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The particulate organic carbon and nitrogen, and the dissolved organic carbon in the Gotland Deep in May 1968

by

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The distribution of the particulate organic carbon and nitrogen, and of the dissolved organic carbon as a function of depth and of time is investigated. A common pattern of these distributions is found with certain deviations from a mean value. The ratio N/C (particulate) is calculated. The variation of this parameter with depth shows a maximum at 10 m depth indicating increased biological activity. Also calculated are the ratios and the correlation coefficients between the concentrations of dissolved and particulate organic carbon and between the protein content of the particulate organic matter and its organic nitrogen content. Conclusions on the biochemistry of the phytoplankton are drawn from these computations.

Der partikuläre organische Kohlenstoff und Stickstoff und der gelöste organische Kohlenstoff im Gotland Tief im Mai 1968.
(Zusammenfassung): Die Veränderlichkeit der Konzentration an partikulärem organischen Kohlenstoff und Stickstoff und gelöstem organischen Kohlenstoff mit der Tiefe und mit der Zeit werden untersucht. Die Veränderlichkeit dieser Parameter mit der Tiefe hat zu verschiedenen Zeiten ein ähnliches Aussehen mit gewissen Abweichungen von einem Mittelwert. Das Verhältnis N/C der partikulären Substanz wurde berechnet. Die Tiefenverteilung dieses Parameters hat ein Maximum in 10 m Tiefe, das erhöhte biologische Aktivität anzeigt. Ebenfalls berechnet werden die Verhältnisse zwischen den Konzentrationen von partikulärem und von gelöstem organischen Kohlenstoff und der Korrelationskoeffizient zwischen beiden Größen. Die gleichen Berechnungen werden angestellt mit dem Proteingehalt der partikulären Substanz und ihrem Gehalt an organisch gebundenen Stickstoff. Aus diesen Berechnungen werden Schlüsse gezogen über die Biochemie des Phytoplanktons.

Introduction

The formation of particulate organic carbon and nitrogen by the living cells of phytoplankton is the first link in the marine food chain through which inorganic nutrients and carbon dioxide are transformed into living organic matter. The phytoplankton cells, however, are not only used as food by higher organismus, but will probably also excrete a certain amount of the photosynthesized material into the surrounding water as a normal function of their metabolism (NALEWAJKO, C., 1966. WATT, W.D., 1966). The chemical nature of these excretions is still largely unknown, but some compounds have already been identified: carbohydrates, amino acids, saturated and unsaturated fatty acids, glycolic acid, and peptides. Growth promoting and growth inhibiting factors may also be present. Furthermore, certain phytoplankton organismus such as dinoflagellates can use organic compounds as a source of nitrogen, when the inorganic nitrogen is depleted. PROVASOLI (1963) points out that some photosynthetic organisms can grow in the dark on exogenous carbon sources. All these observations strongly suggest, that a close relation should exist between the particulate and the dissolved organic matter in the upper water layers. In the deeper water layers, however, the bulk of the dissolved organic substances originates from deaying detritus. This process is assumed to be slow, the particulate matter resulting from this decay having a high

1) The author wishes to thank the Deutsche Forschungsgemeinschaft for financial aid in this research.

physiological and chemical stability with respect to its environment. (SKOPINTZEW, 1959). Because this „water humus", as it is sometimes referred to, might be removed from the layers of its formation by sinking to greater dephts, no such correlations can be exspected in these layers.

The aims of these investigations in the Gotland Deep were therefore the following: The evaluation of the distribution with depth of particulate and of dissolved organic matter, the study of the short time variations of these parameters in several levels and the possible correlations of these parameters. Additionally, the connection between the particulate organic nitrogen in the phytoplankton cells and their protein content will be examined.

Methods

During the anchor station in the Gotland Deep from the 8th to the 12th of May 1968, a 3–1–Hydrobios bottle was lowered to 10 depths from 1 to 230 m every three hours. For the cross section through the Gotland Deep (Fig. 6, plate 2) essentially the same procedure was employed. 1 l of the sea water from every depth is passed through a 300 μ mesh nylon net to remove larger particles. It is then filtered through a Whatman GF/C glas fiber filter. The filters had been heated before to 500° C and were kept at that temperature overnight to remove traces of organic contaminations. The remainder of the sample is used for the determinations of the protein content (Lowry at al. 1951). The filtered sea water is acidified by the addition of phosphoric acid. Nitrogen is bubbled through the water to remove the inorganic carbon dioxide. For this purpose a special device has been used (EHRHARDT, M. 1969). This acidified water is transferred into nitrogen flushed glass ampoules by means of a hypodermic syringe. The ampoules are sealed immediately afterwards, and are sterilized for 30 minutes at 100° C to prevent bacterial decomposition of the dissolved organic compounds. The concentration of the dissolved organic carbon is determined in the shore laboratory by means of a newly developed instrument based upon the Technicon Autoanalyzer System (EHRHARDT, M. 1969). The particulate organic carbon and nitrogen is determined on board of the ship with a Hewlett-Packard 185-CHN-Analyzer. This instrument consists of a micro-combustion furnace followed by a gas chromatographic separation of the combustion products. Purified helium is used as carrier gas, a heavy metal oxide supplies the oxygen. The filters were dried at 100° C for 20 minutes prior to the analysis.

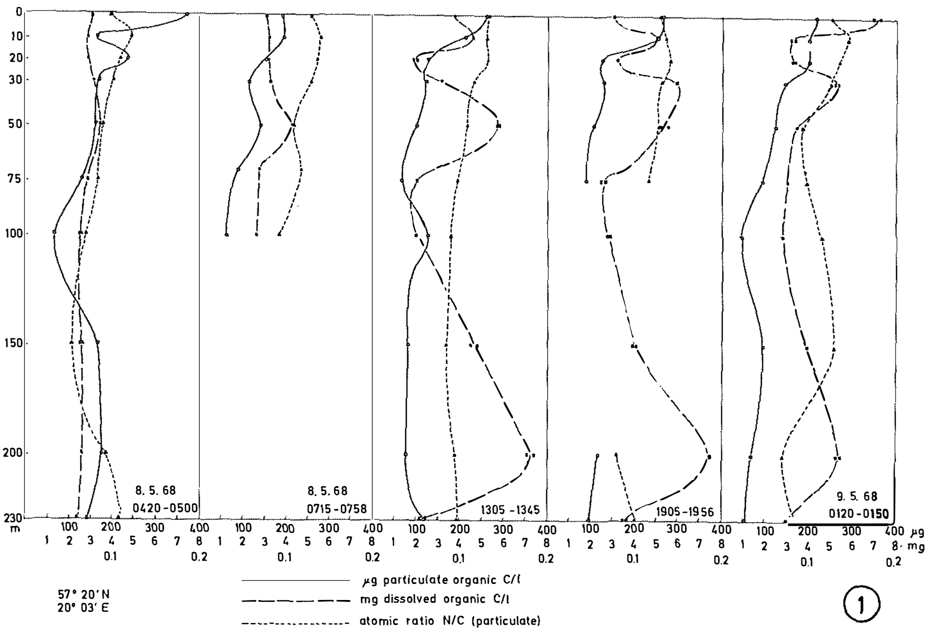
Results and discussion

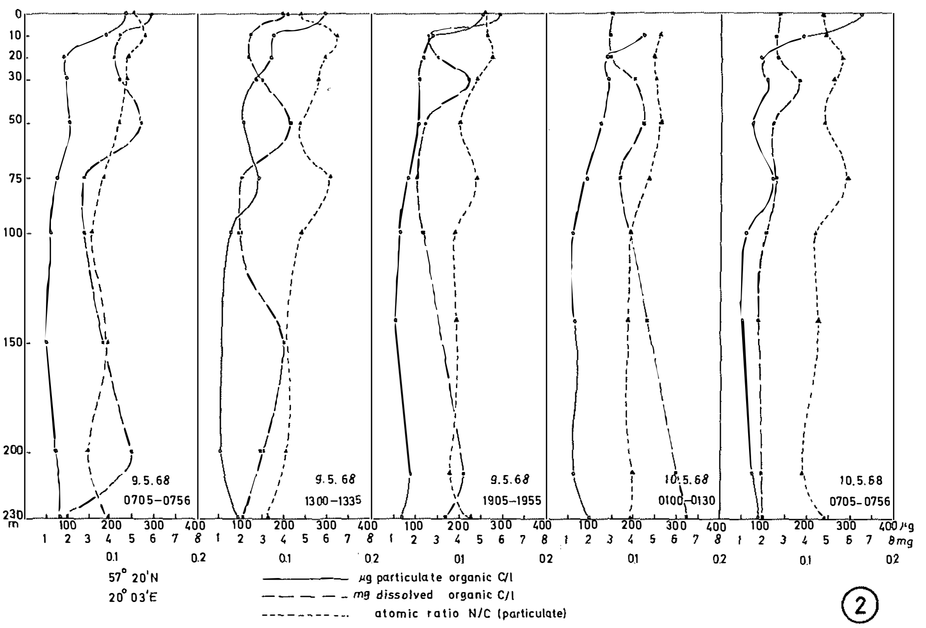
From the plots of the distribution of the particulate and of the dissolved organic carbon as functions of depth it is apparent that these distributions follow a common pattern with certain deviations from a mean value (Fig. 1 and 2, Plate 1, Fig. 3 and 4, Plate 2, Fig. 5, Plate 3, and Fig. 6, Plate 4). For the sake of simplicity the values of the particulate organic nitrogen concentrations are not shown in the graphs. Instead, the variation of the atomic ratio N/C (particulate) with depth are presented.

Legenden zu den nebenstehenden Figuren (Tafeln 1 + 2)

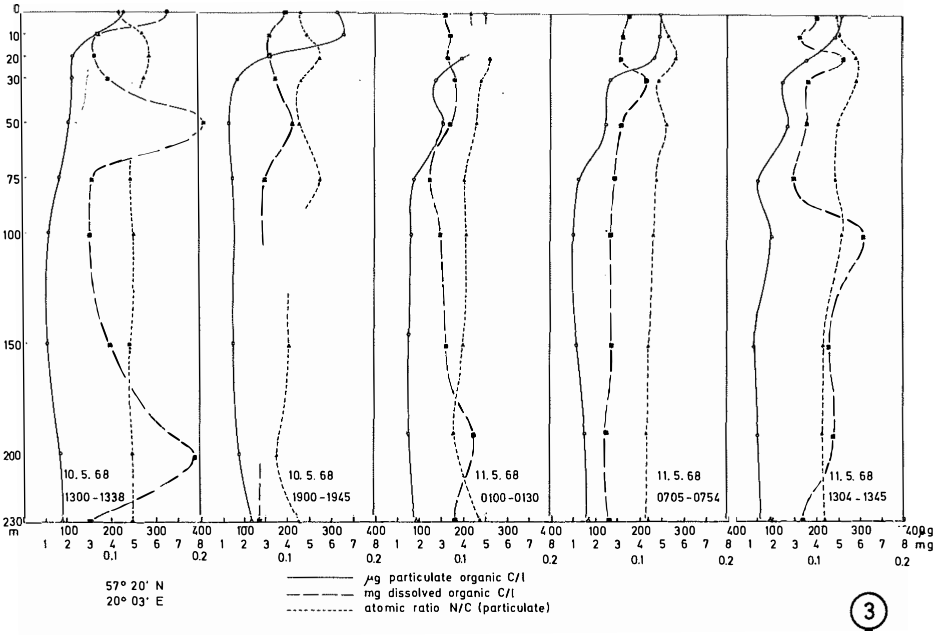
Figure 1 and 2: Distribution with depth of the dissolved and of the particulate organic carbon, and of the ratio N/C in the Gotland Deep in May 1968.

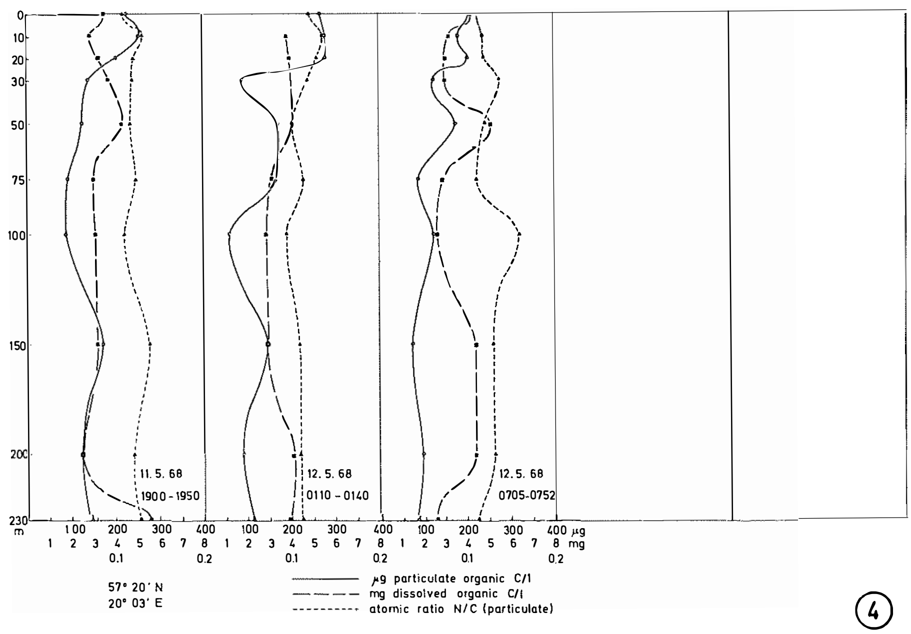
Figure 3 and 4: Distribution with depth of the dissolved and of the particulate organic carbon, and of the ratio N/C in the Gotland Deep in May 1968.



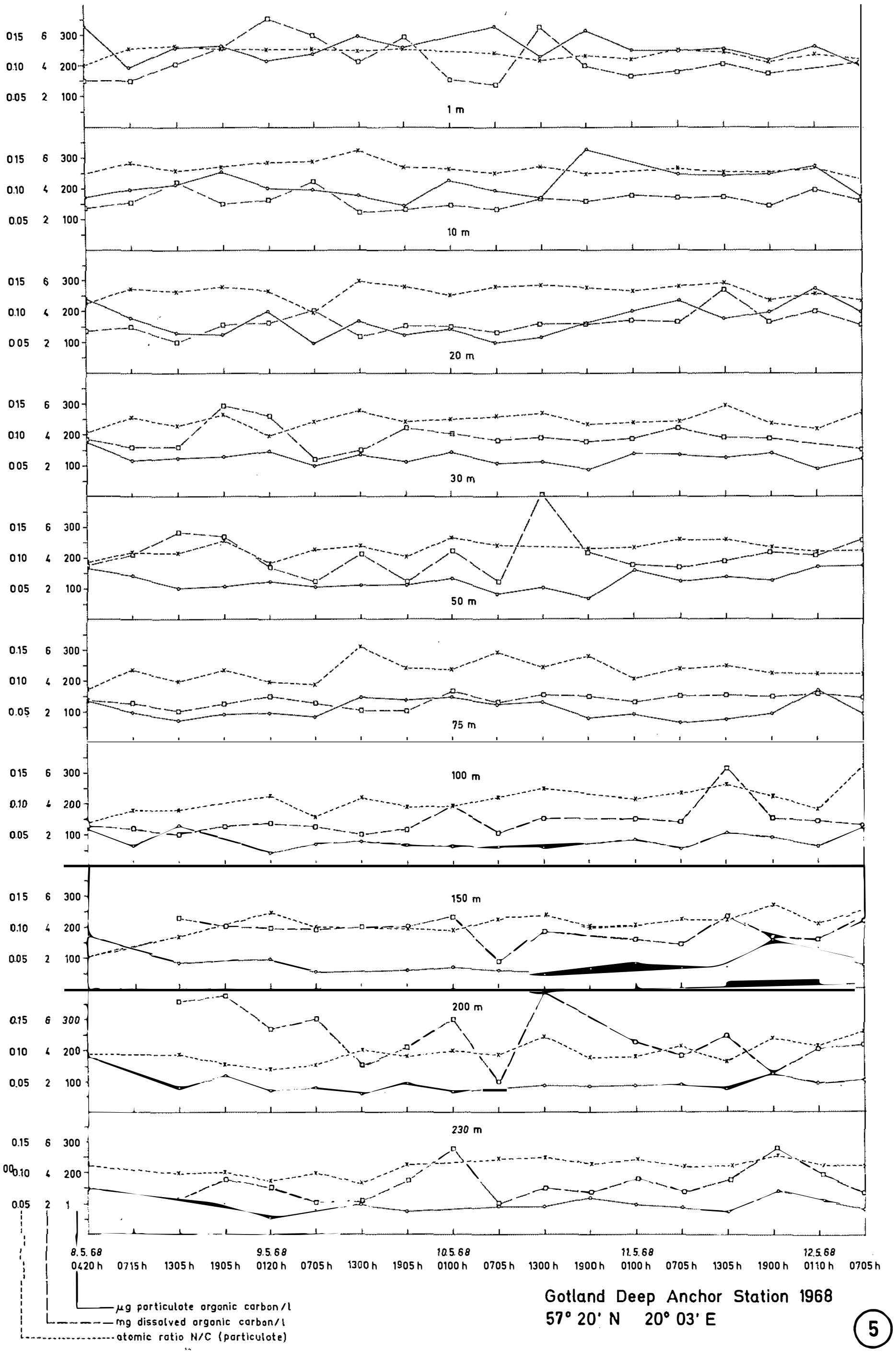


Tafel 1 (zu Ehrhardt)

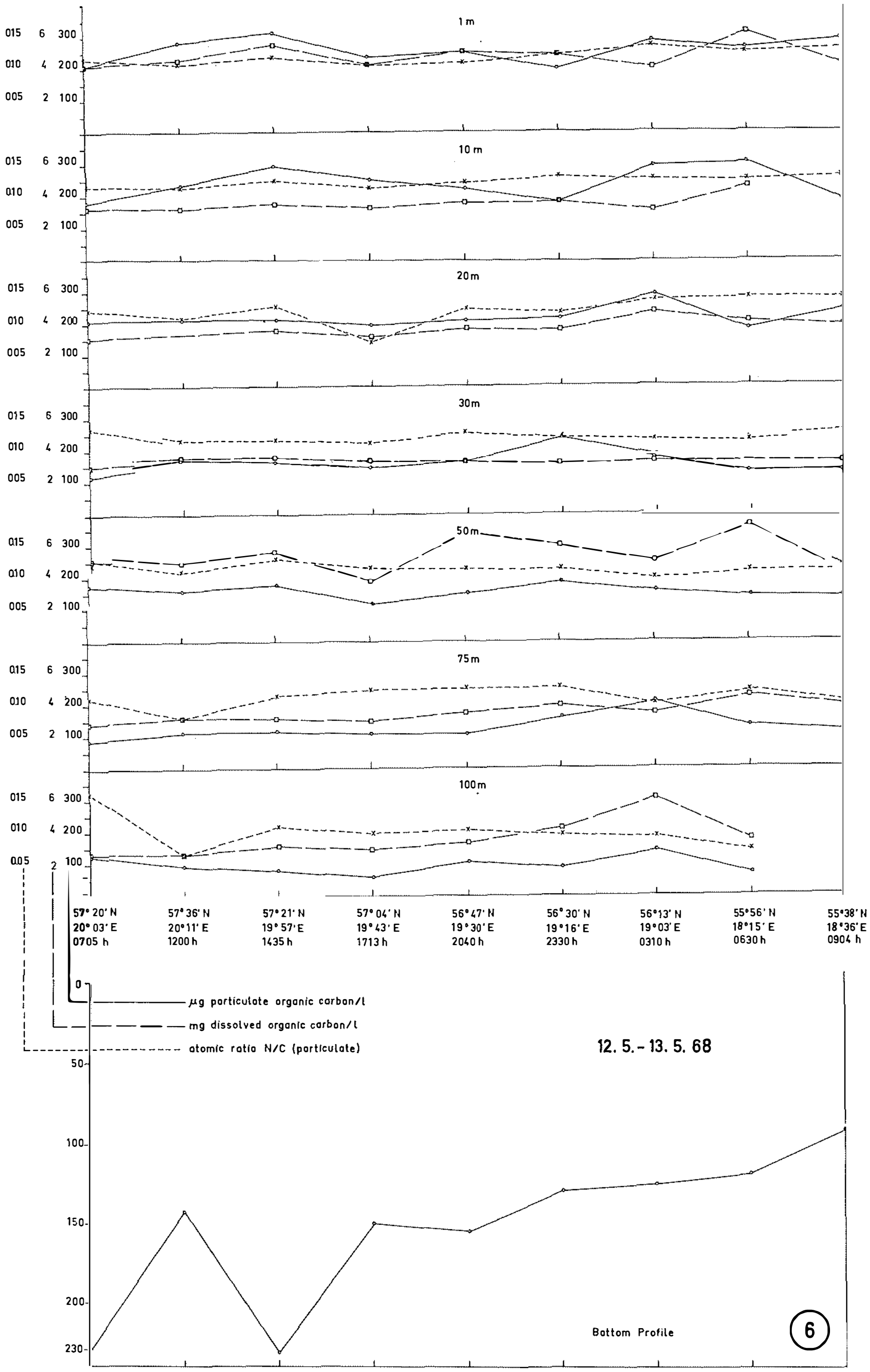




Tafel 2 (zu Ehrhardt)



Tafel 3 (zu Ehrhardt)



Tafel 4 (zu Ehrhardt)

A maximum of the particulate organic carbon at the surface does not coincide with the first maximum of the atomic ratio N/C (particulate). The latter maximum occurs at the depth of 10 m (Fig. 7 shows a mean value of the reciprocal, see also table 1). It coincides with the maximum of the protein/N organic ratio (Tab. 1 and Tab. 2), and also with the highest oxygen saturation (GIESKES, J.M.T.M., this volume). This seems to indicate the region of the most intensive primary production. The assumption is in good agreement with the results of ROCHON (1968), who found, that in the Arkona Basin and in the Bornholm Deep the primary production was highest not at the surface but at 5 – 10 m depth. DUGDALE and GOERING (1967) reported a maximum uptake of ^{14}C and ^{15}N at a depth of 25 m in the Gulf of Maine in August 1963. This observation points into the same direction.

Table 1: Gotland Deep anchor station plus cross section 1968

Depth (m)	$\mu g\ C_{part.}/l$	$mg\ C_{diss.}/l$	$C_{diss.}/C_{part.}$	$N/C_{part.}$
1	259.8 ±38.0	4.54 ±1.14	18.0 ± 4.7	0.120 ±0.009
10	228.8 ±49.5	3.3 ±0.5	14.9 ± 3.2	0.130 ±0.011
20	183.7 ±50.9	3.38 ±0.7	19.8 ± 6.9	0.128 ±0.015
30	138.4 ±30.1	3.7 ±0.7	27.5 ± 7.6	0.123 ±0.010
50	132.6 ±29.3	4.6 ±1.4	35.9 ±13.8	0.115 ±0.010
75	107.5 ±33.2	3.0 ±0.6	29.7 ± 7.6	0.117 ±0.016
100	83.4 ±30.3	3.2 ±1.1	40.9 ±13.1	0.104 ±0.019
150	99.2 ±40.2	3.68 ±0.96	43.9 ±20.3	0.107 ±0.018
200	91.3 ±27.5	4.7 ±1.8	55.6 ±24.1	0.097 ±0.016
230	97.7 ±23.3	3.23 ±1.19	34.4 ±12.7	0.108 ±0.013

Table 2: Gotland Deep Anchor Station 1968

Depth (m)	μg protein/l	$\mu g\ N_{part.}/l$	$protein/N_{part.}$
1	393 ± 76	36.2 ±6.1	11.33± 3.61
10	423 ±131	33,0 ±7.2	13.10± 6.3
20	221 ± 74	23.6 ±7.0	9.4 ±1.7
30	170 ± 55	17.7 ±2.8	9.8 ±3.6
50	124 ± 38	15.5 ±4.0	8.3 ±2.4
75	85 ± 35	14.1 ±5.0	6.8 ±3.3

Legenden zu den nebenstehenden Figuren (Tafeln 3 + 4)

Figure 5: Variation of the dissolved and of the particulate organic carbon, and of the ratio N/C in several depths in the Gotland Deep in May 1968 as a function of time.

Figure 6: Variation of the dissolved and of the particulate organic carbon, and of the ratio N/C in several depths on a cross section through the Gotland Deep as a function of time.

The correlation coefficient of the dissolved organic carbon as a function of the particulate organic carbon has a negative value at the depth of 10 m (Fig. 7). No unequivocal conclusion regarding the uptake or the excretion of the dissolved organic carbon can be drawn from these computations. If we consider the minimum of the ration $C_{diss.}/C_{part.}$ (Fig. 7), and also the extremely low concentrations of the inorganic nutrients phosphate and nitrate (GIESKES, J.M.T.M., and K. GRASSHOFF, 1969), it seems likely that uptake is predominant.

The absolute maxima of the particulate organic carbon and nitrogen at the surface seem to be due in some part to the formation of particulate matter from dissolved organic material. This conclusion is supported by the observation that at the surface the correlation of dissolved organic carbon to particulate organic carbon is negative (Fig. 7), i.e., the more particulate organic matter the less dissolved organic carbon is found, and vice versa. The finding of Derenbach (DERENBACH, J., personal communication) that the number of phytoplankton organismus per unit volume of the sea water under investigation was largest in 10 – 20 m depth and not at the surface further supports this supposition.

In the 30 – 75 m region cold winter water is found (GIESKES, J.M.T.M. and K. GRASSHOFF, 1969), that is rich in dissolved organic carbon. The ratio dissolved organic carbon to particulate organic carbon also has a maximum value in this region. The correlation of these parameters is slightly positive (Fig. 7). The atomic ratio N/C (particulate) drops to an intermediate minimum. The oxygen concentrations sharply decrease below 50 m, and nitrate and phosphate begin to appear in analytically accessible quantities. Analysing these observations one is led to conclude that between 30 and 75 m dead and decaying planktonic organisms have lost and are still loosing most of their body fluids rich in organic nitrogen. This results in the N/C minimum of the remaining particulate material.

In 75 m a slight net increase in both particulate organic carbon and the atomic ratio $N/C_{(particulate)}$ can be noticed. It is most probably due to the accumulation of detritus in the main halocline. Below this halocline in about 75 m depth the distribution of the particulate organic carbon and of the atomic ratio $N/C_{(particulate)}$ is rather uniform with the exception of a small increase of both these parameters near the bottom. Sediments and bottom bacteria disturbed by bottom currents seem to be the reason for this increase. The concentration of the dissolved organic carbon raises from 75 to 200 m depth, but in the last level ample variations may be observed.

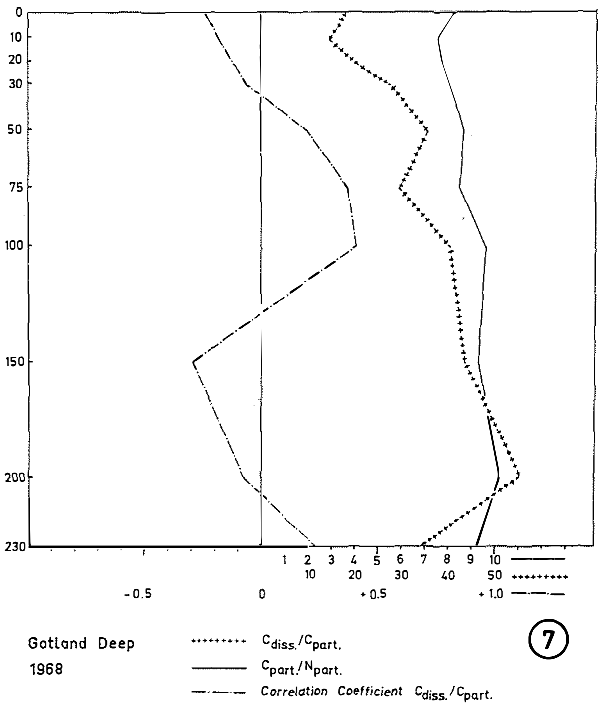
A patchlike distribution seems to be responsible for this phenomenon. J.M. GIESKES and K. GRASSHOFF (1969) arrived at a similar conclusion. The correlation between the dissolved and the particulate organic carbon is zero or negativ, thus indicating that the degradation of the particulate organic matter is complete. The ratio $N/C_{(particulate)}$ very closely approaches the figure 0.1 which is in excellent agreement with Skopintzew's results (SKOPINTZEW, 1959). He states that the end product of complete decomposition of marine organisms is a „water humus", a carbon-protein complex of high biochemical stability having a C/N ratio of 10.

Legenden zu den nebenstehenden Figuren (Tafel 5)

Figure 7: The ratios $C_{diss.}/C_{part.}$ and $C_{part.}/N_{part.}$, and the correlation coeffient $C_{diss.}/C_{part.}$ as functions of depth in the Gotland Deep in May 1968.

Figure 8: The ratio protein/$N_{part.}$, the correlation coefficient protein/$N_{part.}$, and the particulate organic nitrogen as function of depth in the Gotland Deep in May 1968.

Tafel 5 (zu Ehrhardt)



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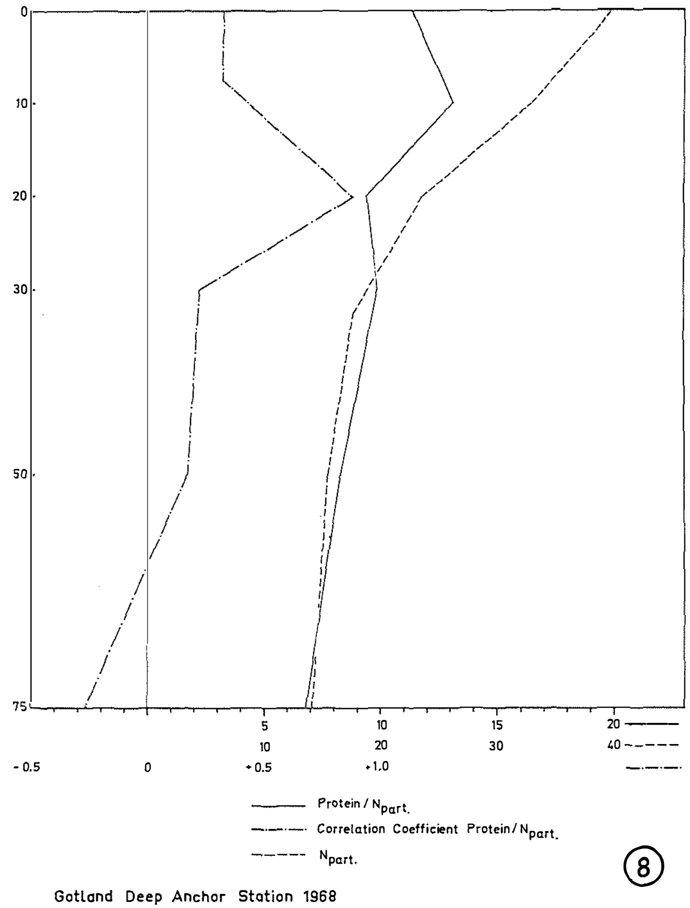

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Figure 8 (Plate 5) reveals another interesting feature, when one compares the plots of the mean values of the ratio protein/$N_{organic}$, and of the particulate organic nitrogen as a function of depth. It is clear that in the particulate matter at the surface there must be present some nitrogen containing organic compounds, that are not detected by the Lowry method (LOWRY, loc.cit.). They should, therefore, be of nonprotein character. The chemical nature of these compounds still remains to be elucidated. This will be one of the subjects of further investigations. In conclusion the author likes to point to the remarkable result that the ratios $C/N_{(particulate)}$ and $C_{diss.}/C_{part.}$ run closely parallel (Fig. 7). In mathematical terms

$$\frac{C_{part.}}{N_{part.}} = f(z) \cdot \frac{C_{diss.}}{C_{part.}}$$

in which f is some function of depth. Rearranging this equation we obtain

$$C_{diss.} = f'(z) \cdot C_{part.} \cdot \frac{C_{part.}}{N_{part.}}$$

This means that the concentration of the dissolved organic carbon in the sea area under observation is a depth dependent function of the particulate organic matter and of the ratio $N/C_{(particulate)}$. When planktonic organisms are decaying, therefore, nitrogen rich substances are the most subject to degradation, consequently raising the carbon content of the unaffected matter. The dissolved organic matter should, generally, be richer in nitrogen than the particulate organic matter. This has been demonstrated clearly by HOLM-HANSEN, STRICKLAND, and WILLIAMS (1966).

References

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