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Tolerance Limits of Microbial Life in Terrestrial Permafrost

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The evolution of life on Earth started 3.8 Ga ago, when living conditions on Mars were similar to those on early Earth. Assuming that first life on both planets was determined by complex microbial communities, the Martian life must have adapted to drastically changing environmental conditions or become extinct again. One possibility for survival of Martian primitive life might be subsurface lithoautotrophic ecosystems. Comparable environments exist in permafrost regions on Earth.

Terrestrial permafrost habitats are colonized by highly specialized microorganisms like methanogenic archaea and nitrifying bacteria. Both groups of microbes will be used as *key-organisms* for studies on life in extreme environments. They are characterized by lithoautotrophic growth, whereby energy is gained by the oxidation of inorganic substances and carbon dioxide can be used as the only carbon source. Lithoautotrophic growth is an important presumption for long-term survival and might be a specific adaptation to the oxygen and organic free environment of early Earth. Methanogenic archaea are strictly anaerobic microorganisms, which can grow and survive only under anoxic conditions like in deep permafrost sediments. Here, they are able to produce methane at sub-zero temperatures (tested to − 6 °C). Although nitrifying bacteria are traditionally regarded as aerobic organisms, they possess a high physiological flexibility and show various adaptation strategies to microaerophilic and anoxic conditions. There is first evidence of metabolic activity in the permanently frozen sediments also for nitrifying bacteria.

In the planned project we contribute to the questions discussed within the field of astrobiology: What are the tolerance limits of microorganisms in extreme environments like terrestrial permafrost and what can we learn from these studies for the search of life in comparable extraterrestrial permafrost habitats like on Mars?

In order to examine these questions, lithoautotrophic microorganisms derived from Siberian permafrost in addition to known species will be used as *key-organisms* to investigate their potential to survive adverse living conditions. The tolerances of these organisms in pure cultures as well as in their natural environment will be tested with regard to different stress factors. The borders of growth influenced by desiccation, temperature extremes, radiation, starvation and increased salt concentrations will be analyzed for the different physiological groups.

For the planned research pure and enrichment cultures of methanogenic archaea and nitrifying bacteria from Siberian permafrost soils are already available. For further studies on sub-surface life permafrost sediments of Holocene and late Pleistocene age were drilled in 2002 and transported in frozen condition to Germany. These sediments are characterized by a high methane concentration and a high archaeal biomass. After thawing of the sediment a microbial methane production between 0.01 and 1.13 nmol CH_4 h^{-1} g^{-1} was analysed.

The comparative system studies will serve to understand the modern Mars cryosphere and other extraterrestrial permafrost habitats. This knowledge represents an essential basis for searching and understanding of extraterrestrial life, if present, especially concerning possible protected niches on present Mars.