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The Exomars 2020 mission and the search for chemotrophic biosignatures

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Abstract

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1. Introduction

The ExoMars 2020 mission aims at searching primarily for traces of past life within a specific geological context. The potential landing sites, Oxia Planum and Mawrth Vallis represent a variety of sediment types, including volcanoclastic sediments and their alteration products, such as clays, as well as possibly chemical sediments (salts, amorphous silica) of Early Noachian to Hesperian ages. In both areas, finely layered Noachian deposits have been altered by aqueous processes to produce Fe/Mg clays (~300 m in Mawrth and ~20m in Oxia) that are overlain by fluvial (Mawrth) and fluvio-deltaic sediments (Oxia) of Early Hesperion age [1-3]. In addition, the Mawrth deposits were later traversed by fluids that infilled cross-cutting fractures, possibly related to the nearby Oyama impact, indicating fluid circulation. The top of the Mawrth succession was then altered to Al phyllosilicates and hydrated silica. Both locations were subsequently covered by other deposits that are slowly being eroded away.

In terms of habitability, Mawrth and Oxia have seen varying environmental conditions ranging from possibly subaqueous, through fluvial/deltaic to pedogenic, with the possibility of hydrothermal or groundwater percolations. In an overall anoxic context and the fact that the lack of long-term habitability of the isolated and temporally distant habitats, means that it is unlikely that, if life did emerge on the planet, that it evolved beyond a chemotrophic metabolism [4], any preserved life forms from these two locations would be chemotrophic in origin [4]. On Earth, the only habitat that shares some of these environmental constraints was that of the early anoxic Earth [Westall 2015] and certain "extreme" environments on more recent times. Understanding the preservation of chemotrophic life forms and their fossilized signatures in lithified (cemented) sediments is, thus, greatly aided by study of relevant terrestrial analogues.

2. Fossilised chemotrophs in Early Archaean rocks

Early Archaean volcanic sediments altered to phyllosilicates (smectite) in aqueous environments and influenced by hydrothermal fluids are excellent analogues for early Mars [4]. Deposited in similar anoxic conditions, they host fossilized traces of chemotrophic life forms [4, 5]. Chemotrophs (lithotrophs) colonized the surfaces of volcanic grains, becoming colonised in turn by organotrophs, and they also formed spiky colonies that grew *in situ* in hydrothermally-precipitated, siliceous chemical sediments. However, while the lithotrophs appear to have been fairly widespread in their distribution, even in relatively oligotrophic waters (i.e. poor in nutrients), the distribution of the organotrophs was distinctly controlled by their vicinity to nutrient-rich hydrothermal fluids.

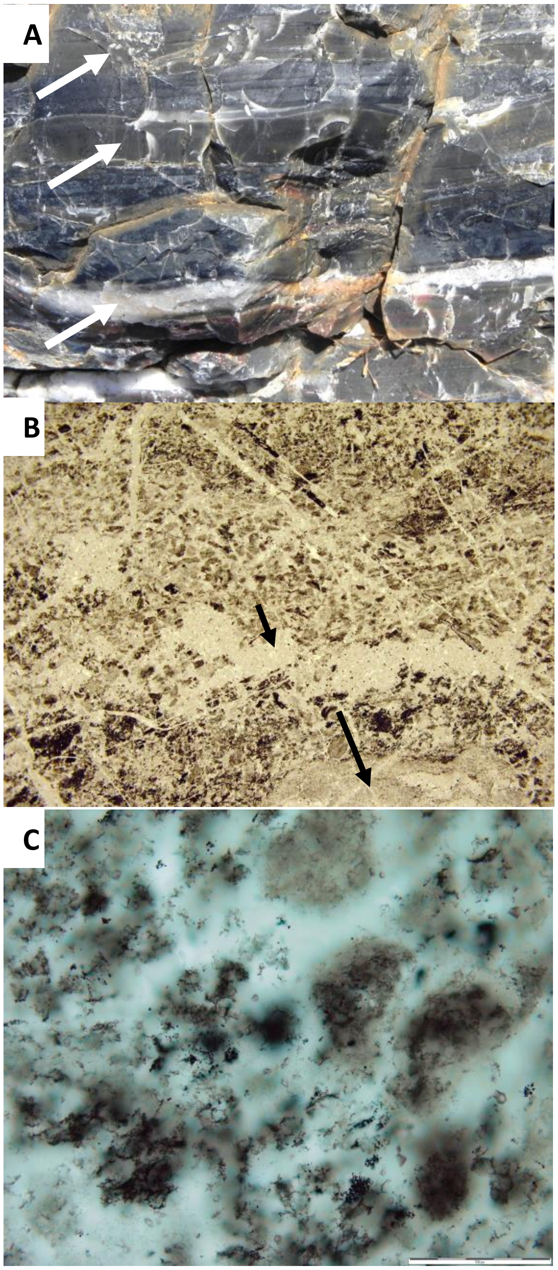

Figure 1. A Field photograph of layered hydrothermal sediments (arrows show macroscopic hydrothermal infiltrations) containing (B, C) chemotrophic colonies (dark clots) infiltrated by hydrothermal fluids (black arrows). Early Archaean, Barberton, South Africa.

These primitive organisms were preserved by rapid encapsulation in a mineral cement (silica in this case) resulting in a variety of biosignatures: (1) the physical remains of cells, colonies of cells, biofilms, (2) degraded organic carbon either associated with the fossils of disseminated in the fine-grained argillaceous or chemical sediments, (3) as corrosion tunnels in the surfaces of volcanic grains.

For the ExoMars payload, while individual fossil cells are too small to be identified (<1µ), colonies in the form of clots or biofilms could be observed microscopically as dark patches or layers within martian sediments. The presence of carbon associated with potential biosignatures would be revealed by Raman and IR spectroscopy and the structure of the carbon molecules, including their chirality would be revealed by the MS techniques. Geological context on large to microscopic scales is essential for correct biosignature identification and would be also provided by the rover instrument suite.

3. Conclusions

While the Early Archaean fossils are highly relevant for understanding how chemotrophic life forms can be preserved, the fossilised remains have undergone a greater degree of metamorphism than that expected on Mars. Younger chemotrophic colonies, e.g. those forming carbonate mud mounds (sulphate reducing bacteria), inhabited an inherently oxygenic environment and were preserved in oxygen-controlled conditions. Their relevance is therefore limited. The remains of microbes in evaporite environments also suffer from the same problem. The solution is to use experimental studies to provide preserve chemotrophs from these diverse environments and to age them in martian conditions.

Acknowledgements

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