OCCURRENCE AND SIGNIFICANCE OF CARBONACEOUS MATTER AT THE SURFACE OF MARS.

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Introduction: The Noachian (>3.7 Ga old) is the sole period in Mars' history for which surface habitability could have been sustained[1]. It was the only period hosting simultaneously standing water, a relatively dense heterogeneous and insulating atmosphere, 'plate tectonics', a magnetic dynamo and a nutrient cycling resulting from this dynamic geological system. Mars' small size led to rapid heat loss, early "death" of its dynamo, and a concomitant shutdown of almost all geodynamism, including the global rock cycle[2].

Consequently, any putative surface biosphere which may be preserved in the Martian stratigraphy was necessarily restricted to being active in the earliest history of the planet. The aforementioned 'planetary death', after which exceedingly high surface radiation levels, combined with other environmental stresses (limited, transient water activity, high oxidation, presence of perchlorates) would prevent the flourishing of life, may have occurred in less than several hundred million years. This severely restricts the timescale over which cellular evolution could have occurred.

The Early Archaean as an analogue: The most accurate available analogue for the Noachian Mars is therefore the time-equivalent Early Archaean Earth (3.85-3.3Ga). Environments, such as volcaniclastic sediments in standing bodies of water[3], shallow, littoral shorelines[4], short-lived oases of water in craters and other depressions[5], together with volcanogenic rocks supporting chemotrophic endolithic life are known from Archaean deposits and, pivotally, are either demonstrated or plausible in early Martian conditions. Ergo, the biospheres that may have been harboured on Mars would be best appraised by studying their definitively and putatively biogenic counterparts in the Archaean geological record.

Although the most recognisable biosignatures are morphological, these do not likely represent the majority, or even most probable, of possible biosignature detections; presently, enigmatic carbonaceous matter is conceivably the key to understanding the full extent of the domain of palaeobiology. Our approach to studying these biosignatures is thus focussed on the nature of the carbonaceous material in >3 Ga old rocks from the Barberton and Pilbara regions. Using a complementary suite of techniques commencing with optical petrographic study and Raman spectroscopy at the cm- to µm-scale, we seek to elucidate the spatial and geochemical contexts of carbon in the Archaean record. These measurements could shed light on poorly understood organic and mineralogical biosignatures, and will yield datasets directly comparable with those gathered by the CLUPI, MicrOMEGA and RLS instruments (ExoMars) or SuperCam, PIXL and SHERLOC (Mars2020). The specific nature of the carbon, *i.e.* its genesis and alteration with geological time, is pivotal.

Our pluri-technique approach: Using a combination of sample observation, Raman, SEM, particle induced X-ray emission (PIXE) spectroscopy, laser-ablation ICP-MS and SIMS, the <µm-scale elemental, mm-scale mineralogical and >m-scale geological associations of carbon can be determined. Uniting multiple techniques at flexible spatial scales can shed further light on the genesis of carbon. Organic carbon in Archaean sediments is of endogenous biological, abiotic (e.g. organics produced by Fischer Trospch synthesis) and probably extraterrestrial origin. In a single layer of sediment, a combination of these types can occur; this complicates the assessment of biogenicity.

Imagine, on a Noachian palaeoshoreline, organic matter derived from a putative Martian chemotrophic biosphere, organic matter emanating from the hydrothermal springs and volcanic epithermal systems which would likely have been very common on the ancient Mars, and organic matter deposited by the unceasing influx of extraterrestrial matter. The resulting mélange holds valuable information on Martian carbon, but cannot be understood without first comprehensively studying the record available to us on Earth.

Perpectives: The characterisation of the nature of carbonaceous material in our Noachian analogue rocks is a complex procedure demanding of a multi-technique approach. Without *in situ* geochemical measurements of carbonaceous material on the Martian surface or by conducting similar experiments on returned samples, it will be difficult to disentangle the relative contributions of abiotic and putative biotic sources. Until such distinction is possible, definitive proof of a Martian biosphere will be evasive.

References: [1] Lammer, H., *et al.*, 2009. Astron. Astrophy. Rev., 17, 181-249. [2] Terada, N., *et al.*, 2009. Astrobiology, 9, 55-70. [3] Cabrol N.A., Grin, E.A., 2005. Springer. [4] Westall, F., *et al.*, 2006. GSA Special Paper, 405, 105-131. [5] Westall, F., *et al.*, 2015. Astrobiology, 15, 998-1029.

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