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SUBFOSSILIZED MICROORGANISMS FROM THE BIOGENIC LAMINATED DEPOSITS OF THE SHORE ZONE OF THE HEL PENINSULA

UKD 561.26:551.351.051:552.581(438 – 17)

Until quite recently much more attention was paid to the algal mats and stromatolites from carbonate and mixed (carbonate and gypsum in generally siliciclastic deposits) environments than to siliciclastic environments. These investigations embeded both sedimentological and geomicrobiological aspects of stromatolites and microbial mats (e.g. 7, 16, 11, 8, 2, 14). Only since quite recently more attention has been given to the algal mats and stromatolites from siliciclastic environments (1, 3, 12, 5, 6).

In constrast to the mats from subtropical carbonate environments, carbonates mineralisation does not occur in the humid climate-belt microbial mats. Generally the processes of calcification occur neither in microbial mats in temperate regions nor in those from tropical siliciclastic environments (1, 6, 7, 12). This is the main reason why it was thought that these microbial deposits could not be fossilized. It is a widespread belief that microorganisms developing on the quartz-sandy deposits have a rather small chance to be preserved, unless they have been rapidly buried, and anaerobic conditions have prevailed in the decay environment (15).

Geredes, Krumbein and Reineck (5, 6) investigated modern deposits from the tidal environment, the North Sea, which are created by microorganisms and in order to describe them they proposed the term "biogenic laminate subfacies".

All of the above quoted papers present the results of investigations carried out in hypersaline or marine environment, whereas there are not materials devoted to brackish-water environment. On the other hand it is known that in terrestial environments, like peat bogs, microorganisms are mainly represented by fungi and heterotrophic bacteria (9, 4).

Sedimentological and microbiological investigations of biogenic laminated deposits (organic matter intercalated with quartz-sand) at the shore zone of the Inner Puck Bay have been carried out.

THE STUDY AREA

The Puck Bay is the Western part of the Gdańsk Bay and is separated from the open Baltic Sea by the Hel Peninsula. The waters of the Puck Bay with the salinity around 7 to 8‰ represent a brackish-water environment (mixomesohaline). Among the hydrodynamical factors responsible for sediment transport in the Puck Bay, currents created by the water level changes are the most important ones. These changes caused by meteorological conditions appear irregularly but they can rise the water level by up to 1.0 m (average 30 cm). They are caused by heavy eastern or western winds blowing constantly for some period of time (12). At the extremely low water

levels, extensive areas of the bottom – even at the distance of few hundreds meters from the shore line – are exposed.

The microbial mats at the coastal zone of the Puck Bay are composed of diverse cyanobacteria, chemoorganotrophic bacteria, chemoautotropic bacteria (genus Begiattoa), photosynthetic-anaerobic purple sulphur bacteria, diatoms and green algae. All of microorganisms which were found in biogenic laminated deposits have also been observed in the Puck Bay (10).

The biogenic laminated deposits (locally designated as coastal peat) occur along the coast of the Hel Peninsula. They form a kind of microcliff of approx. 0,5 m height. Near the shore line they are often destroyed by the waves at high water storm levels.

METHODS

Samples of the deposits with high content of organic matter were taken into sterile test tubes and immediately transferred to the laboratory. Then they were poured with medium for cyanobacteria after Allen and incubated in room temperature at light. After one month of incubation, when the growth of phototrophic microorganisms was observed, BG_{11} medium (agar plates) and F1 medium (in flasks) were used to obtain unialgal and unicyanobacterial cultures. Field samples were also observed directly after sampling under the light microscope.

RESULTS

An examination of the deposits at the shore zone of the Hel Peninsula revealed densely packed organic (peaty) layers of subrecent microbial mats intercalated with quartz-sandy deposits.

The organic layers are from several millimeters up to 1.5 cm thick. They are irregular in shape, the upper and lower surfaces are undulating. An internal bipartition is visible. In the lower one (about 20 cm in thickness), the quartz-sandy deposits prevail. Three layers of peaty microbial mats are embedded in sands with bi- to multi-modal grain size distribution and a significant admixture of pebbles. The upper part (about 15 cm thick) is composed of peaty microbial mats alternating with medium sized quartz-sand.

Microscopic examinations enabled us to find in the biogenic laminated deposits the presence of a differentiated set of microalgae and bacteria. In the organic layers of the lower part of the deposits Chlorophyceae prevailed from the genera: *Ankistrodesmus* and *Scenedesmus* and unicellular forms from the order Chlorococcales (the most common). Less frequent were Bacillariophyceae (genera: *Navicula*, *Diploneis* and *Coscinodiscus*)and Cyanobacteria (genera: *Lyngbya*, *Phormidium* and coccoid forms).

The set of microorganisms from the upper part is much more differentiated. In some layers the Cyanobacteria prevailed but in others Chlorophyceae. There were established the unicellular and the filamentous forms. The filamentous forms were represented by the Cyanobacteria (*Oscillatoria* sp., *Lyngbya* sp., and *Phormidium* sp.) and Chlorophyceae (*Ulotrix* sp.). These forms were incubated only from some layers but the empty sheaths of filamentous forms were present in layers from lower and upper parts.

Among the coccoid Cyanobacteria, *Synechococcus* sp., *Microcystis aeruginosa*, *Merismopedia punctata*, *M. glauca* and *M. tenuissima prevailed.* Less frequently *Gloeocapsa minima* and *Aphanothece castagnei* occurred. Like in the lower part the unicellular Chlorophyceae from the order Chlorococcales and the representatives of genera *Ankistrodesmus* and *Scenedesmus* were present.

Diatoms occur in all layers. The following forms were identified to the genus level: *Navicula*, *Nitzschia*, *Achnantes*, *Diploneis* and *Coscinodiscus*.

Besides, the phototrophic microorganisms, chemoorganotrophic bacteria (rod shaped and coccoid) and fungi equally frequently occurred. The examination of samples suspended in sterile water revealed the presence of microbial detritus. Sheaths of filamentous and coccoid forms were found as well as fragments of colonies.

CONCLUSIONS

The laminated microbial mat deposits comprise some typical mat forming cyanobacteria with some eukaryotic algae admixed. The coccoid and filamentous Cyanobacteria: *Synechococcus*, *Microcystis*, *Merismopedia*, *Aphanothece*, *Gloeocapsa*, *Oscillatoria*, *Lyngbya* and *Phormidium* as well as Chlorophyceae (also coccoid and filamentous), *Chlorococcales*, *Ankistrodesmus*, *Scenedesmus* and *Ulotrix* were recorded quite frequently in the peaty material. The diatoms *Diploneis*, *Achnantes*, *Navicula*, *Nitzschia* and *Coscinodiscus* were recorded less frequently.

The environmental factors (salinity and temperature) are much less extreme than in the tropical microbial deposits. Eukaryotes therefore are very important constituents of this community. Besides, viable microorganisms, many empty sheaths of both filamentous and coccoid forms were found to be preserved in large amounts. Because of the method used it is too difficult to estimate quantitative relationships between the particular groups of microbes and viability of cell fractions.

The sedimentological and microbiological analysis enabled us to find similarities between the laminated deposits from the Puck Bay and processes described by Stolz and Margulis from Laguna Figueroa, Mexico (15). It is likely that the sand transported by the currents during increases of the water level in the Puck Bay have rapidly buried the layers of microbial debris. After that burying the reductive conditions could be created by the activity of sulphatereducing bacteria.

In conclusion it is possible to state that these deposits seem to manifest that the preservation of distinguishable microorganisms (especially Cyanobacteria) in a quartz-sandy environment is possible but depends on conditions of preservation. Acidity of peat like deposits in a brackish-water environment may favour the preservation even more, than in siliciclastic Atlantic or North Sea intertidal stromatolitic systems.

ACKNOWLEDGEMENTS

The authors wish to express their thanks to Dr. J. Nieradko from the Department of Microbiology, University of Gdańsk for his help in the study of microbiological methods, and to Dr. T.M. Peryt for his critical reading of the manuscript.

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STRESZCZENIE

Laminowane osady biogeniczne (naprzemianległe laminy piasków kwarcowych i materii organicznej) ze strefy brzegowej Płw. Helskiego badano przy użyciu metod sedymentologicznych i mikrobiologicznych. Próbki osadów pobierano do sterylnych probówek i po przewiezieniu do laboratorium zalewano płynną pożywką Allena a następnie oświetlone inkubowano w temperaturze pokojowej.

W wyniku przeprowadzonych badań mikroskopowych w laminach organicznych obok mikroorganizmów typowych dla środowiska mat glonowych (sinice) stwierdzono również występowanie organizmów eukariotycznych (zielenice, okrzemki). Wśród sinic obserwowano zarówno formy jednokomórkowe: *Microcystis*, *Merismopedia*, *Gloeocapsa*, *Aphanothece* jak i nitkowate: *Oscillatoria*, *Lyngbya*, *Phormidium*. Podobnie wśród zielenic obserwowano formy jednokomórkowe: *Ankistrodesmus*, *Scenedesmus*, *Chlorococcales* i nitkowate – *Ulotrix*. Natomiast okrzemki reprezentowane były przez *Navicula*, *Nitzschia*, *Diploneis*, *Achnantes* i *Coscinodiscus*.

Przeprowadzone badania pozwalają na stwierdzenie, że laminowane osady biogeniczne świadczą o tym, iż fosylizacja mikroorganizmów w środowisku piasków kwarcowych jest możliwa, ale zależy od warunków w jakich proces ten przebiega.