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Volcanics and chemotrophic life on Mars

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Abstract

One of the main objectives of the MSL, ExoMars 2018, and Mars 2020 missions is to search for traces of past life in Noachian-Early Hesperian terranes. Chemotrophic life in volcanic habitats will be sparsely distributed, unless fed by localised hydrothermal systems. Study of the distribution of anaerobic, chemotrophic life in a terrestrial analogue environment (early Earth) provides valuable information to help search for life on Mars.

1. Introduction

Mars is predominantly volcanic in composition, as are the majority of sediments deposited in the actual or potential landing sites of interest (with additional sulphate and oxide minerals concretions and veins). There is also evidence for hydrothermal siliceous deposits, although sparse [1]. These kinds of environments in the anaerobic conditions existing on early Mars could have hosted chemotrophic life forms, *i.e.* lithotrophic organisms living off inorganically produced energy (e.g. H2, Fe2+) or organotrophs using energy produced by the oxidation of organic matter, if it existed.

Similar to early Mars, the early Earth was an anaerobic, volcanic habitat. The main difference between the two planets was that the Earth was permanently habitable while Mars was sporadically and heterogeneously habitable. Other differences are that ocean waters on the early Earth were saltier and slightly acidic (pH 6-7) [2], and all aqueous environments were very much influenced by hydrothermal activity [3]. If interpretations of the orbital IR data for Mars are correct, the pH of early martian waters was neutral and there is only sporadic and possibly impact-related evidence for hydrothermal activity [1]. Nevertheless, on a microbial scale, there are great similarities between habitat types on both early planets [4].

The traces of life occurring in Early-Mid Archaean (3.5-3.33 Ga) sediments in Australia and South Africa occur as carbonaceous remains that have been preserved in a cement of hydrothermal silica. Note that, while the terrestrial volcanic sediments were almost permanently in contact with water, the very rapid obstruction of pore space by a silica cement (within the space of days to months) means that phyllosilicate alteration, although common, was not total.

2. Nature and distribution of life on the early Earth

Terrestrial carbonaceous remains include sometimes visibly identifiable colonies of chemotrophs coating volcanic sand grains or “floating” in hydrothermal silica gel [5,6]. Within the silty to sandy volcanic sediments (altered aqueously to phyllosilicates), the distribution of carbon coated particles is widespread but their colonisation is thin (Figs. 1A,B), presumably due to nutrient limitation. Nutrients here would have been obtained from redox reactions at the surfaces of volcanic particles, e.g. volcanic glass shards, pyroxenes, olivines and carbon from CO_2 dissolved in water. However, in the vicinity of hydrothermal sources, the abundant supply of nutrients in the form of H_2 and organic compounds facilitates the formation of mats or films of unsupported colonies or thickly colonised mineral or rock particles (Figs. 1C,D). Chemoorganotrophs also could have sourced their nutrients from the dead remains of lithotrophs.

Note that detrital carbon (of biological or abiological origin) is also a common component of these volcanic sediments, settling out with the finer volcanic particles.

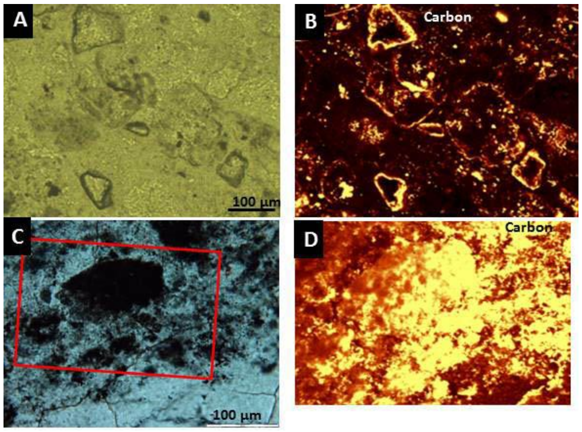

Figure 1. 3.5-3.33 Ga-old volcanic particles coated with the carbonaceous remains of chemotrophic microorganisms. (A,B) Thin films of carbon representing mono-layer colonies on volcanic grains. (C,D) Thickly coated volcanic particle in the vicinity of a hydrothermal vent.

3. Relevance for Mars

Study of the Early-Mid Archaean terrestrial sediments demonstrates that, even in an anaerobic setting, chemotrophic life can be widespread, if it is situated in or can reach the potentially habitable environment. However, without the input of hydrothermal nutrients, its development is limited. Nevertheless, it should still be detectable *in situ* on Mars with Raman or LD-GCMS-type instruments.

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