secure long cores of undisturbed sediment, as is required for geological, geochemical, and geophysical purposes. Cores obtained by the earlier coring technique seldom exceeded a length of 2 meters, the longest core measuring about 3 meters.

The expedition used a new coring technique developed by Kullenberg (*1*); his piston corer made it possible to obtain cores of record length—in soft sediment, up to 20 meters and more; in relatively hard oceanic sediments the length of the cores averaged about 12 meters. When the slow rate of sedimentation (from 0.5 to 8 centimeters in 1000 years) was taken into consideration, it was determined that some of the cores collected by the expedition reached the Tertiary. On board and after the return of the expedition, the cores were kept in cold-storage rooms, and sections of them were distributed to specialists for further investigations. I was commissioned with the investigation of the diatoms contained in the cores.

Diatoms are autotrophic plants—that is, plants that do not require organic nutrients. Their nutrition is based essentially on a process of assimilation of carbon dioxide under the influence of light. Consequently, the life-cycle of these plants is restricted to the upper strata of the oceans, because light of sufficient intensity does not penetrate more than a few hundred meters below the surface of the sea. Diatoms are the main component of marine plankton and the principal, primary source of food of pelagic animals such as protozoans and microscopic crustaceans, which, in their turn, are eaten by larger animals: larger crustaceans, coelenterates, worms, mollusks, pteropods, fish, and finally marine mammals. After the death of the diatoms or their passing through the digestive system of animals, their siliceous valves slowly sink to the sea floor, together with mineral particles and remains of other pelagic organisms. This slow, but constant, fine rain of particles is responsible for the formation of oceanic sediments (at least in the deep sea).

During their settling, the valves are exposed to the dissolving effects of sea water; although they are generally resistant (but by no means "indestructible," as is often asserted in textbooks), they are sensitive to high *p*H values (alkaline reaction of sea water). A kind of physicochemical selection takes place, valves of delicate pelagic diatoms being more easily dissolved than those of thick-walled species, and my investigations have shown that the diatom assemblages of the sea floor differ substantially from planktonic communities. The sea-floor assemblages are poor in thin-walled species, completely lack the delicate pelagic forms, and are relatively rich in coarse species, including ones that are scarce in the plankton community. An interesting fact was disclosed: the diatom assemblages of the sea floor of the tropical belt of all oceans are surprisingly uniform.

Still, there were exceptions. Some long cores, for instance, contained at their lowest levels diatoms which have long been extinct. An identification of the species showed that the corer had secured sediments formed as early as during the last phases of the Tertiary (*2*).

One of the most interesting observations was the unexpected presence of many fresh-water diatoms in certain cores taken by the expedition's ship *Albatross* parallel to the coast line of Equatorial West Africa at a great distance off the coast (see Fig. 1).

Location of Finds

The finding of stray specimens of fresh-water diatoms in deep-sea sediments is not an entirely new fact in itself. Lohman (*3*) and some earlier observers reported a few fresh-water diatom species from deep-sea soundings; in most cases, however, these finds were rare, and only a few single valves were encountered. My own investigations of the numerous cores collected by the Swedish Deep-Sea Expedition in the equatorial belt of the Pacific and Indian oceans did not reveal a single specimen of fresh-water species, except in the close vicinity of continents or large islands.

The novelty of the present observations lies in the constant occurrence of fresh-water diatoms in Atlantic deep-sea cores, the large number of individuals, and the relatively great variety of species. More than 60 fresh-water species, belonging to various ecological groups, were observed: plankton and benthonic forms, species typical for habitats rich in nutrients and even for some poor in nutrients, most forms being common cosmopolites—that is, species of world-wide distribution (Fig. 2).

In most levels, only a few (5 to 50) valves in a small, given volume of sediment could be observed; in others the frequency was great to very great. The

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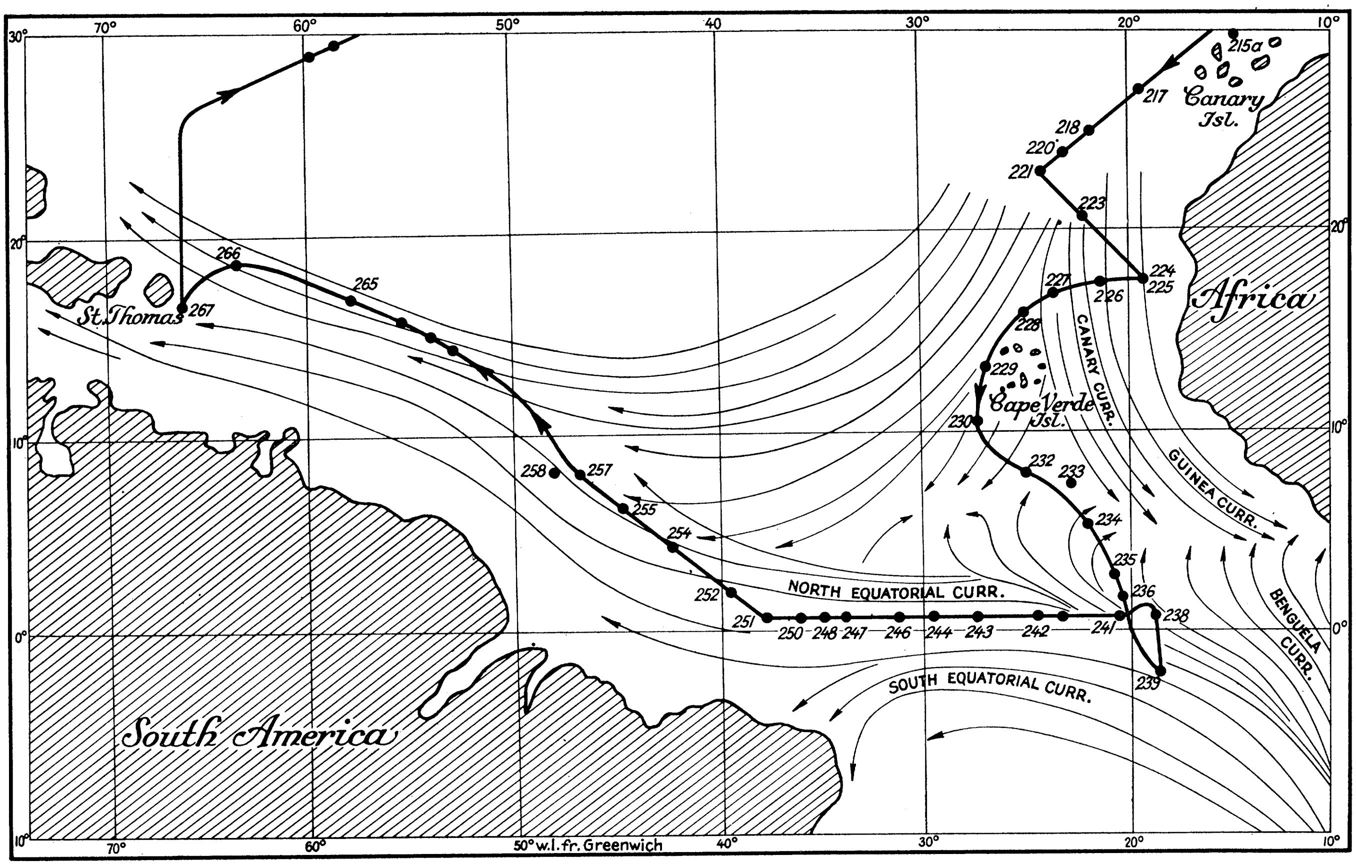

Fig. 1. Atlantic cruise of the *Albatross*. The numbers by the side of small circles are core numbers.

most frequent fresh-water diatom was *Melosira granulata* (Ehr.) Ralfs, with its varieties. Incidentally, its frequency was surprising; this sometimes amounted to more than 1000 valves per slide, and in one sample about 3600 valves per slide could be counted. A certain level (552 centimeters below the top of core 234) deserves special mention; it contained fresh-water diatoms exclusively, the only exception being a single fragment of a marine form. With regard to diatoms, this level gave the impression of belonging to a fresh-water sediment. In addition to the ever-present *Melosira granulata,* as many as 17 fresh-water species could be observed in this level. This "fresh-water community" seemed to be confined to a thin stratum; the next higher level contained only a few individuals of *Melosira granulata* and the usual marine assemblage, while all the levels below this thin stratum and down to the end of the core (1351 centimeters) were totally devoid of diatoms.

Cores remarkable for the highest frequency of *Melosira granulata* are those with the numbers 229, 230, 234, 235, and 238 (from Romanche Deep, 7315 meters, one of the greatest depths in the Atlantic, named after the French frigate *Romanche,* which discovered it). The localities represented by these cores surely cannot be considered "near-shore" stations. Table 1 shows the approximate distances from the nearest continents for three of these cores.

An observation concerning another group of objects of nonoceanic origin may be pointed out: the regular and rather frequent occurrence of silicified epidermal cells belonging to terrestrial plants (Cyperaceae and Gramineae) in many cores. These characteristic small objects are the replicas of short epidermal cells whose whole interior becomes filled with silica during the life of the plant. The compact siliceous "casts" are obviously highly resistant to the corroding effects of sea water. They are to be found in fresh-water sediments and sometimes in near-shore marine deposits but, to my knowledge, are not known in deep-sea sediments. In Atlantic cores they occurred together with *Melosira granulata* and were almost as common as this form.

Table 1. Approximate distances from nearest continents of three cores taken by the *Albatross* parallel to the coast line of Equatorial West Africa.

Core No.	Geographic position	Distance (km) from	
		Africa	South America
234	N5°45′, W21°43′	930	1960
235	N3°12′, W20°25′	990	1900
238	S0° 7′, W18°12′	1050	1990

Origin of Fresh-Water Diatoms

Let us consider the possible explanations for the presence of fresh-water diatoms in the depths of the Atlantic, far from their present-day natural habitats. It is evident that these forms are allochthonous—that is, were transferred to their place of deposition and cannot have existed in the ocean. Where did the fresh-water diatoms come from and by what means of transportation were they removed from their natural habitats, carried away, and deposited at distant parts of the sea floor? In view of the great frequency of occurrence of fresh-water diatoms (at least in certain sediments), it is likely that great quantities of fresh-water material must have been (and probably are still being) conveyed over many hundreds of miles of sea.

The most obvious and natural explanation seems to be the transport by rivers and sea currents (potamic transport). Africa, from the Gulf of Guinea to the system of the Congo, is a country of lakes, rivers, swamps, and so on, presenting good living conditions for diatoms of various ecological types. Great rivers—the Niger, the Congo—and a multitude of tributaries, small streams, and rivulets carry enormous quantities of living diatoms and their valves towards the sea —in the present case, towards the Gulf of Guinea. Once at sea, dead and dying fresh-water forms, other organic remains, and mineral particles are taken up by sea currents. In the present case, the currents in question are the Benguela, the Guinea, and the South Equatorial currents, the complicated countercurrents, and the circulation, turbidity, and convection currents. Under the combined influence of these current systems, the valves move slowly, both downwards and horizontally, until they sink through the so-called "oceanic troposphere" (*4*) and reach the abyssal zone—the "bathysphere," an immense volume of practically undisturbed water which allows the valves to sink with hardly any horizontal locomotion—where they finally come to rest on the sea floor.

As for the place of deposition, it is at present impossible to guess the distance that can be traveled or the direction that can be taken by the diatoms during their settling process. The settling time, or period of their sinking through the troposphere, is an unknown factor; attempts to determine the settling velocity, even in undisturbed water, have differed widely, and the whole question becomes more complicated if the influence of complex and little-known hydrodynamic factors connected with the current systems is considered.

It is possible that there is another means of transportation: transport by wind and sea currents (aeolian transport). The transportation of great quantities of diatoms by wind would not seem very probable were it not for the particular geographic position of the majority of the cores in question. The following paragraphs are quoted from my report on the Atlantic cores (*5*).

"The West Coast of Africa is entirely in the zone of influence of the desert winds which periodically carry large quantities of fine sand and dust particles [*6–8*]. The strong influence of the dust storms is best illustrated by the ill fame of certain parts of the Atlantic near and south of the Cape Verde Islands. Early navigators feared this near-shore part of the Atlantic (from about lat. 30°N to lat. 5°S) and this sector was named 'the Dark Sea,' 'Dunkelmeer,' and 'Pot-au-Noir.' At certain periods the fine dust carried by the NE trade wind blowing from the Sahara Desert produces a haze, reducing the visibility at sea to 1–2 km and in some cases even to 150 m (Pratje) [*9*]. . . . According to this author, from whose paper I summarize the following information, the Sahara dust has been analyzed and found to contain mineral particles only. The Sahara dust is responsible for some mineral sediments in the deep-sea cores, but probably not for the freshwater diatoms which these cores contain.

"South of the district discussed and overlapping it, another dust phenomenon is well known, although not so feared as the Sahara haze. It is the 'Harmattan' haze; it is also caused by the NE Trade. Its zone extends from about 15°N almost to the Equator [*7–9*]. Harmattan haze has been analyzed by Hustedt (1921) [*10*] and was found to consist mainly of diatom valves and their fragments. Hustedt gives a list of 51 freshwater diatoms (varieties excluded), mostly common cosmopolitan forms. About half of them (25) were also found in our sediments.

"The places of origin of the 'Harmattan' diatoms are supposed to be the dry, but periodically inundated swamp districts of the Niger and its tributaries. The NE Trade often causes prairie fires and the ashes of burnt plants are one of the components of the 'Harmattan' dust. This could explain the presence of the silicified epidermal cells in the sediments."

It is not known how far diatom valves can be carried out to sea by the wind, but there is reason to believe that they can be carried for very great distances; they settle on the sea, where they are taken up by the currents and carried along until they are finally deposited on the sea floor.

An interesting attempt to explain the presence of fresh-water diatoms in certain Atlantic deep-sea cores has been made by Malaise (*11*). According to this author, parts of the Mid-Atlantic Ridge must have existed as large islands facing the west coast of Africa up to the end of the last Ice Age or later and were submerged in early historical times. These islands gave rise to the Atlantis saga, which Malaise and others consider to have been founded on a reality; Malaise bases his arguments (see, for instance, *12*) on geologic facts and Odhner's (*13*) "constriction hypothesis." According to this explanation, core 234, with its peculiar layer of (exclusively!) fresh-water diatoms, is located in a part of the Mid-Atlantic Ridge which formerly was above sea level, and the corer happened to hit the bottom of a former lake. Malaise considers the finding of this layer to be one of the arguments in support of his theory. Not being a geologist, I do not attempt to discuss the probable validity of Malaise's hypothesis. However, one point is certainly in its favor—the fact that it provides a natural explanation of the layer consisting exclusively of fresh-water diatoms, which is otherwise difficult to comprehend.

To summarize Malaise's hypothesis, the sediments of fresh-water diatoms (at least in core 234) are autochthonous—that is, the diatoms lived at their place of deposition—and had their origin in

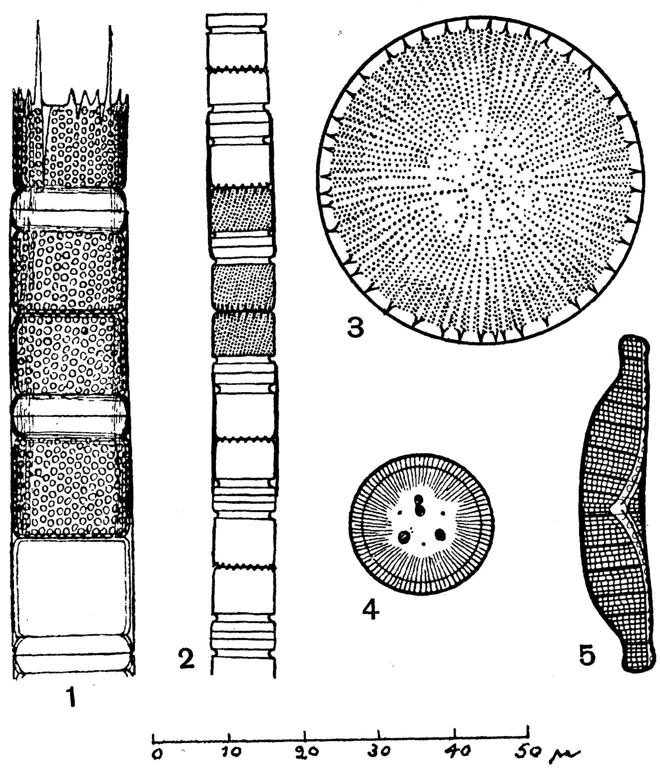

Fig. 2. Some fresh-water forms frequently encountered in Atlantic deep-sea sediments. The species are: (1) *Melosira granulata* (Ehr.) Ralfs; (2) *Melosira ambigua* (Grun.) O. Müll.; (3) *Stephanodiscus astraea* (Ehr.) Grun.; (4) *Cyclotella ocellata* Pant.; (5) *Epithemia zebra* (Ehr.) Ktz. (× 1000). [After Hustedt, 1930]

lakes or other fresh-water habitats located in a part, or parts, of a former continent (Atlantis).

We have thus three possible explanations for the presence of fresh-water diatoms in deep-sea sediments of the Atlantic:

Potamic theory. The diatoms originated in African lakes, swamps, and rivers; they were transported by rivers into the Atlantic and were drifted to, and deposited at, the present off-shore localities.

Aeolian theory. The diatoms originated in African lakes, rivers, and swamps. In dry seasons and after the desiccation of these swamps, rivulets, and so on, the fine dust of their bottom mud (often together with ashes of burnt plants) was taken up by the trade winds, blown into the sea ("Harmattan" dust), and finally deposited at the present localities.

Malaise's theory. The diatoms originated in a lake of the hypothetical continent Atlantis or of its remaining islands. The continent sank deep under the present sea level, and the geographic position of the locality of fresh-water diatoms remained unchanged.

All three explanations include a certain element of speculation; future investigations may decide which of them holds true.

References and Notes

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6. The phenomenon was mentioned by Edrisi as early as 1160 (see *7*). Charles Darwin gave a vivid description of it (*8*); he stated that great quantities of dust were periodically blown into the sea, and he foresaw that "a widely extended deposit may be in the process of formation; and this deposit . . . . will in chief part consist of Polygastrica and Phytolitharia." *Polygastrica* is the term used by Ehrenberg chiefly for diatoms and *Phytolitharia*, for silicified parts of terrestrial plants.
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The Challenge to Dentistry

A Tribute to William J. Gies

Theodor Rosebury

William J. Gies, the founder of the International Association for Dental Research and of its *Journal*, died in his 85th year on 20 May 1956. It is my privilege to offer a tribute to his memory. Dr. Gies was primarily a medical educator and researcher. Among his many accomplishments before he became interested in dental problems was the distinction of founding, in 1898, the first department of biochemistry in a medical school. We are primarily interested in his achievements in the dental field—in education, research, and organization. These subjects claimed his energies increasingly during more than half of his long lifetime. Rather than attempt to catalog all he did, I propose to single out just one of his many works to symbolize his influence on dentistry. I am thus leaving biography and obituary to others (*1*). I intend to point out that dentistry, although it has made notable advances in the last few decades, remains short of the goals Gies set for it, particularly in the light of the inevitable comparison of dentistry with medicine. Dentistry, in my opinion, owes William Gies an incalculable debt of gratitude, which we can repay only by carrying forward the work he started. This suggestion is the essence of my tribute.

Bulletin Number Nineteen

It is of his famous *Bulletin Number Nineteen* (*2*) that I wish to write: the survey of dental education in the United States and Canada that Gies made for the Carnegie Foundation for the Advancement of Teaching. Published in 1926, the volume came to my notice a year later—just 30 years ago—while I was a dental student. A fellow-student and I read and studied it with intense interest. We found it then, as I find it now, a monument to the courage, the vision, the learning, and the literary grace of its author. It is incidental that, through my interest in the *Bulletin*, I came to know Gies, to win the Fellowship in Biological Chemistry in his name at Columbia University, and thus to derive from him the personal guidance and inspiration that led me into a career in dental research and teaching.

Since he died I have reread the *Bulletin*. I am struck with its persistent validity and vitality after three decades, and particularly with the light it throws both on our progress in dental education since he wrote it and on our deficiencies, which still remain to be corrected.

I select a few representative details. In the concluding part of the introduction to the *Bulletin* Gies speaks of the primary educational needs of dentistry as he saw them at the time. He asked, for example, for 2 years of college as a predental requirement; for the development of graduate instruction; for better cooperation between dentistry and medicine; for more complete dental libraries; for expansion of dental research; and for the disappearance of independent or proprietary dental schools. He emphasized the need for increased financial support for dental education and called for greater appreciation by dental teachers of the biological and medical side of dentistry. In a later section of the *Bulletin* he suggested that dental disease was being treated too mechanically and empirically because of lack of fundamental knowledge in the field, and that the means for prevention of dental disease were largely lacking, for the same reason.

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