Geological and geochemical conditions controlling microbial colonization of igneous oceanic crust – implications for life on Mars

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Introduction

The igneous oceanic crust has long been considered as an inhabitable place in the Earths ecosystem. Research within geomicrobiology has however revealed that this in fact may harbour one of the world's largest potential habitats (Schrenk et al. 2009, Ivarsson et al. 2013).

The aim of this project is to understand the geological and geochemical conditions that are needed for microbes to survive under the extreme conditions found in the deep biosphere. The study will focus on the surrounding mineralogy with alteration minerals and textures, morphology and chemistry of the fossilized microbes as well as fluid compositions, temperature and Eh-pH during the time of fossilisation. This might help us to understand why some fluid pathways become colonized with microbes while others reseal with traditional secondary alteration minerals. If we can understand the living conditions for microbes in the deep biosphere on Earth, we might be able to understand where similar life would be expected on other planets.

Sampling site

Sampling was made in December 2015 during a field excursion to the 91 Ma Troodos ophiolite in Cyprus (Osozawa et al. 2012). Twenty-four samples from the mantle and progressively upwards in the ophiolite sequence was taken, with focus on the upper oceanic crust where microbes should be more abundant.

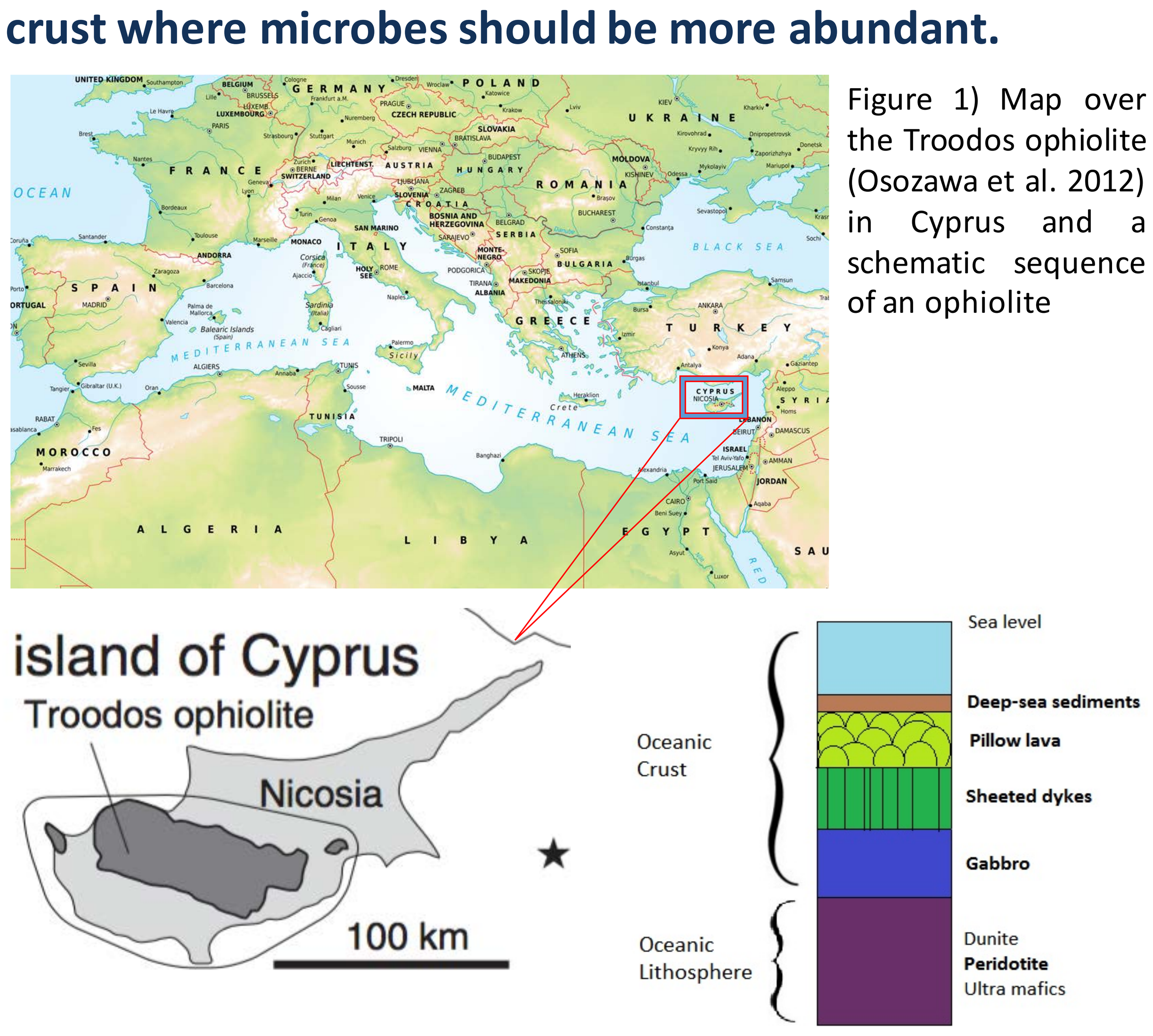

Figure 1) Map over the Troodos ophiolite (Osozawa et al. 2012) in Cyprus and a schematic sequence of an ophiolite

Methods

Petrography	Quantitative and qualitative petrography will be made with optical microscopy, Environmental Scanning Electron Microscope and Raman spectroscopy.
Fluid inclusion	Fluid inclusion study will be made with a LabRAM HR 800 to determine chemical fluid composition, temperature and Eh-pH during fossilization of the microbes.

Optical and electron microscopy of pillow lavas

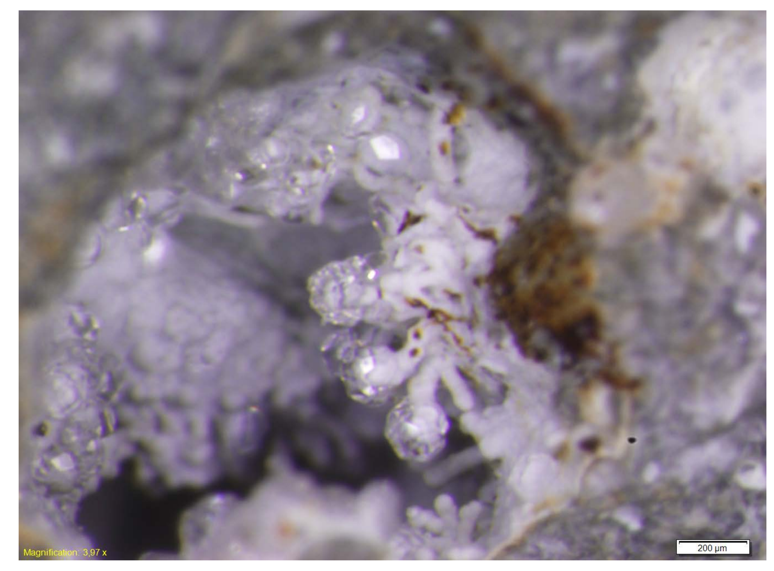

Figure 2) Filamentous structures in an open vesicle with secondary mineralization found at the edges. Cross cutting of some filaments shows strand like features. (Hand sample)

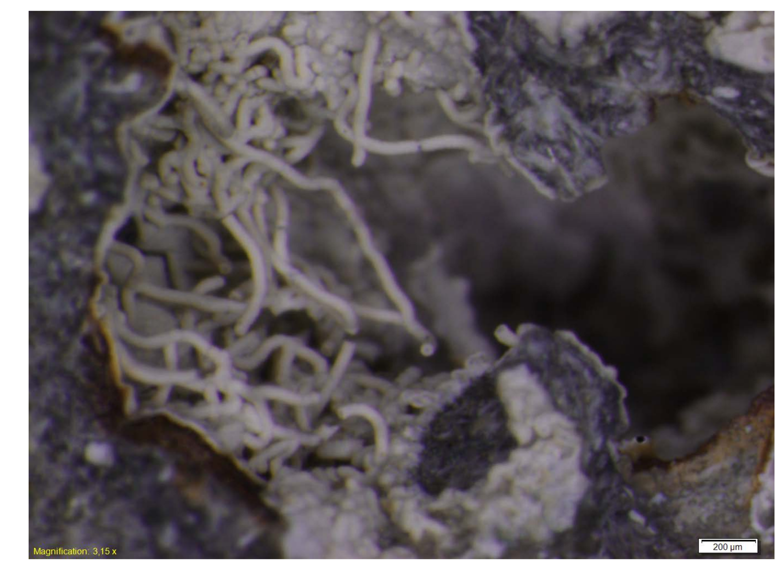

Figure 3) Filamentous structures in an open vesicle, where some shows a branching structure. (Hand sample)

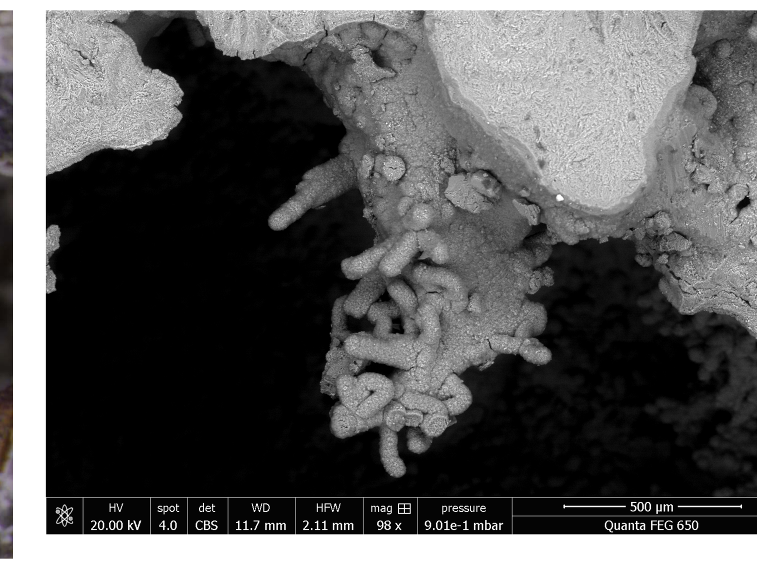

Figure 4) Filamentous structures in an open vesicle. Cross cutting of some filaments shows strand like features. (Hand sample)

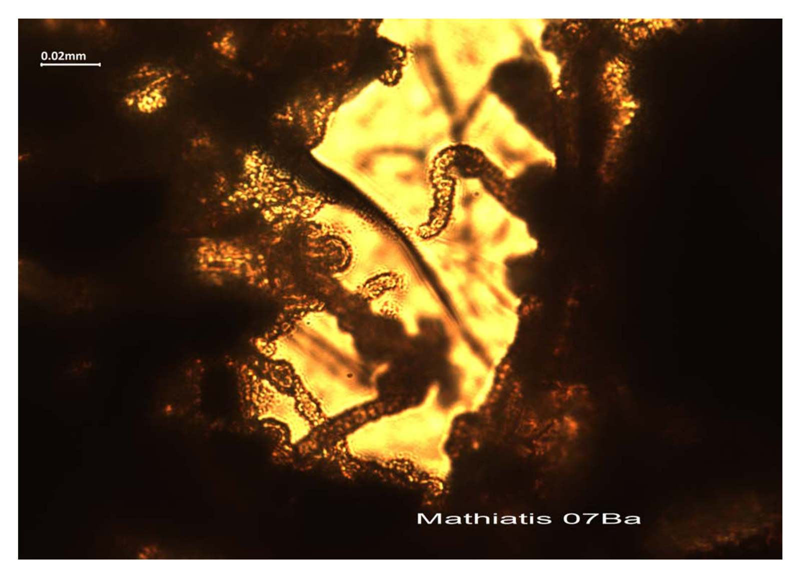

Figure 5) Filamentous structures, embedded in secondary mineral, containing septa and swelling like textures. (Thin section)

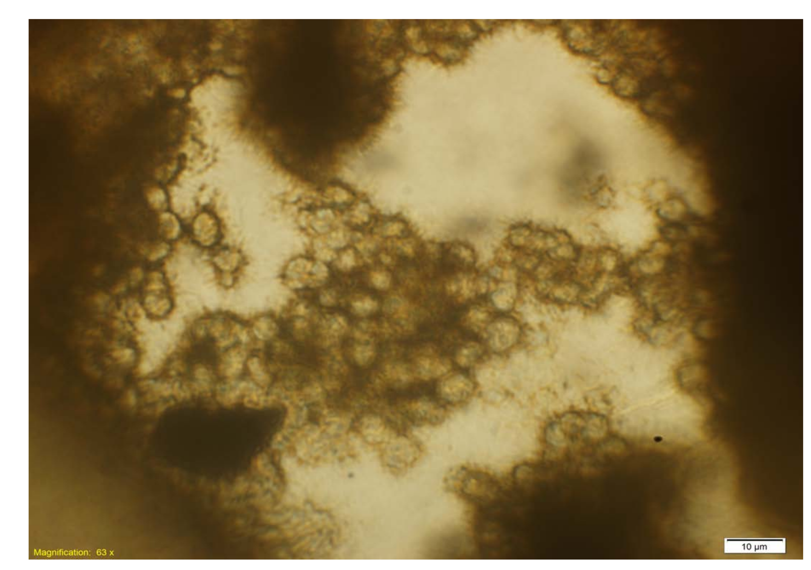

Figure 6) Yeast like structures embedded in secondary mineral. (Thin section)

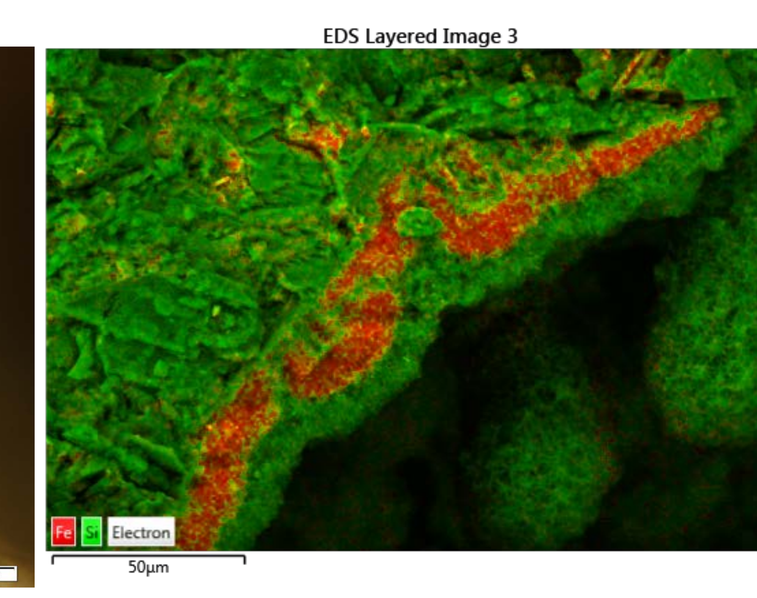

Figure 7) Stromatolite like structure along the edge of an open vesicle showing Fe (red) and C (yellow) enrichment in a Si (green) rich environment. (Hand sample)

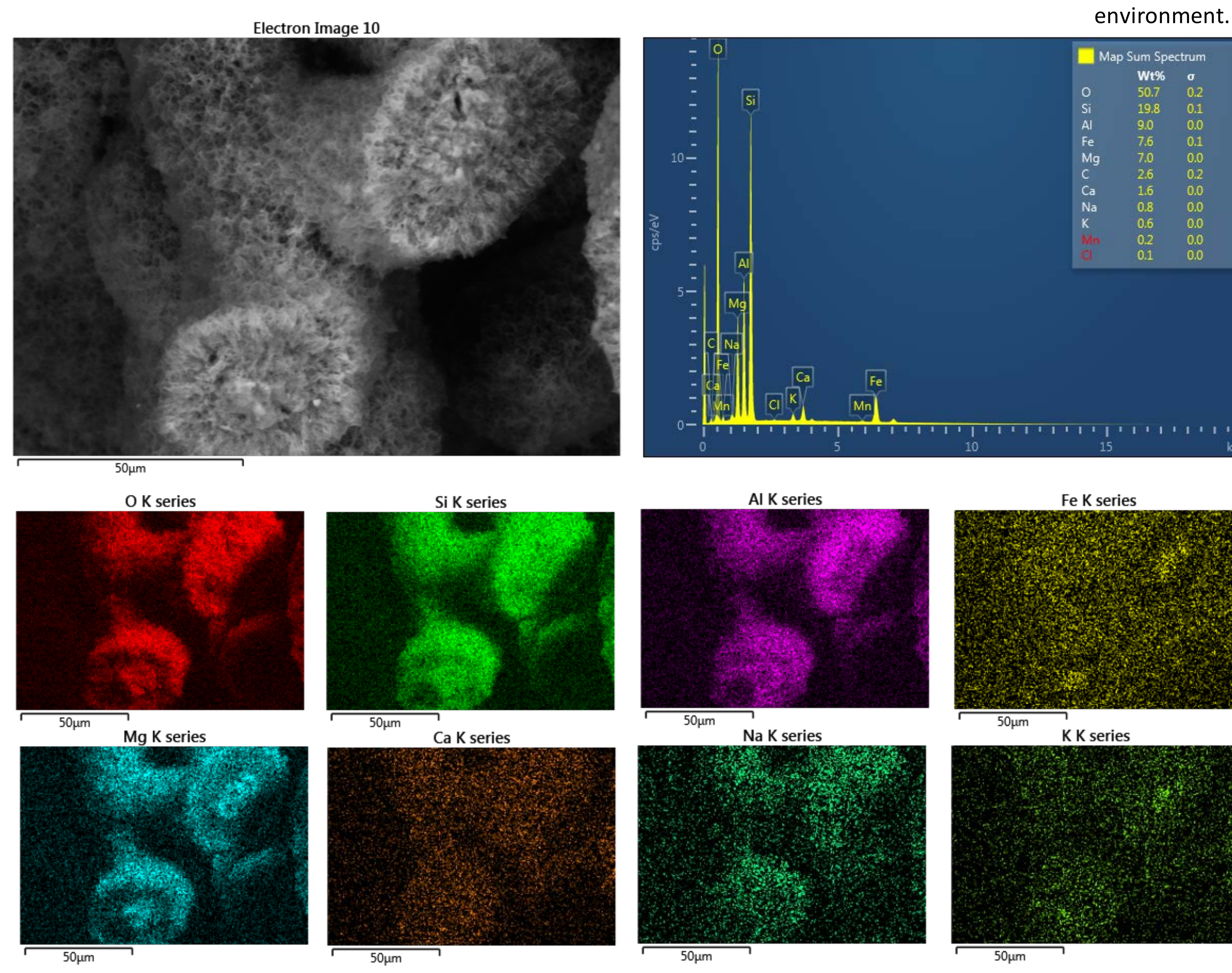

Figure 8) Cross section of filamentous structures, where ESEM mapping shows Fe and K enrichment in the core and Mg enrichment in the outer layers of the filament. (Hand sample)

Upcoming analyses

The data so far seems to indicate a relationship between the microbes and the abundance of oxide minerals as well as tectosilicates in their direct environment. The filaments have a mineral composition consistent with illite or smectite clays, where the inner parts are more Fe and K rich. Further analyses and evaluation of filamentous textures, yeast, septa, strand and nucleus like structures as well as the diameter and length of the filaments needs to be done in order to distinguish between abiotic and biotic origin, as well as possible prokaryotic and eukaryotic domains. Stromatolite like textures have also been found at the edges of the vesicles containing filamentous structures, and a possible symbiotic relationship needs to be further investigated.

Raman will be used to determine the origin of the carbon as well as look on the direct bindings between the elements. The interest lies in understanding what elements are present and how they are distributed within the fossilized microbes as well as in the direct surrounding mineralogy. Another interest lies in understanding how the fluids might have contributed to the movement of these elements, what temperature these microbes once lived in and the fluid compositions.

Future research

The direct connection between microbes in the deep biosphere and hydrothermal fluids might give us the possibility to use the igneous oceanic crust as a climate archive with fossilized microbes as a proxy. This could help us reconstruct past ocean chemistry, and climate changes on Earth, as well as help us understand other planetary bodies in our solar system that today is known to be suffering from total glaciation. It is also of interest to understand the role of biomineralization and the connection between life and metals. Both of these aspects could give us a better insight prior to future space missions.

References

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