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DOCTRINA-VIM-PROMOVET-INSITAM

The Fifth International Conference "Environmental Micropaleontology, Microbiology and Meiobenthology"

EMMM'2008

Conference Materials

Chennai India

The Fifth International Conference "Environmental Micropaleontology, Microbiology and Meiobenthology" EMMM'2008

Department of Applied Geology, University of Madras, India

February 17-25, 2008

International Society of Environmental
ISEM
Micropaleontology
Microbiology
Meiobenthology

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THE HALOPHILIC ALGAE-BACTERIAL MATS AND MN-STROMATOLITES OF KERCH PENINSULA

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Keywords: Crimea, hypersaline lakes, ancient and recent halophyl communities, Mn-oxidizing bacteria

INTRODUCTION

The algal-bacterial and cyanobacterial communities (mats) of hyperhaline lakes and lagoons attract much attention because their study helps to understand the processes leading to mass development of ancient stromatolites on the Earth. Stromatolites are laminated organosedimentary structures that appear as a result of microbial communities growth and their interaction with environment. This interaction involves binding of carbonate particles by cyanobacteria and their concentration into a rock. Stromatolites dominated throughout the Precambrian period of the development of the biosphere. In the Phanerozoic Eon, the number of stromatolites drastically decreased due to the appearance and expansion of Metazoa organisms which competitively displaced cyanobacterial communities in econiches with extreme conditions. We know now that besides common carbonate occurrences, these structures can be mineralizited by metallic oxides (Fe, Mn), phosphates, sulfates, silica, etc. Stromatolites are built mainly by bacteria and cyanobacteria, which may organize themselves into simple or complex communities. As a rule it is a cyanobacterial community. But algae-bacterial communities are found particularly in Mesozoic and Cainozoic stromatolities. The majority of recorded oldest stromatolitic developments appear to have occurred in very shallow (often intertidal) setting, in condition with abnormal conditions. Oncolites are the particular case of stromatolites. They are spherical form from several mm to several centimeter with concentric laminated structure. They are formed by clods of algae, cyanobacteria, bacteria which swim on the surface of water. As stromatolites onkolites are developed in the shallow water in the reservoirs with fluctuating salinity and swelling water in the tidal zone of the sea.

METHODOLOGY

Photographs of stromatolites and recent mats were taken by an electron scanning microscope (SEM) CamScan, serie 4, with microanalizator LINK 860 at the Palaeontological Institute.

RESULTS

Five saline lakes in Kerch peninsula (Koyashskoe, Kirkoyashskoe, Marfovskoe, Shimakhanskoe and Tobechikskoe) were studied (Figure 1). They are not large, with small depths. In the summer the majority of them partially or completely dries up, and on the most of its area is covered with a mineral crust of white, white-pink or white-grey color under which almost always there is a very thin layer of brine. There is black and black-grey mud with significant contents of water below this layer (Shadrin, Naidanova, 2002). The salinities in these lakes varied from 13 to 350‰ according to the point and season of sampling.

Different cyano- and algae-bacterial biofilms and mats, containing *Cladophora* sp., cyanobacteria and purple bacteria as the main phototrophic organisms, were represented especially in small shallow waters (Figure 2, 3). Their morphological characteristic is a laminated structure. There are usually three different collared zones: green (cyanobacteria), pink (purple bacteria) and black (anaerobic heterotrophs) (Mikhodyuk *et al.*, 2005).

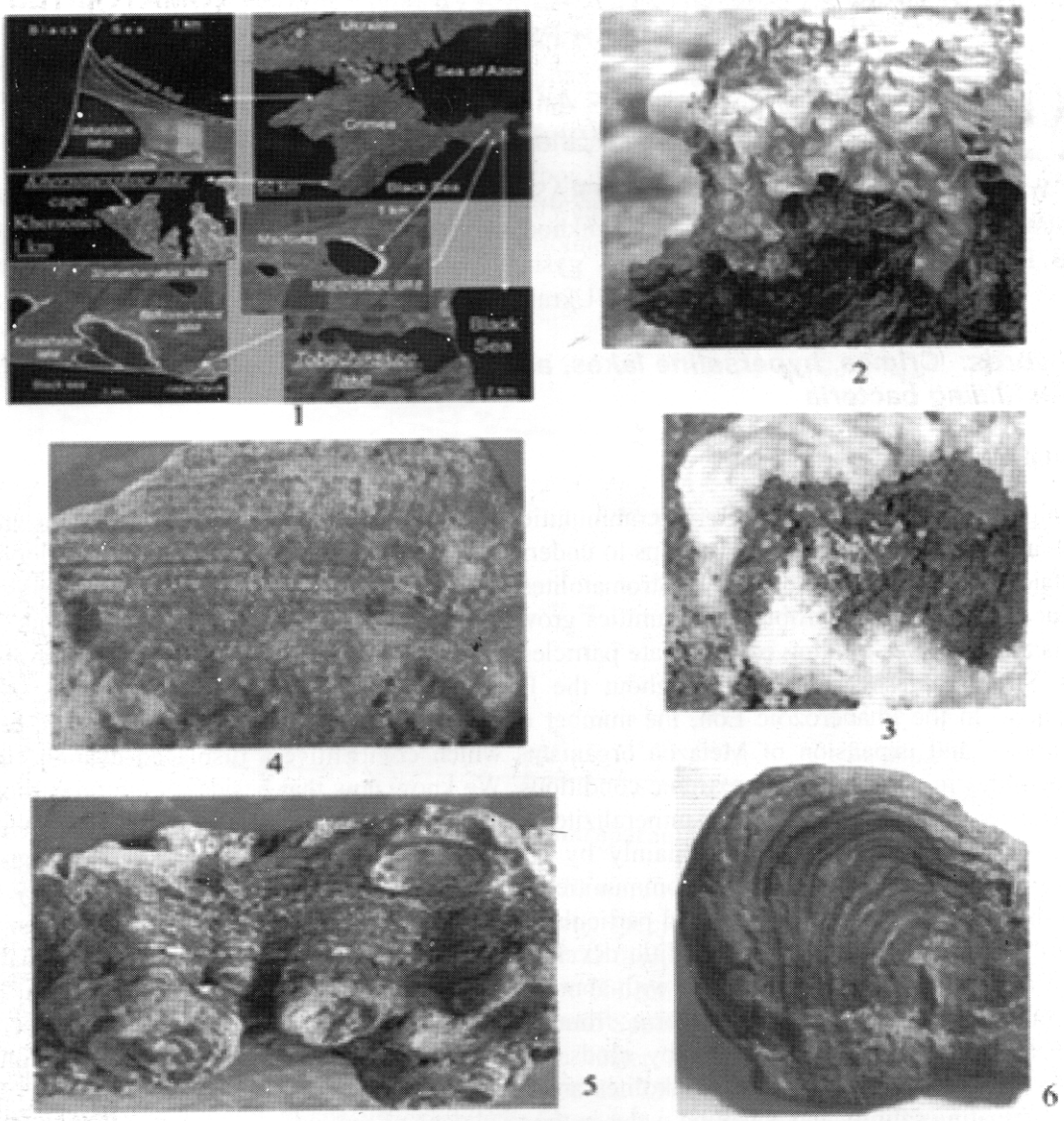

Figure 1. Map of Crimea.

Figure 2. Modern plant-bacteria community with Ruppea: cyanobacterial mat developed on Ruppea.

Figure 3. Cyanobacterial film within salt deposit (recent, lake Koyashskoe).

Figure 4. Miocene Mn-stromatolite (near lake Marfovskoe).

Figure 5. Column form of Miocene Mn-stromatolite (near lake Tobechikskoe).

Figure 6. Pliocene Mn-onkolite (near lake Koyashskoe).

There are good outcrops of Miocene and Palaeocene deposits in Kerch peninsula near studying saline lakes. These outcrops contain of stromatolites and oncolites. The studying of latter enable to compare the mineralizated algal-bacterial communities contained in stromatolites and oncolites with the modern communities of saline lakes (Figure 7, 8, 14, 15).

Stromatolites in the upper part of the sand-carbonate strata of Karagan horizon (middle Miocene) develop especially widely near v. Marfovka (near saline lake Marfovskoe) (Krylov, 1975) and near the coast cliff of the lake Tobechiksckoe (Figure 4, 5).

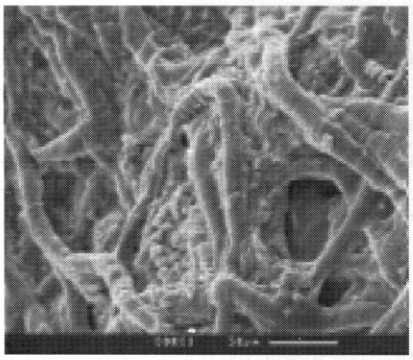

Figure 7. The modern algae-bacterial mat with trichomes of cyanobacteria and Cladophora.

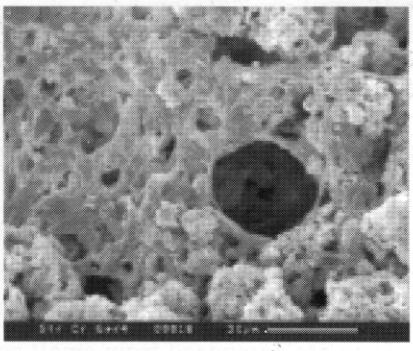

Figure 8. Miocene stromatolites from Marfovskoe.

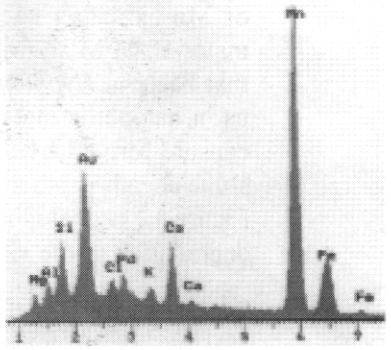

Figure 9. Rentgenogram of the dark layer from stromatolites.

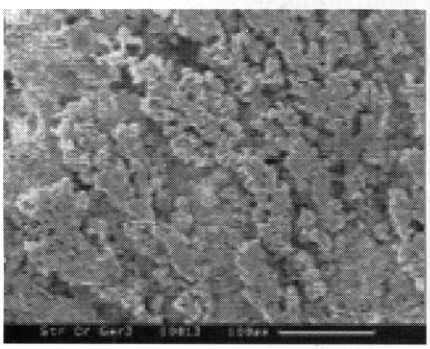

Figure 10. Stromatolites with bushs of algae.

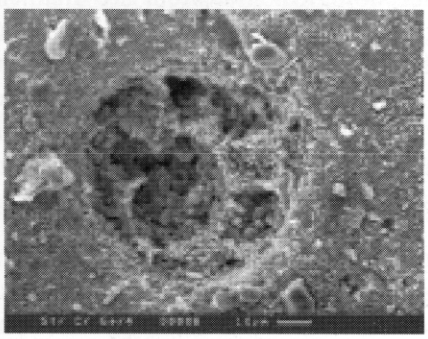

Figure 11. Manganized foraminifera in the stromatolite from Marfovskoe

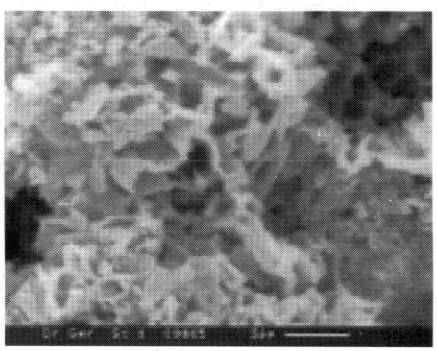

Figure 12. The transverse section of bacteria trichomes in the dark layer of stromatolite (Tobechikskoe).

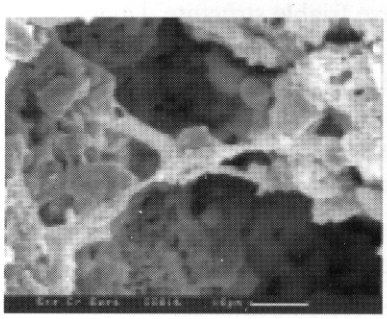

Figure 13. Slime threads in the dark layer of stromatolite (Tobechikskoe)

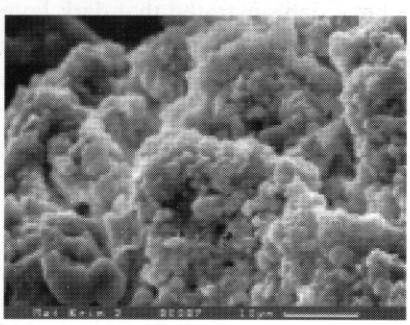

Figure 14. Modern bacterial mat from saline lake Koyashskoe

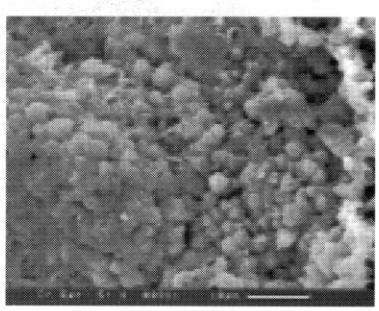

Figure 15. Fossilizited bacterial mat from Myocene stromatolites (Marfovskoe)

Stromatolites of Marfoskoe are rather large-scale biohermes sometimes (according to I.N.Krylov they have a height to 70-80 cm and the extent to next m). They have well-defined undulating lamination with alternation of lighter and darker layers. The sections with small column buildings were found among the stromatolites strata. These stromatolites were described as carbonate ones. The literature data are absent that they belong to Mn-stromatolites. However the presence of Mn and Fe in the dark layers was found with Link-analysis. Typically Mn-mineral structures were found with SEM (Figure 8, 9). The dark layers have peculiar picture like the growing bush (Figure 10). Possibly they belong to the benthic green algae *Pseudendoclonium submarinum* (cells 5 x 20 mkm, brunching trichomes from 5-10 cells, large sliming uncorrect accumulations in course of age), which are growing now in lateral zones of the sea. The second variant: probably the bushes were formed by the green algae Cladophora, for which the attaching mode of life is typical for beginning of life cycles. The mechanism of formation of Mn structure on our opinion was: soon after entrance Ca-carbonates in water it was precipitated on the algal surface. But algae was not mineralised totally and entering Mn replaced the organic material. It is difficult to answer on a question: is the substitution or presence of Mn iones and Ca-carbonate stimulated the development

of Mn-oxidizing bacteria? But it is absolutely exact that Mn precipitates on the detrite organic material. SEM shows the manganised remains of the worms, foraminifers (Figure 11). It is known that bacteria *Hyphomirobium* are met among Mn-oxiditing bacteria. These bacteria were found by us in halophilic mats of Crimea saline lakes (Vasilieva *et al.*, 2007). All these bacteria have slime capsule formed by acid polysaccharides at which Mn oxide was precipitated. Leptothrix with it slime sheath is other possible organism-participator of the process of Mn-precipitation. Pure on the Figure 12 is analogous to the wisp of those Leptothrix filaments. Mineralised sheath remains after degradation of the latter.

Stromatolites from the south shore of the lake Tobechiksoe belong to same stratigraphic horizon as Marfovskoe stromatolites. They are composed from small column-like constructions. The structure of dark Mn-contenting layers is similar to Marfovskoe stromatolites. But SEM had shown that dark layers have more friable structure: compact colonies are connected by links of small (microns) size. It is possible to suppose that this is the result of life-activity of Mn-oxidizing organism Metallogenium. Their morphological indicators are filaments-araii, Mn-oxides set around them (Figure 13). Unusual organism Metallogenium was described by B.V.Perfiliev in the beginning of 60 years XX century, when he studied microorganism diversity in the bottom deposits from ore-lakes (Zavarzin, Kolotilova, 2003). It is appeared, that there are no membranes or some another structures from alive cells in this organism. Fluorescent stain is shown absent of nucleotides. It was supposed that Metallogenium is no cell organism, but chemical product of life activity of bacteria. Several "species" of Metallogenium exist in the fungus culture or with other bacteria.

The oncolites samples from the Koyashskoe lake shore are interesting as well (Gerasimenko *et al.*, 2005) (Figure 6). Stratigraphic level of beds including oncolites is not known exactly, but most likely they belong to Pliocene Kimmery or Akchagyl horisons. This was a time of accumulation of iron and manganese ores of Kerchenskii peninsula. (Stratigraphy of USSR, Neogene system, 1986).

Oncolites are large size (10-15 cm in diameter), clear-cut concentric lamination (Figure 6). The thin-section from onkolites have demonstrated that dark layers have friable structure. Under SEM it was elucidated that more compact light layers consist of calcium carbonate and dark layers keeping Fe and Mn have no identical structure: among light calcium carbonate crystallites there are dark globules of different size similar to bacteria colonies. It is known that manganese-oxidized bacteria could have forms of coccus, bacilli, vibrio. All these bacteria are organotrophic and need in the organic carbon. The last one was taken from different carbohydrates, exometabolites of algae or cyanobacteria.

The comparing of morphological peculiarities of algae and cyanobacteria remnants found among fossil stromatolites with algae and cyanobacteria from saline lakes Kerch peninsula shows that they are almost identical. The studying within several years of Crimea salt lakes have recognized the high season and days alteration of salinity, pH, temperature, oxygen regime. These lakes are unical place for inhabit extremophylic halophylic organisms: cyanobacteria, bacteria, including Fe, Mn-oxidizing bacteria, some algae of type Cladophora. It is possible to suppose that the formation of Karagan stromatolites and Pliocene onkolites occurred in the sea lagoons, on the shallow waters. The extremophylic biota similar biota living now in hipersaline lakes took part in this process. The participation of microbiological process in the extraction of metals including manganese from see water and transport its to deposits was described repeatedly (Lisiuk, 2000).

CONCLUSION

The finds of microflora remnants located in the layers of shallow sea deposits are illustrated of their active participate in formation of Fe-Mn concretions. The comparing of such Fe-Mn structures from different regions indicated their principal morphological similarity (Shkolnik et al. 2004) and allows to speak about common mechanism of origin with microbiota helping. A comparison of modern cyanobacterial and algae-bacterial associations with the ancient stromatolites allows us to reconstruct the biosphere of the past.

The research has been carried out with financial support from Presidium of RAS (Program "Biosphere origin and evolution").

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