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Fe-S biomineralization in hot springs biomats and sediments

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Recently, biomineralization in natural environments is one of the key points in the study of the interactions between microorganisms and minerals. Among prokaryotes, there are few examples of controlled mineral formation: bacteria produced ferromanganous micronodules, varieties of stromatolites, the formation of crystalline iron oxides and sulfides by magnetotactic bacteria and others. Bacterial role in formation of sulfide minerals in natural environments is essential, Fe-S biomineralization might be the main process in pyrite formation.

In this study, biomats, water and sediments were collected in July 2001 from three hot springs: Kotelnikovskij, Hakusy and Zmeinaya, besides Lake Baikal, Siberia, Russia. The samples were carried on energy dispersive X-ray fluorescent analysis, optical and epifluorescent microscopy and were micromorphologically investigated by scanning electron microscope, equipped with an energy dispersive X-ray spectrometer.

With field measurements of water, strong anaerobic conditions were found in Kotelnikovskij and Zmeinaya hot springs. ED-XRF analysis of samples revealed that Si and Ca content were high in water, biomats and sediments from all hot springs. S was detected only in water samples. High concentration of sulfur under strong anaerobic conditions in Zmeinaya hot springs might lead to formation of sulfide minerals. Biomats and sediments in all hot springs contained high concentrations of Fe, K and Al with traces of Mn, Ti, and Sr. Content of Fe in biomats from hot springs was higher than that of sediments, suggesting selective accumulation Fe in biomats. Optical and scanning microscopic observation revealed that biomats, diatoms, algae and microorganisms showed variety of shapes and forms at the same ecosystem.

Silica and calcium biomineralization are the processes caused by microorganisms that can effectively mediate mineral mobilization and fixation. These organisms: bacteria and algae, might be the sites for nucleation, because of high surface area-to-volume ratio, existence of active groups on the surface of cells and sometimes of active substances produced by microorganisms. In this study, precipitation of silica and calcium chemically and biologically mediated were found in Kotelnikovskij hot springs. High concentration of silica and high water temperature in hot springs water caused rapid precipitation of silica exact in hot springs source, - content of Si in sediments were more then 88 wt%. While Si and Ca grains observed in biomats contained characteristical peaks of Mg, P, S and sometimes additionally Fe and Ti. These grains might to be biologically mediated. Fe-utilizing microorganisms can be nucleation sites for silicate and calcite mineral formation.

Iron is the only macro-bioelement of the heavy metals and is biologically the most important heavy metal cation. Microorganisms can affect the mobility of iron as well as its accumulation. Iron ions could be transported into bacterial cells by uptake systems. In this study with EDX analysis the presence of high Fe peaks in photosynthetic filamentous algae and bacterial cells from Hakusy hot springs green biomats were detected. Iron accumulation in or on cells of microorganisms might to lead iron mineral formation.

Many sulfide minerals under near-surface natural environmental conditions can only be produced by microbiological action on specific precursor metals. In this study Fe-S biomineralization on the surface of diatoms has been observed in Zmeinaya hot springs biomats. EDX analysis revealed presence of phosphorus together with S and Fe peaks in bacterial cells, attached to diatoms. Considering strong anaerobic conditions in hot springs water and high content of sulfur in it, we can suggest that the process of pyrite formation can occurred on the surface of diatoms by Fe-utilizing microorganisms.