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The potential of Methanogenic Life in the Solar System

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Abstract

Methanogens from the domain Archaea are obligate anaerobic chemolithoautotrophs or chemolithoheterotrophs producing methane (CH_4). For the CH_4-production they primarily use various C1 type-compounds (like carbon monoxide (CO), carbon dioxide (CO_2), formate (HCO_2^-)), but some strains are also able to utilize methanol (CH_3OH), acetate, or even methylsulfides for energy production. The capability of methanogens thriving under various extreme environments on Earth is astonishing. Their enormous diversity and the similarity between their growth conditions and the environmental conditions on extraterrestrial bodies throughout the Solar System make methanogens to an ideal test object for astrobiological experiments.

1. Introduction

Methane (CH_4), the smallest hydrocarbon molecule, is found on all planets in the Solar System and its presence has also been verified on other Solar System bodies, e.g. on Saturn's icy moons Titan [8] and Enceladus [13] or on Mars [2, 7, 14]. On Earth, most of the CH_4 available is of biogenic origin whereby only methanogens are known to produce CH_4 [5]. Therefore, the detection of extraterrestrial CH_4 could serve as an indirect indication for (methanogenic) life on another Solar System body.

2. Eco-Physiological Characteristics of Methanogens

On Earth, methanogens can be found from hot vents in the deep oceans to icecold permafrost soils. The temperature range lies between below 0 and 122 °C. They are also capable to thrive under both extremely high and low amount of pressure, at a broad pH-range and are able to withstand UV radiation up to 4 Wm^{-2} (see Table 1). Their energy metabolism is independent of oxygen and it is likely that it developed early on Earth [6]. Due to the fact that most of the methanogens found so far are prototrophs, they seem to be ideal candidates for inhabiting or surviving on planetary bodies other than Earth.

Table 1: Non-strain specific minima and maxima of methanogens [11].

	Ranges	Ref.
Salinity	1.71 to 2.57 mol L^{-1} NaCl	[9]
Pressure	0.005 to > 75 MPa	[3, 4]
pH	4.5 to 10.2	[1, 15]
Radiation	4 Wm^{-2} (UV)	[10]
Temperature	< 0 to 122°C	[12]

3. Potential Habitats of Methanogenic Life in the Solar System

3.1. Mars

Life on Mars would have to resist strong UV radiation due to the lack of an ozone layer. Furthermore, the low surface temperature, low pressure, and desiccation on Mars' surface may act as an inhibitor for life forms, such that they could rather thrive in the subsurface water reservoirs which would be sheltered from radiation. Since 2012, the Rover Environmental Monitoring Station (REMS) on board of NASA's rover Curiosity has returned a huge amount of data concerning the surface UV radiation as well as humidity, pressure, wind, and temperature.

3.2. Moons and Small Icy Bodies

The findings of the last decades, that icy moons may harbour a large amount of liquid water under their ice shells have opened new horizons in the rising field of

Astrobiology. Nevertheless, liquid water alone may be sufficient, but not necessary for icy moons to be habitable. Several aspects – like the possibility of liquid water being in direct contact with the silicate core or seafloor, or the salinity and amount of ammonia in the aquifer – have to be ascertain to determine if the subsurface liquid aquifer of a certain celestial body may be able to harbour life-as-we-know-it.

4. Summary and Conclusions

Methanogens are able to survive under a broad range of environments including those applying multifactorial stress conditions to the organisms. Laboratory induced adaptations could act as a basis for inferring the potential capability of methanogens to be able to inhabit environments other than Earth in the Solar System. We conclude, that prototrophic methanogens of the genus *Methanosarcina* exhibit extraordinary physiological features making them promising organisms for astrobiological research endeavours [11].

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