Methanogenesis under Extreme Environmental Conditions in Permafrost Soils: A Model for Exobiological Processes?

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INTRODUCTION

The evolution of life on Earth had already 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. Therefore, terrestrial permafrost, in which microorganisms have survived for several million years, is considered to be a model for extraterrestrial analogues.

METHANOCENIC ARCHAEA

Responsible for the microbial methane production (methanogenesis) is a small group of highly specialised microorganisms, called methanogenic archaea. They are regarded as strictly anaerobic microbes, which can grow and survive only under anoxic conditions. They are characterised by lithoautotrophic growth, whereby energy is gained by the oxidation of hydrogen and carbon dioxide can be used as the only carbon source. Because of the specific adaptations of methanogenic archaea to conditions like those on early Earth (e.g. no oxygen, no or little organic substrates) and their phylogenetic origin, they are considered as key-organisms in astrobiological research.

METHANOGENESIS

Studies of CH₄ production in the active layer showed methanogenesis at in situ temperatures between 0.6 and 1.2 °C as well as at -3 °C (0.1 – 11.4 nmol CH₄ h⁻¹ g⁻¹) and -6 °C (0.08 – 4.3 nmol CH₄ h⁻¹ g⁻¹). In Holocene permafrost deposits, high CH₄ concentrations were proven and methanogenesis could be initiated after thawing of the sediments. The results indicated the existence of a methanogenic community which has well adapted to the low in situ temperature of permafrost.

CONCLUSION

The presented results show that methanogenic archaea are suitable key-organisms for further studies about adaptation strategies and long-term survival in extreme environments. Microbiological studies in combination with geochemical and physical analysis can give insights into early stages of life in terrestrial permafrost, which can be used as a model for exobiological processes.