Microbial growth in simulated martian environments

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Microbial growth in simulated martian environments

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Abstract

In this study, four new simulants have been developed, and their associated fluid chemistries have been derived for use in a series of microbiological simulation experiments. These experiments will determine if aqueous environments on Mars, past or present, could potentially support microbial life and identify any key geochemical bio-signatures that may arise as a result of that life.

1. Introduction

The widespread presence of hydrated minerals and geomorphological features on Mars suggests water may once have been present on the surface, as result of a hydrological cycle [1-3] producing valley networks and lacustrine environments, or due to long lived impact generated hydrothermal systems [4-5] producing crater lakes. Today, the conditions at the surface are not conducive to sustain liquid water, however, liquid water may exist in the martian subsurface. If so, potentially habitable environments may have existed in the past or exist in the subsurface today, which warrant further investigation. Therefore, we will be conducting a series of simulation experiments that mimic past lacustrine environments and modern subsurface environments. For this the chemical conditions of four key environments will be created, using newly developed simulants and their associated fluid chemistries. These experiments will determine if these environments could support microbial life and identify key bio-signatures that may be produced.

We will present initial results obtained from these simulation experiments. In addition to this, results from thermochemical modelling of these simulated environments will also be presented to show how these environments will develop over geological timescales.

2. Experimental programme

2.1 Simulating the chemical environment

Regolith simulants were developed to reflect varied chemical environments that may have existed over Mars' history, as proposed by [6], and are evidenced by the varied lithologies identified on Mars today. Using published geochemical data to support their design, we have based these new simulants on the following environments: an ancient and unaltered martian bedrock, based on a basaltic shergottite [7]; a contemporary and global regolith chemistry based on Rocknest at Gale crater [8]; a sulfur rich regolith potentially produced under an acidic aqueous environment, based on Paso Robles at Columbia Hill [9]; a haematite (Fe^{3+}) rich regolith that may have formed in an oxidizing and dry environment, based on Haematite slope at Meridiani Planum [10]. The composition of the fluids that could be found on Mars would be representative of the geochemical environment [11]. Therefore, fluid compositions were derived by modelling the water-rock interactions between the simulants and pure water [12]. These fluid chemistries and simulants will then be used in simulation experiments.

2.2 Simulation experiments

Abiotic and biotic experiments will be conducted to identify geochemical changes that may occur as a result of microbial life. Biotic experiments will be inoculated with a microbial enrichment collected from Pyefleet mudflats in the Colne estuary (Essex, UK), rich in sulfur-reducing bacteria and methanogens [13]. These will be added to the simulants and fluids within a benchtop reaction vessel that will simulate the physical conditions found in the martian subsurface. Experiments will mimic a past lacustrine environment at a pressure of 1 bar and temperatures of 10 and 25 °C, to represent a warm, wet Mars as proposed by [3]. Subsurface environments will be simulated using pressures of 1 and 200 bar (equivalent to a depth of 10 m and 2 km, respectively [14]), and temperatures of 5 and 30 °C (representative of depths of 10 m and 2 km, respectively, assuming a surface temperature of 5°C and a thermal gradient of 13 °C km^{-1} [15]). The reaction vessel has a flow-through system, whereby fluid is continuously pumped through the reaction chamber, which is more representative of the open systems that are found on Mars. This system also enables the continuous sampling of the fluid, meaning changing of fluid chemistries can be monitored without altering the water-rock ratio or depressurising the chamber. This offers a significant advantage over traditional batch culture experiments.

Thermochemical modelling using titration and flow though models in CHIM-XPT [16] will determine the resultant fluid chemistries and the secondary minerals formation of these environments, which will help our understanding of how these abiotic and biotic systems might evolve over geological timescales.

3. Implications

The results from these experiments will contribute to our understanding of whether or not the geochemistry and physical conditions found on Mars could support microbial life. It will also identify any geochemical changes that might occur as a result of microbes being introduced to the chemical environment, which could be used as bio-signatures. Any potential bio-signatures identified from these experiments could be targeted by future exploration rovers as indicators for life.

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