

**Baltica 14 (2001) 34-39****Distribution of organic walled microfossils within single lamina from the Gotland Basin, and their environmental evidence***Wolfram W. Brenner***Abstract**

Initial investigations on laminated sediments from the Gotland Basin show that it is possible to sample sediments in millimetre dimension for quantitative analysis of organic walled microfossils. This first result leads to the assumption, that in the investigated sequence extreme environmental variations within a few years take place. They are reflected in the microfossil content within single laminae. Especially the dinoflagellate cysts *Pyxidiniopsis psilata* and *Ataxiodinium choane* are only abundant in small layers within single lamina. From these results it can be assumed that the assemblage change of organic microfossils in the Litorina Sea phase reflects rather the frequency of specific environmental and/or climatic conditions than general assemblage changes of the microfossils. Additionally, the use of absolute abundance of specific organic-walled microfossils as sedimentation rate indicators is discussed.

□ *Baltic Sea, Gotland Basin, laminated sediments, organic-walled microfossils, dinoflagellate cysts, environmental change.*

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INTRODUCTION

In the Baltic proper today an area of almost 100 000 km² become periodically anoxic, and from this area 70 000 km² are covered with laminated sediments (Emelyanov 1988, Jonsson et al. 1990). During the marine-brackish Litorina and Post-Litorina phase of the Baltic Sea the sediments of this area are not continuous laminated, reflecting significant changes in the redox condition at the sediment – water interface even in the deepest parts (e.g. Sohlenius et al. 1996, Jonsson et al. 1990, Andr n et al. 2000, Winterhalter 1992, Sohlenius and Westman 1996, Lepland and Stevens 1998, Huckriede et al. 1996).

Laminated sediments provide the highest available resolution for studies of environmental changes in the fossil record. Due to the difficult preparation of single laminae for micropalaeontological analyses only few investigations have been done hitherto. The most common technique to prepare laminae from unconsolidated sediments is to impregnate the core with resins and to prepare thin sections. It is also possible to put a laminated sediment part without further preparation under

a scanning electron microscope or to cut single laminae for micropalaeontological investigations (e.g. Hagadorn et al. 1993, Brodie and Kemp 1994, Grimm et al. 1997, Brenner 1998, Mingram 1998).

In contrast to annually or subannually laminated lake sediments, the lamination of marine sediments is much more complex and controlled by various factors. Even the causes for laminae succession of basins located close to each other can be different as for example the Californian Borderland Basins, Santa Barbara Basin, and Santa Monica Basin. Whereas the lamination in the Santa Barbara Basin is annually in response to the seasonal migration of the North Pacific High Pressure system, in the sheltered geographic position of Santa Monica Basin only strong El Ni o Southern Oscillation events allow a deep water overturn, pointing to a laminae succession on 3-6 years time scale (Berelson 1991, Hickey 1991, Hagadorn et al. 1995). Beside the time variation for laminae there are also variations of laminae types within one laminated sequence. Brodie and Kemp (1994) describe three different types of laminae within a laminated sequence from the Peruvian coastal upwelling zone. One type is laminated in the

sub-millimetre area and is thought to be annually varved. An other type is a solitary diatom ooze lamina with a thickness of 2-10 mm, which may represent a single diatom bloom as well as a period of several years. The third type is an irregular spaced lamina composed from couplets of diatom layers with a thickness of 1 mm and a terrigenous influenced part with a thickness of 2-6 mm. The diatom layer represents a single diatom bloom, whereas the terrigenous influenced part may represent several years. Further inconsistencies of the laminae successions, thought to be annual, are reported by Crusius and Anderson (1992), from the Black Sea.

In the Baltic Sea the composition of single laminae varies. Most common is a combination of light or white layers of rhodochrosite and organic rich grey to black layers composed by clay sediments and organic material. However, Sohlenius and Westman (1998), found layers in the north-western Baltic proper with a thickness up to 2 mm consisting almost entirely of diatoms, and layers up to 0,2 mm of chrysophyte cysts. They interpret these layers as single algae blooms which were deposited in restricted areas of the sea floor within a few days or weeks.

The origin of the rhodochrosite layers is caused by the inflow of oxygen rich Atlantic water into the Baltic Sea. The mechanism for concentration of manganese enriched layers is still controversial (e.g. Huckriede et al. 1996, Huckriede and Meischner 1996, Hartmann 1964, Suess 1979, Emelyanov 1986, Sternbeck and Sohlenius 1997, Lepland and Stevens 1998, Sohlenius and Westman 1998). Börngen et al. (1990) and Stigebrandt (1987) found a periodicity of approximate 15 years for stronger salt influxes into the Baltic Sea. Frequency and intensity of the major inflow of highly saline and oxygenated water into the Baltic Sea show a significant correlation with the North Atlantic atmospheric circulation leading to the assumption that the North Atlantic Oscillation (NAO) is the main influencing factor on the dynamic of the recent Baltic Sea System (Alheit et al. submitted, Koslowsky and Glaser 1999, Matthäus and Schinke 1994, Matthäus 1995, Hänninen et al. 2000).

This clearly shows, that laminated marine sediments can not be simply regarded as the "tree rings of the ocean" but rather as the product of interactive processes which are controlled by sedimentation mechanisms and environmental change. In principle, laminae are a seasonal to annual signal, which can be overwritten by other cyclic processes as NAO, and solar or lunar cycles, which influence the meteorological situation within few years to several decades or centuries.

The subject of this investigation are first improvements of the possibilities for detailed analysis on the origin of single laminae and their variation within a sequence, based on quantitative distribution of organic

walled microfossils. These investigations can give a new insight in the dimension of environmental dynamics on annual to decadal scales as well as the velocity of environmental changes.

MATERIAL AND METHODS

The material for the present investigation has been taken from core 211 660-6 (57°17.0283N / 20°07.1386E) of *R/V Petr Kottsov* cruise in July and August at 314-316.5 cm depth below sediment surface. The sampled interval contains three lamina triplets which are composed of dark organic rich, a pale, and a white rhodochrosite layer. This interval is stratigraphically located at the top of the ecostratigraphic interval ESI V after Brenner (2001) of the Litorina Sea phase.

For subsampling the single laminae a quadratic subcore with a side-length of 2 cm were cut from the original core sample and transferred to a glass slide. The sides and the top of the subcore were cleaned with a spatula, so that the lamination could be observed from all sides.

The sample top was cut down to the surface of a lamina, which can be clearly identified by colour change. For the sampling itself, colour changes and sediment structures, which could be identified over the whole surface of the subcore, are used to differentiate the samples. The sediments were cut with a micro spatula.

Prior to the preparation of the organic walled microfossils the samples were freeze-dried. Defined quantities of *Lycopodium* spores have been added to the sample, to get a reference number for the absolute abundance of microfossils in the sediment. In the next step the samples were treated with 10% hydrochloric and 40% hydrofluoric acid to remove the carbonates and silicates. They were extensively washed through a six-micrometer sieve to remove the amorphous organic material. The residue was mounted on microscopic slides with glycerine jelly.

H. Kunzendorf generated the geochemical data with energy-disperse X-ray fluorescence (EDX) at the Gamma Dating Centre at Riso National Laboratory, Roskilde.

Age calculation for the sampled sequence

Voss et al. (2001) calculate a sedimentation rate of 0.16 mm/a for this time interval and Kotilainen et al. (2000) found in the same core deposition rates from 0.17 to 4.28 mm/a varying over very short time intervals with a linear average sedimentation rate of 0.88 mm/a. Huckriede et al. (1996) calculated the sedimentation rate of laminated sequences in the Gotland Basin to be 0.25 to 0.35 mm per year.

The investigated interval is composed of three triplets starting with a dark organic rich layer followed by a pale layer and end with a white rhodochrosite layer. The thickness of the upper two triplets, which are additionally identified by chemical analysis (Fig. 1), is

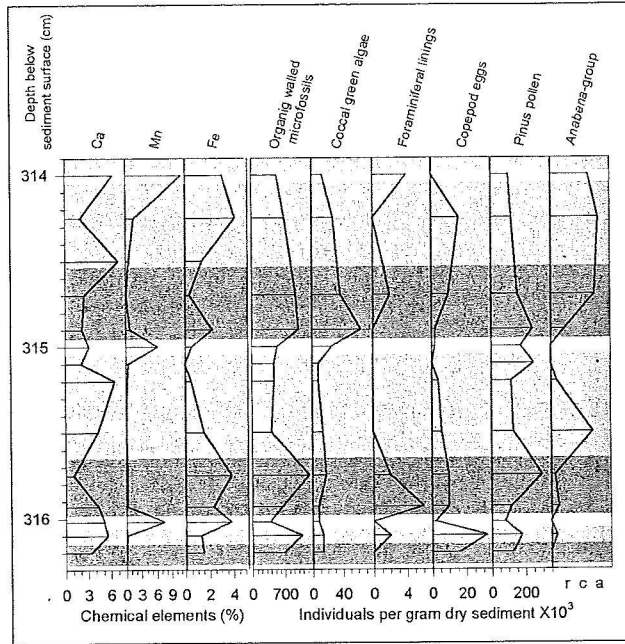


Fig. 1. Distribution of Ca, Mn, and Fe in the laminated sequence, absolute abundance of selected organic-walled microfossils. Cyanobacteria of the *Anabena*-group occur in cluster up to several hundred cells make an absolute counting impossible; the abundance is therefore given in: r (rare) – c (common) – a (abundant). The shadowing of the graphic reflect the sediment colour and composition, the white part is the rhodochrosite layer and the grey and dark grey areas reflect the pale and dark sediments.

10 mm and the lower triplet 3 mm. This corresponds to a maximal age of approximately 60, respective 18 years for a triplet after the calculation of Voss et al. (2001) and a minimal age of 11 respective 3.5 years after the average calculation of Kotilainen et al. (2000).

Cycles of 35 years (Brückner Cycle) and 22 years (Hale Double Sunspot Cycle) which are correlated to the solar activity and the NAO, are well known from Scandinavian tree-rings as well as from varved lake sediments (Hoyt and Schatten 1997, Negendank et al. 1990, Schove 1983, Landscheidt 1990). Taking into account the age calculation of Voss et al. (2001) and Kotilainen et al. (2000) as well as the possibility that the cycles mentioned above are reflected in the laminated sediments as interval between the rhodochrosite layers, it can be assumed, that a 1 cm laminae triplet has a sedimentation rate of 0.28 to 0.5 mm/a. Based on this calculation an age between 1 and 10 years for a single sample used for this investigations can be estimated. However, in this stage of the investigation, these correlations are rather speculative and a detailed analysis of a longer laminated sequence is essential to confirm the reflection of solar cycles in the lamina succession of the Gotland Basin.

Distribution of organic walled microfossil within the laminae

The sampled interval is stratigraphically located at the top of the ecostratigraphic interval ESI V in the Litorina Sea phase after Brenner (2001). The abundance of single species and the composition of the assemblage vary unexpectedly compared to the mean of all samples and to the bulk samples from the Litorina Sea phase of the same core as described by Brenner (2001). Especially *P. psilata* and *A. choane* show extreme changes in abundance within and between the different parts of the laminae (Fig. 2). Even the mean values of the microfossil abundance for the three investigated lamina triplets vary significantly (Fig. 3). Whereas in the upper two triplets the absolute abundance of *O. centrocarpum*, *L. machaerophorum* and *Spiniferites* spp. is nearly constant, the abundance in the lower triplet is approximately half (Fig. 3). A similar distribution can be found for pine pollen and for organic walled microfossils in general. Assuming that *O. centrocarpum* is an opportunistic species which is not significantly influenced by environmental changes in the investigated interval, and the distribution of pine pollen do not vary much within a few decades, this finding points to a nearly double sedimentation rate for the lower triplet. Taking this assumption into account, no significant change in the accumulation rate of *O. centrocarpum*, *L. machaerophorum*, *Spiniferites* spp. and pine pollen can be found in the three laminae triplets. The abso-

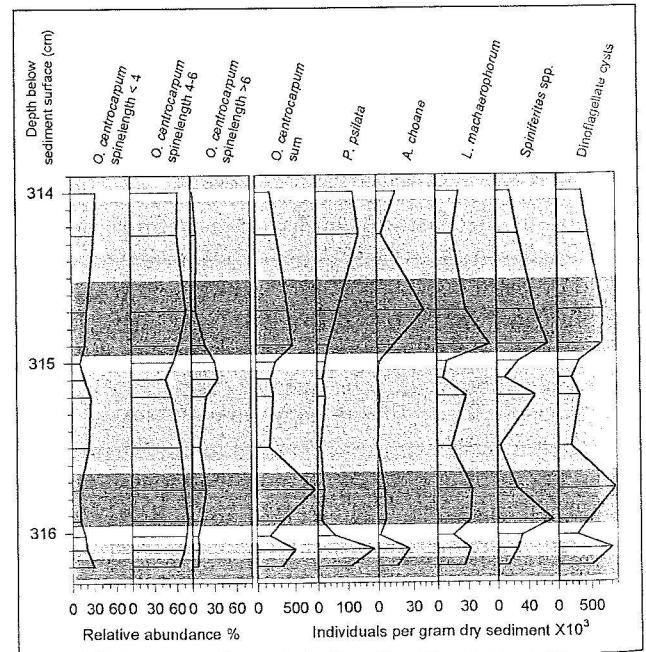


Fig. 2. Relative distribution of *O. centrocarpum* with different processes length, which can be interpreted as salinity signal. Absolute abundance of selected dinoflagellate cysts. The shadowing of the graphic reflect the sediment colour and composition, the white part is the rhodochrosite layer and the grey and dark grey areas reflect the pale and dark sediments.

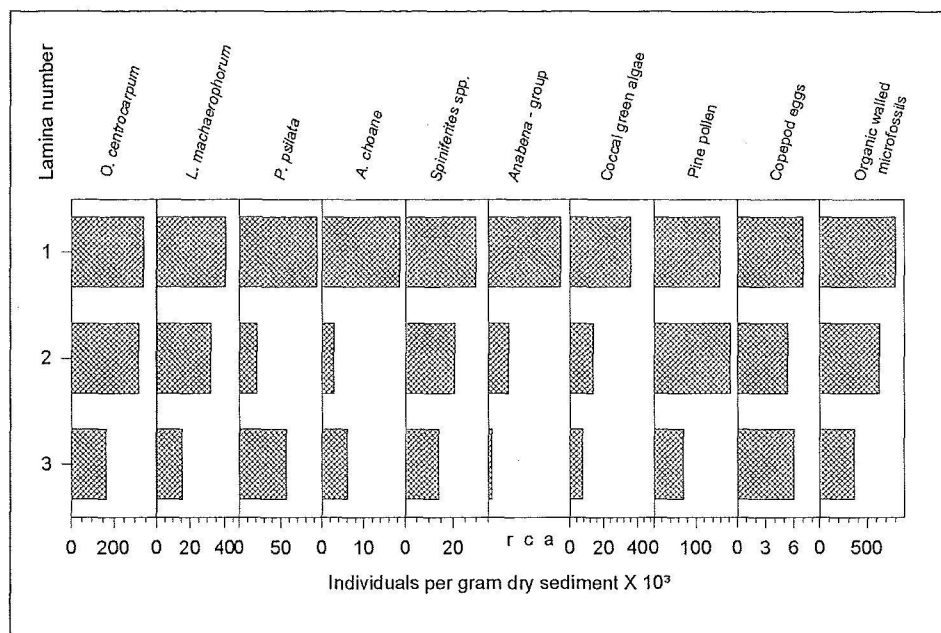


Fig. 3. Mean distribution for selected organic-walled microfossil in the different laminae triplets. Cyanobacteria of the *Anabena*-group occur in cluster up to several hundred cells make an absolute counting impossible; the abundance is therefore given in: r (rare) – c (common) – a (abundant).

lute abundance of these microfossils may therefore be a good proxy for sedimentation rate.

P. psilata and *A. choane*, however, are drastically reduced in the middle triplet, coccal green algae are dominant in the uppermost triplet and nearly no cyanobacteria can be found in the lower triplet (Fig. 3). This suggest, that these organisms need specific environmental conditions which occur only in intervals of several years or decades and that those are different to the mechanisms that trigger the laminary sedimentation.

In general, the abundance of organic walled microfossils is higher in the dark parts of the lamina pointing to a higher accumulation of organic material. This can be caused by higher primary productivity as well as by a reduced sedimentation of inorganic material as suggested by Lepland and Stevens (1998) for the Landsort Deep, roughly 180-km north west of the Gotland Basin. No significant abundance change can be found between the pale intervals and the rhodochrosite layer in the upper two triplets, suggesting that there is no difference in sedimentation rate between the pale and the manganese enriched rhodochrosite layer (Figs. 1, 2). In the lower rhodochrosite layer a decrease of organic-walled microfossil abundance suggest a higher sedimentation rate for this layer.

DISCUSSION

Already the distribution of organic-walled microfossils in the investigated lamina triplets shows that there are environmental variations within the single triplets

and that there is no correlation between sedimentological processes and the environmental influence on the composition of the organic-walled microfossils assemblage (Fig. 3). Much more differentiation of the organic-walled microfossil assemblage can be seen between the single laminae (Figs. 1, 2). In the dark laminae of the upper two triplets, the dinoflagellate cyst abundance is higher than in the pale part and in the rhodochrosite layer, leading to the assumption that there was a significant higher primary production or the sediment accumulation rate was lower as proposed by Lepland and Stevens (1998). Within the

lower triplet, however, the accumulation rate of organic walled microfossils is higher in the pale layer than in the dark layer suggesting that the correlation between sediment colour and productivity should be used carefully.

Assuming that there is no significant change in the forest composition within a few decades up to a century, pine pollen seems to be useful for calculation of the sedimentation rate. The nearly identical abundance variation of the complete organic-walled microfossils assemblage with the pine pollen record seems to confirm the assumption that this value can be used as proxy for sedimentation rates. Identical absolute abundance variation can be found by the dinoflagellate cyst *O. centrocarpum*. Since this cyst is the dominant form in the whole Litorina Sea phase in the central Baltic Sea (Brenner 2001) and it is assumed that the mean productivity within few years do not change significant, this species may be also a useful proxy for sedimentation rates. Based on this assumption, a nearly identical sedimentation rate for the upper two laminae triplets can be proposed, where the sedimentation rate in the pale interval is slightly higher than in the dark one. In the lower triplet however, the distribution of the abundance in the pale and dark interval is vice versa, suggesting that different processes lead to the formation of this lamina.

Furthermore, if the assumption of Huckriede and Meischner (1996) that the sedimentation of the rhodochrosite layer is a rapid process is true, a significant decrease in microfossil abundance should be take place in those layers. Within the investigated sequence the abundance of microfossils in the rhodochrosite layer of the upper two rhodochrosite layers do not change

or is continuous compared to the sample above and below, whereas in the lower rhodochrosite layer most organic-walled microfossil show a decrease in abundance (Figs. 1,2). This shows that there is not necessarily an increase in the sediment accumulation rate during sedimentation of rhodochrosite layers and possibly different processes leads to the formation and sedimentation of rhodochrosite.

Relative salinity changes can be identified by the variation of spine length of *O. centrocarpum* (Brenner 2001, Dale 1996), which suggest a slightly higher salinity only in the dark interval at 315.7 to 315.9 cm core depth and in the upper part of the pale interval and the rhodochrosite layer at 315.0 to 315.2 cm (Fig. 2). This finding suggest that there is no correlation between the surface salinity and the sediment succession or lamina formation. The missing of correlation between salinity and dinoflagellate cyst abundance and assemblage is obvious in the investigated sequence, suggesting that this signal might be overwritten by other environmental influences and should be carefully used to interpret the palaeosalinity.

Another very interesting finding is the abundance variability of several dinoflagellate species as *P. psilata* and *A. choane* which are only abundant in the upper and lower triplet and only few specimen are present in the triplet between 315 and 316 cm (Fig. 2). Coccal green algae are only common in the upper triplet with the highest abundance in the lower part of the dark interval, and cyanobacteria of the *Anabena*-group are only present in larger numbers in the upper triplet and in the basal part of the pale interval of the middle triplet (Fig. 1). The fact that some species occur only in specific layers in larger numbers lead to the assumption that they are blooming only under very specific environmental conditions which occur in a frequency of several decades in the case of the investigated sequence. In contrast, no extreme or rapid abundance change of those species can be found, if a sample size of 1 cm is used, as it is the case for the investigation of the whole core 211 660-6 by Brenner (2001). This finding has a significant consequence for the interpretation of relative and absolute abundance change of microfossil assemblages and the environmental interpretation. The increase or decrease of species abundance in a sediment succession must therefore not necessarily be the effect of higher or lower abundance of the species in the primary environment, it could be as well an accumulation or frequency variation of specific environmental conditions which favour the blooming of specific species. Following this hypothesis, natural ecosystems seem to be highly dynamic and extreme changes of the fossil assemblage can take place within several years whereas the system is still stable. Assemblage changes, as for example during the Litorina Sea phase in the Gotland Basin (Brenner 2001), may reflect therefore rather the frequency of specific weather and consequently environmental condition as

an environmental change suggested by different assemblage compositions during the different intervals. However, to confirm this hypothesis, which has the potential for a new understanding of the climate driven environmental dynamics and stability, longer laminated sections from different localities must be studied.

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