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Analysis of organic compounds, minerals and biota: Preparation for future Mars life detection missions

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1. Introduction

Several space missions are currently planned to investigate the habitability of Mars and the possibility of past or present life existing on the Red Planet. These include the Mars Science Laboratory (MSL) and the ExoMars mission. In order to determine the best locations to find whether signatures of past and/or present life may still exist in the Martian regolith, it is necessary to perform preliminary analyses on terrestrial soils that resemble Mars [1]. A good understanding of the interactions between the organic, mineralogical and microbial components of desert soils is crucial to determine the best locations for future life detection missions on Mars. In the present study we have measured the amino acid content of Mars analogue soil samples, and related those results to the microbial and mineralogical data of the soil samples. These were performed on soils collected near the Mars Desert Research Station (MDRS) in the Utah desert (Figure 1), during the EuroGeoMars 2009 campaign [2,3]. The Utah soil displays mineralogies similar to Mars, with sedimentary deposits of sands, evaporites, clays and gypsum [4].

2. Experimental Procedure

Soil samples were collected under sterile conditions close to the MDRS, Utah, during the EuroGeoMars 2009 campaign (Table 1, Figure 1). The samples were later distributed to various laboratories for subsequent analysis of the organic content [5], mineralogy [4] and microbiology [6]. Amino acids were extracted from the soil samples and analyzed on a Gas Chromatograph-Mass Spectrometer (GC-MS) [5]. Mineralogy analyses were performed using IR spectroscopy and X-ray diffraction (XRD) [5]. Culture-independent molecular analyses directed at ribosomal RNA were used to identify biota of several domains (Bacteria, Archaea, Eukarya) [6].

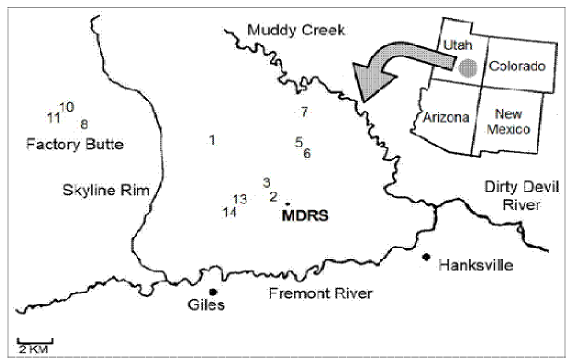

Figure 1 - Map showing the locations where the MDRS desert soil samples were collected (south-east area of Utah, USA). The right-corner inset shows the states surrounding the state of Utah (USA) [5,6]

3. Results and Discussion

Total amino acid abundances were very heterogeneous in the MDRS samples, with values ranging from non-detectable to 100,000 parts-per-billion (ppb). When present, the most abundant amino acids were L-glutamic acid, D-glutamic acid, L-aspartic acid, L-valine, L-alanine, L-leucine and glycine [5]. The presence of both D- and L-amino acids (except in sample P-14) suggests that racemization (i.e. conversion of L- into D-amino acids) has occurred over time and amino acids may be fossil remains. These results were interpreted in the context of mineral content. The MDRS soils with high percentage of gypsum (calcium sulfate dihydrate) had a high/medium amino acid content, while the ones with high percentage of total clay had lower abundances of detectable amino acids. In addition, the exact clay mineral content (e.g. smectite/illite ratio) influenced the extraction of compounds such as amino acids and DNA from the mineral matrices [4-6]. In relation to microbial analyses, all three domains of life (Archaea, Bacteria and Eukarya) were observed but not in all samples. No microorganisms were detected in soil sample P-14. However, this soil sample had a high level of present life amino acid (i.e. presence of L-amino acids only). Spiking experiments revealed that this is due to adsorption of DNA on the mineral surface [6].

Table 1 - The MDRS desert soil samples (see Fig. 1 for location) and the corresponding coordinates, altitude and depth from which they were collected [5].

Sample Name	Coordinates	Altitude (m)	Depth
P-1	N38. 43621° W110. 81943°	1350	surface
P-2	N38. 40746° W110. 79280°	1382	surface
P-3	N38. 40737° W110. 79261°	1375	surface
P-5	N38. 42638° W110. 78342°	1400	cliff
P-6	N38. 42638° W110. 78342°	1400	cliff
P-7	N38. 45424° W110. 79092°	1357	surface
P-8	N38. 43755° W110. 88725°	1482	surface
P-10	N38. 43896° W110. 89001°	1500	surface
P-13	N38. 40630° W110. 79547°	1405	surface
P-14	N38. 40630° W110. 79547°	1405	15cm

4. Summary and Conclusions

We have measured the amino acid content of Mars analogue soil samples collected near the MDRS, in Utah, and related those results to the microbial and mineralogical content of the soil samples. The results show a large amino acid variation between the soil samples, even the ones that were collected from the same location. The variations in the organic matter abundances appear to reflect the ability of soils to preserve organic signatures of life and also to allow their extraction from the mineral matrix. These multidisciplinary findings have implications for future life detection missions to Mars. They are crucial to successfully target locations that may host organic matter, as well as extract and detect signatures of life on Mars.

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