ASTROBIOLOGY AND HABITABILITY STUDIES SUPPORTING MARS RESEARCH AND MISSIONS

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Introduction: Several robotic exploration missions will travel to Mars during this decade to investigate habitability and life beyond Earth. Field research at Mars analogs sites such as desert environments can provide important constraints for instrument calibration and landing site strategies. We report on astrobiology field research from the Mars Desert Research Station (MDRS) in Utah Hanksville conducted during the EuroGeoMars 2009 campaign [1-9]. We have investigated 10 selected samples from different geological formations (Mancos Shale, Morrison, and Dakota) and also chose a variety of locations (surface, subsurface and cliffs). We compiled the individual studies and try to establish correlations among environmental parameters, organics markers and biota. The results are interpreted in the context of future missions that target the identification of organic molecules and biomarkers on Mars.

Rationale for EuroGeoMars campaign: Extreme environments on Earth often provide similar terrain conditions to landing/operation sites on the Moon and Mars. In order to maximize scientific return it becomes more important to rehearse mission operations in the field and through simulations. EuroGeoMars 2009 was an example of a Moon-Mars field research campaign dedicated to the demonstration of astrobiology instruments and a specific methodology of comprehensive measurements from selected sampling sites. Special emphasis was given to sample collection and prescreening using in-situ portable instruments. In this paper we describe the protocol, in-situ and post-analysis of the astrobiology research campaign at MDRS.

Results We have characterized the mineralogy, organic compounds and microbiology of 10 selected sample sites from the Utah desert. The samples were collected under sterile conditions at desert areas of Utah in the vicinity of MDRS in Hanksville. The samples were partly analyzed in situ and later distributed to the various laboratories for post-analysis. Soil sample properties such as pH value and elemental composition of K, P, Mg, and nitrate were measured in the MDRS habitat laboratory (Table 1). On-site Polymerase Chain Reaction (PCR) using specific primers in combination with agarose gels identified biota of several domains shortly after collection [3]. Post-analysis studies determined the total carbon content [5]. The concentrations of polycyclic aromatic hydrocarbons (PAHs) have been determined by using the solid phase micro extraction (SPME) method that provides good recoveries for small PAHs that are usually targeted by planetary missions [5]. Amino acids were extracted from soil samples and analyzed on a Gas Chromatograph Mass Spectrometer (GC-MS) [7]. Culture-independent molecular analysis directed at ribosomal RNA, was used to investigate the detailed microbiology of desert samples. Phylogenetic analysis revealed an extraordinary variety of putative extremophiles, mainly Bacteria but also Archaea and Eukarya. These comprised radioresistant, endolithic, chasmolithic, xerophilic, hypolithic, thermophilic, thermoacidophilic, psychrophilic, halophilic, haloalkaliphilic and alkaliphilic microorganisms. In summary, the data revealed large difference in occurrence and diversity over short distances [4]. Mineralogy investigations were performed using Infrared spectroscopy and X-ray diffraction analysis [6].

Table 1. Sample location, in-situ soil kit analysis and post-analysis data of the polycyclic aromatic hydrocarbons naphthalene $C_{10}H_8$ using solid phase micro extraction (SPME) method [5,6].

Sample	Depth	Formation	pH	P ppm	OM %	PAHs ng/g
P1	Gully	Mancos	7.6	5	2	12
P2	Cliff	Morrison	8.1	12	1	4.9
P3	Surface	Morrison	8.0	12	1	3.1
P5	Cliff	Morrison	9.0	100	2	8.6
P6	Cliff	Morrison	7.6	85	2	8.0
P7	Riverbed	Morrison	9.6	10	2	4.9
P8	Surface	Mancos	8.5	5	4	20
P10	Surface	Mancos	8.5	5	5	9.2
P13	Surface	Dakota	8.7	100	2	9.2
P14	15cm	Dakota	7.0	80	3	5.3

Compared to extremely arid deserts (such as Atacama), organic and biological material can be identified in a number of samples and subsequently be used to perform correlations studies. Among the important findings of this astrobiology field research campaign are the diversity in the mineralogy composition of soil samples even when collected in proximity, the low abundances of polycyclic aromatic hydrocarbons and

amino acids and the presence of biota of all three domains with significant heterogeneity [3-7]. Clay-rich samples from the Morrison formation seem devoid of amino acids and biota.

In-situ analysis investigations of habitability were optimized to quantify organic molecules that are targeted by planetary organic detection instruments, such as amino acids and PAHs. Whereas PAH concentrations and in particular naphthalene (likely of atmospheric origin) could be measured in all samples, the abundances did not exceed ng/g levels [5], see Table 1. Amino acid levels showed a larger heterogeneity; only 4 samples showed abundances in the ppm level [7] similar to results obtained from the Atacama desert [10].

We investigated and sampled some endolithic mats near the MDRS. The macroscopic pictures and close-up views indicated surface epilithic lichens. After detachment of the crust, we confirmed the presence of microbial endolith population with green and orange-brown constituents, and the presence of endolith under a purple brown coating. Samples of endolith attached to the host crust were taken to the MDRS laboratory.

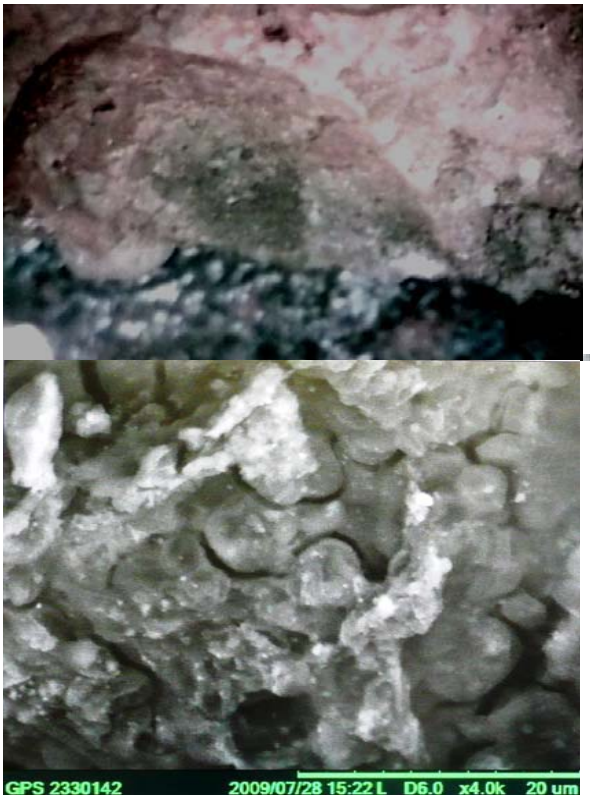

Figure 1. Post –campaign SEM Study of endolithic microbial communities performed at NASA Ames: sample close-up context, FOV 1 cm (top), SEM x4000 FOV 40 microns (bottom).

The visual and microscopic inspection confirms the presence of different layers: an outer varnish, a cemented crust, a brown microbial mat, a green mat attached to the rocks. After detachment of the crust and varnish layers, the endoliths appear in 3 different colour units, with variations within 0.1-0.5 mm scales. The analysis of the varnish with the XRF shows an overabundance of iron and manganese [1].

Results from the EuroGeoMars 2009 campaign show that samples in which microorganisms could be observed after PCR amplification, had significantly lower clay particle content than samples in which microorganisms were not detected. No significant correlation was observed between amino acids and DNA yield or positive PCR signals. Microbial numbers and diversity does not appear to be correlated with neither organic content nor mineralogy. Instead, the dominant factor in bacterial number may be soil porosity and lower clay particle content. Regions where organic material could be formed and at the same time be preserved over long time periods may be associated with minerals that resist efficient extraction of organics and biological material [8]. Of prime importance is to further optimize extraction procedures.

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