Studies on Naturally Occurring Suspended Organic Matter in the Waters Adjacent to Japan (III)*

On a process of organization of planktogenic organic matter as examined by the electron microscope

By

TOKIMI TSUJITA**

1. Preface

It has been known that there are large forms of the suspended organic matter organized by the aggregation of plankton after its death in the ocean water. This has been previously studied by the author (1949, '53a, '53b, '55). Armstrong, P.A.J. and Atkins, W.R.G. (1950), Jerlov, N.G. (1950, '51a, '51b, '53), Krey, J. (1952, '53), Atkins, W.R.G., Jenkins, Pamela G. and Warren, F.J. (1953, '54) and Fox, D.L., Isaacs, J.D. and Corcoran, E.F. (1952) also studied the organic matter and turbidity of sea water. However, they have never proved directly the hypothesis that the suspended organic matter taking a part of the turbidity of sea water is actually organized by plankton nor the process of its origin.

For the purpose of showing the process of the origin of the suspended organic matter, the author (1953) examined its biotic structure by using the electron microscope. At the same time, he tried to compare the characteristic features of living plankton with those of dead plankton organizing suspended matter.

In December, 1949, the author and his staff carried out the oceanographic observation of Tsushima Strait, especially of the seas around the Tsushima Islands. There seemed to be much suspended organic matter in the plankton samples collected during the period of the observation. Those materials were put forward for the examination.

2. A study of the suspended organic matter by means of the electron microscope

In studying the biotic structure of the suspended organic matter, the author (1949, '53a, '53b) has often stated that the large forms of the suspended organic matter in the sea are formed by three such components as protoplasm, skeletal remains of explosively grown population of plankton and living plankton attached to the suspended matter. Moreover it has been made clear that another factor of its organization is such magnitude of population density of plankton as the blooming of diatoms, Trichodesmium and others. Then he has discussed that, in addition to such a factor concerning plankton distribution as intrinsic population growth rate, maintenance of a given density of organisms in the given water mass is an important factor for the appearance of the large forms of the suspended organic matter in the sea.

Considering that the protoplasm of plankton in the state of natural coagulation forms the matrix of the suspended matter, the problem here is whether the organic part of the suspended matter is living plankton aggregated mechanically due to its high population density, or is a mass of dead protoplasm. It may be worth while to examine the granular structure of the protoplasmic feature.

* Contribution No. 58 from the Seikai Regional Fisheries Research Laboratory. Received Nov. 4, 1955. (Sponsored by the Seikai Regional Fisheries Research Laboratory).

** Seikai Regional Fisheries Research Laboratory.
Materials provided for electron microscopic photographs in Plate I were collected from the waters around the Tsushima Islands in Tsushima Strait during the oceanographic observation from December 12 to 19, 1949. As the results of this observation, the author (1950) has reported that suspended organic matters were seen at every observed station. There was jelly-like suspended matter in the samples of water and plankton. They have had various microscopic features in shape and structure. This showed the source from which the jelly-like organic substance was derived. We can assume that the protoplasm of plankton transuded through areolae of the diatom cell skeleton and was congelated without destruction of its skeletal structure. Suspended organic matters consisting of various structural features and of skeletons of plankton connected together can be seen in the Figures of Plate I. These skeletons of diatoms are empty and show the sculpturing of the frustule. The protoplasmic feature of the organic part of the suspended organic matter is often granular as shown in Figs. 1 and 4. Such structural features of the organic part of the suspended matter as minute granules may be the origin of the turbidity factor or marine leptopel. These features are perhaps formed after the death of the plankton diatoms. In addition to these structural features of the suspended organic matter collected from the waters around the Tsushima Islands, it is recognized that there exists suspended organic matter in various structural features and developmental stages in the sea.

In stating his views of the electron microscopic examination, the author concludes that the protoplasm of plankton is coagulated as soon as it leaves the cell after the death. For the purpose of examining more exactly whether the plankton cell organizing the suspended organic matter is empty, or not, and what sculpturing of the frustule of diatoms is seen, the method using the electron microscope was chosen. For a comparison of the sculpturing of the plankton species which forms the suspend-
ed organic matter, two species of Genus *Rhizosolenia*, the red tide plankton, were presented. Figs. 1-3 in Plate II show *Rhizosolenia styiformis* Brightwell, the white water plankton (Tsujita, 1953, '55), and Figs. 4-6 in Plate II are *Rhizosolenia styiformis* var. *latissima*, the pink water plankton. These figures show absence of protoplasm in the cell and net-work sculpturing of the frustule. During the author's test, a 50,000 V electron beam could not penetrate the cell of diatoms collected in living state and fixed with formarine solution.

4. Discussion

Based upon the results of the examination of the suspended organic matter collected in December, 1949, mentioned above, it may be said that the suspended organic matter will be formed when the plankton has died and its protoplasm has diffused out of its areolae and congelated in sea water. In consideration of such a process of formation of the matter, it is concluded that one cell of plankton diatom may form a particle of suspended organic matter, and that at a certain time the more the plankton dies, the more the suspended organic matter will be formed; and then the more the dead plankton spreads out in the ocean, the more the suspended organic matter appears in such ocean space.

Diatoms exist commonly in colonial situation in the sea. Accordingly, in general, it is assumed that the unit of the large forms of the suspended organic matter in origination is a colony of plankton.

Though the intrinsic growth rate of a plankton population is a condition for the formation of the large mass of the suspended matter, yet it is a necessary condition for maintaining the high density of individuals or colonies of plankton that the leakage of the structural unit in a given water mass is kept smaller owing to the cyclonic eddy, convergent current rip and other phenomena of the sea.

Ultimately, on the appearance of the large forms of the suspended organic matter in
the ocean from ecological point of view, it is possible to say that a large mass of the suspended organic matter appears normally convergent eddies, current rips or boundaries where the high density of plankton population is recognized. After all, the larger the population size of the senescent plankton, the larger mass of the organic matter is formed, and the size of standing crop of plankton is in proportion to the amount of the suspended organic matter. Therefore, it becomes clear that the suspended matter occurs in large quantity in such a case as the red tide or the diatom flowering, especially in the vernal blooming of diatoms.

Summary

It is shown by the electron microscopic method that the large forms of the suspended organic matter in the sea is formed of microplankton after its death. Examining a process of origination of the suspended matter, the author could detect that protoplasm of diatom was spread out through the areolae of the frustule of diatom, and recognize that granular structure of the suspended organic matter was made from protoplasm of plankton cell. The author assumes that such structural features as organic granules take a part of turbidity factor of sea water. It is said that one cell or a colony of microplankton is the structural unit in origination of the suspended organic matter.

The author expresses his hearty thanks to prof. S. Nomura of the Tohoku University, Sendai, for a number of valuable advice and to Messrs. M. Takahara and H. Takahara of the Zeshinkai Hospital who let me kindly use their electron microscope, for their continued hospitality of collaboration.

References


PLATE I

Fig. 1. ×5000

Fig. 2. ×2000

Fig. 3. ×5000

Fig. 4. ×2000

Fig. 5. ×2000

Fig. 6. ×2000

EXPLANATION OF PLATE I

Electron micrographs of biotic structure of the large forms of the suspended organic matter collected in the waters around the Tsushima Islands off western Japan in December, 1949.

Figure 1. Granular structure of a part of suspended organic matter. It may be assumed that those granules will become causative factor of turbidity of sea water in the ocean. ×5000

Figure 2. Part of the structure consisting of membrane and setae of *Bacteriapstrum varides*. ×2000

Figure 3. Showing protoplasm diffused out of the cell of *Thalassiothrix frauenfeldii*. Areolation of the empty cell can be seen. ×5000

Figure 4. Part of the suspended organic matter showing granular structure and the skeleton of plankton. ×2000

Figure 5. Biotic structure consisting of protoplasm diffused through areolae of *Thalassiosira nordenstamnii* and a gelatinous material. ×2000

Figure 6. Setae of *Chaetoceros* sp. showing that protoplasm diffuses and areolation is seen. ×2000
Electron micrographs of dead cells of the red tide plankton which are part of the large forms of the suspended organic matter organized during their explosive population growth, comparing their biotic structures.


Figs. 1 and 4. Showing side-ventral view of calyptra. Each ×2000

Figs. 2 and 5. Part of girdle showing intercalary bands and areolae in sculpturing.

Fig. 2. ×3000 Fig. 5. ×2000

Figs. 3 and 6. Showing sculpturing of the middle part of the girdle.

Each ×2000

In these figures, it is recognized that the dead cell of the plankton organizing the large forms of the suspended organic matter is empty by diffusion of its protoplasm.