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Molecular evidences of life in a poly-extreme environment in Ethiopia, the Dallol Hot Springs area, based on lipidic biomarkers.

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Abstract

The characterization of biosignatures in extreme environments on Earth with analogies to Mars is relevant to understand how hypothetical life could have developed in similar extreme conditions. The Dallol hot springs region in Ethiopia was studied for the presence and distribution of lipidic biomarkers and stable isotopes. This hydrothermal system is considered a poly-extreme environment of characteristic: high salinity, high temperature and extremely acidic waters (pH~0.2-4). A variety of lipids including *n*-alkanes, isoprenoids, *n*-carboxylic acids, *n*-alkanols, or steroids, was detected, with molecular distributions indicating the presence of (present or past) biological material from hyper-thermophilic and thermophilic bacteria.

1. Introduction

Recent new geological, chemical and computational findings rise up the hypothesis that life originated in hot springs areas on land, over the deep-sea hydrothermal vents theory (Damer, B, 2016). Organic preservation of biosignatures has been described in extreme environments of diverse typology, such as geothermal silica sinter areas from New Zealand or USA (Kaur et al. 2015; Jahnke et al. 2001), hyperarid and hypersaline environments (Sánchez-García et al., 2018), or acidic rivers developed on a Fe- and S-based chemistry (i.e. Río Tinto, SW Spain) (Amils et al., 2007). In contrast, the information is scarce on the distribution, and preservation of biosignatures in systems combining various extreme characteristics (i.e. poly- or multi-extreme environments). Located in one of the most remote, inhospitable, and poorly studied locations in the world, Dallol is a complex active hydrothermal system in the Danakil Depression of Ethiopia (Fig. 1) composed of diverse hot springs that opens into an arid dessert. In Dallol, seawater and hydrothermal fluids mix resulting into a hyper-saline environment of extremely high temperature (mean water temperature of ~90ºC) and water pH below 4 (Frenzson et al., 2015). We aim at investigating the presence and distribution of molecular and isotopic biosignatures in the remote and poly-extreme environment of Dallol hot spring region. The detection of molecular evidences of (past or present) life in the Dallol geothermal system goes with the hot spring hypothesis for life´s beginning and has implications for searching for potential evidences of life in other poly-extreme environments even beyond the Earth.

2. Sample collection

The Dallol hot springs area is situated in the Danakil Depression in northern Ethiopia (Fig 1). During the Europlanet sampling campaign of 2016 (January), a set of 5 geological samples was collected from three different hot springs from the Dallol area (-120 m below sea level) with clean stainless-steel spatula. The samples were stored in pre-cleaned polypropylene containers and maintained at cool temperature until transported to the laboratory, where they were frozen at -20ºC until analysis.

2. 1. Geolipid Extraction

About 30 g of sample were extracted with a mixture of dichloromethane/methanol (DCM/MeOH, 3:1, v/v) during 24 h in a Soxhlet apparatus. Internal standards (tetracosane-D_{50}, myristic acid-D_{27} and 2-hexadecanol) were added prior to extraction. The total lipids extracts were concentrated using rotaevaporation to 2 ml, and activated cooper added for elemental sulfur removal. The extracted sample was then separated into three fractions of different polarity (polar, non-polar, and acidic) using a Bond-elute (bond phase NH_2, 500 mg, 40 um particle size) and Al_2O_3 columns chromatography.

2.2. GC-MS Analysis

The different samples fractions were analyzed by gas chromatography mass spectrometry using a 6850 GC system coupled to a 5975 VL MSD with a triple axis detector (Agilent Technologies), operating with electron ionization at 70 eV and scanning from *m/z* 50 to 650. The analytes were injected (1 ul) and separated on a HP-5MS column (30 m x 0.25 mm i.d. x 0.25 um film thickness) using He as a carrier gas at 1.1 ml min-1.

3. Figures

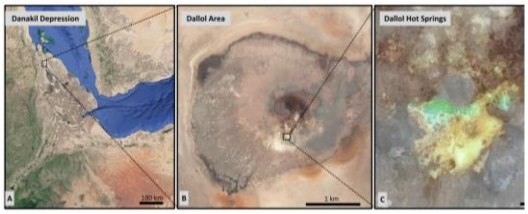

Figure 1: Map of the Danakil depression in Ethiopia (A), showing the Dallol area (B), where samples were collected (C)

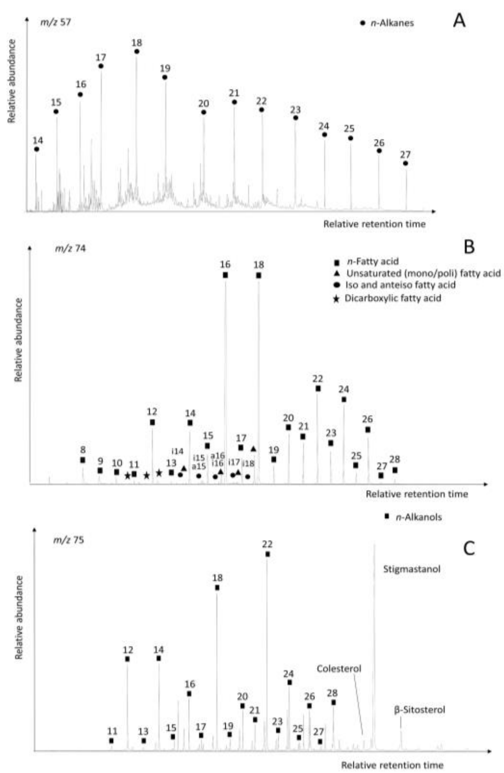

Figure 2 Mass chromatograms of the three lipidic fractions analyzed in the Dallol sample D8; *n*-alkanes (*m/z* 57) (a), *n*-carboxylic acids as methyl esters (*m/z* 74) (b), and *n*-alkanols as trimethyl-silyls (*m/z* 75) (c).

4. Summary and Conclusions

A number of lipidic families (normal and branched alkanes; normal, branched, unsaturated, and dioic fatty acids; normal and branched alkanols; wax esters and sterols) were detected in the Dallol hot spring samples, with distribution patterns revealing the presence of biological vestiges. The general preference for the even-over-odd molecular distributions illustrated the predominance of microbial signatures. Despite the inhospitability of the Dallol Hot Springs, certain microorganisms (i.e. thermophiles) are resistant enough to thrive (past or presently) in this poly-extreme environment. While a definitive distinction between presently active metabolisms or fossilized biological fingerprints cannot be accomplished, the relative abundance of functionalized (i.e. *n*-fatty acids and *n*-alkanols) over saturated hydrocarbons (i.e. *n*-alkanes) points to present or recently active metabolisms producing the typical microbial signatures. Whereas further investigation is needed to identify the microbial communities associated to the hydrothermal and evaporitic substrates, the present study constitutes the first geomicrobial approach to describe the Dallol poly-extreme environment, and has implications for interpreting GC/MS results from current and future missions in the search for life in similar extraterrestrial environments (e.g. Mars). Future work will be addressed to search for archaeal biomarkers (e.g. glycerol dialkyl glycerol tetraethers, GDGTs), metagenomics, and compound specific-isotopic composition.

Acknowledgements

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Analysis of Mars relevant minerals – suggestions for next missions

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Abstract

Several instruments can be used for the identification of rock-forming minerals of Mars analogue samples. One of the most important methods is the X-ray powder diffraction, because the general mineral composition can be identified (e.g. there are olivine, pyroxene and plagioclase in samples). But the infrared and Raman spectroscopy are useful additional methods, because more precise identification (species of these minerals (e. g. pyroxene is augite, plagioclase is anorthite) could be done in several cases. While the most capable method for identification of phyllosilicates is the X-ray analysis, but it is also possible by infrared spectroscopy.

1. Introduction

The basic-ultrabasic magmatic rocks on Mars are covered by regolith by the slow weathering. The components of this regolith are olivine, volcanic glass and sulphates (e.g. jarosite, gypsum), carbonates (e.g. artinite, Ca-Fe-Mg carbonates), layer silicate (smectite), iron oxides-hydroxides (e.g. hematite, goethite, magnetite). The identification and the knowledge of the formation conditions of minerals on Mars are important to understand its geological history and astrobiology aspects. Analyses of analogue samples could help the development of instruments for Mars surface missions, including rovers. The aim of this study is to present the strengths and weaknesses of the different laboratory methods, observational possibilites and characteristics of some basic minerals, demonstrating how the requested information could be acquired from them.

2. Methods

X-ray powder diffraction, infrared spectrometry and Raman spectroscopy were used for the identification of minerals in the analyzed samples. The XRD studies were carried out on a Rigaku Miniflex-600 X-ray diffractometer with CuKα radiation equipped with a graphite monochromator. While an FTIR Vertex 70 (Bruker) infrared spectrometer was applied to acquire IR reflection bulk spectra showing minerals' peak positons together. Mineral analyses can also be made with a Raman spectroscope (Kaiser Optical Systems RamanRxn1™). The spectral performance of this instrument changes from 150 cm^{-1} to 1850 cm^{-1} and the resolution is 6 cm^{-1} in mid-range. The wavelength is 785 nm.

3. Samples

Several Mars analogue samples were analyzed: six basalts from Azores Island (unweathered and varying degrees of weathered basalt) [1] and nine samples: basalt, attapulgite, sepiolite, bentonite, kaolinite-montmorillonite granules from the collection of the Natural History Museum, London and the European Space Agency called ESA2C [2, 3, 4].

4. Results

These samples were measured by X-ray diffraction, infrared analyses and Raman spectroscopy.

2.1 Infrared Spectroscopy

On the average two-three minerals could be identified: olivine, anorthite or augite were found in the basalts sample from the basalt samples. While mainly sepiolite, dolomite and quartz could be detected in different samples from the ESA2C collection (Table 1).

2.2 X-ray diffraction analysis

Most minerals could be detected in this way, so a general picture was get from the composition of the measured samples. A few minerals (plagioclase, K-feldspar, mica and smectite) could be identified from Azores samples, while average 6-7 minerals could be found in the samples from the ESA2C collection (Table 1).

2.3 Raman spectroscopy

The best results came from the basalt samples, like feldspar (anorthite), pyroxene (augite) and olivine (Figure 1). In addition, quartz, muscovite and montmorillonite could be detected from samples of the ESA2C collection. The analysed grains were selected to be representative from among the scanned particles, however the crystallized ones were preferred, which fortunately give more useful spectra.

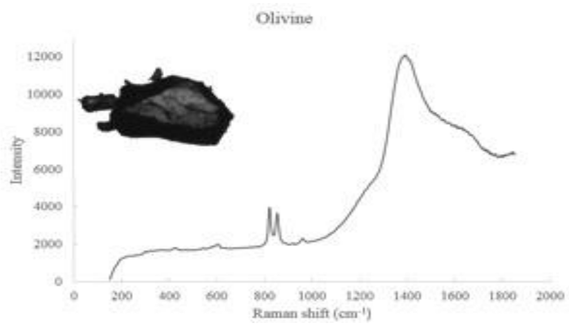

Figure 1: Typical Raman spectra of olivine from the basalt sample of Azores Island.

Table 1: The identified minerals from different type of samples with the used methods: AZ-2017_03 (basalt), 16CY01-6d (kaolinite-montmorillonite granules), 16ES01-6d (sepiolite granules), 16SN01_6d (palygorskite granules). The following acronyms were used: An- anorthite, Aug- augite, Cal-calcite, Cb- carbonate, Dol- dolomite, Ilm- ilmenite, Fsp- feldspar,Gp-gypsum, Kln- kaolinite, Mca- mica, Mnt- montmorillonite, Ol –olivine, Paly-palygorskite, Pl-plagioclase, Px-pyroxene, Q- quartz, Sep-sepiolite, Sme- smectite.

Samples	Infrared spectro.	XRD	Raman spectro.
AZ-2017_03	Ol, An, Aug	Pl	Ol, Px, Ilm
16CY01-6d	Kln, Mnt, Q, Cb (Dol)	Q,Sme, Kln, Mca, Cal,Pl	Q
16ES01-6d	Sep, Dol	Q,Dol, Cal,Mca, Sme, Fsp, Gp	
16SN01_6d	Sep, Dol, Q	Paly,Sep, Fsp, Q Dol,Sme	Dol

5. Summary and Conclusions

Based on our results, the most information, moreover general composition of the rock-forming minerals of samples were obtained by X-ray methods, for example typical basalt minerals, like olivine, pyroxene or sulphate, Fe-oxide minerals could be also detected. But in certain cases, the Raman spectroscopy seemed to be the most informative about the species of the mainly primary minerals (e.g. pyroxene is augite, plagioclase is anorthite). The most capable method for identification of products of weathering (e. g. smectite, kaolinite or sepiolite) is the X-ray analysis (after preparation), but it is also possible by infrared spectroscopy in ideal situation based on the occurrence of water in these minerals. This water content of the minerals could be detected the easiest by infrared spectroscopy. In summary, the best methods to analyse the bedrock on Mars would be the XRD and Raman spectroscopy, but if the main question is the detection of traces of weathering, the XRD and infrared spectroscopy would be the best choice. In addition the most important aim of the EXM 2020 is the search of the traces of life, which is worth looking for by infrared spectroscopy, because the organic material content of the sample can detected from the 5-10% (the other methods can not detected such small amounts of organic material).

Acknowledgements

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Geomicrobiology of Rock Varnish in a natural extreme acidic environment: Río Tinto

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Abstract

Río Tinto is a natural environment due to the microbial activity in the subsurface of Iberian Pyrite Belt (IPB). The river has a high heavy metals concentration in solution and the chemistry of iron in the river maintains a constant pH.

One of the less studied and known niche in the river system is the rock varnish which is clay minerals cemented with Fe and Mn oxides. In these environment, microbial communities are presents and varnish-like materials have great interest in astrobiology.

We are investigating rocks varnish. Analysis with XRD and ICP-MS have been made and biodiversity studied. High-throughput sequencing methods were applied.

1. Introduction

In the XIX century, Alexander von Humboldt reported the first rock varnish in the literature when travelled to South America [10]. Microbiologist have studied rock varnish just only in the last decades. The great interest of these type of rock coatings is its highly oxidative character, the biodiversity present and the biogeochemical cycles on a small scale with tremendous interest in astrobiology [1, 5].

1.1 Rock Varnish

Rock varnish is one type of rock coating found in almost every type of terrestrial weathering. With a thickness of no more than 200 µm, it is composed mainly by clay minerals (Si, Al) cemented on a bedrock with Mn and Fe oxides in variable concentrations with some trace elements in the composition [6]. Categorization and classification in different types the rock varnish from different environments is difficult due to its diversity [8].

1.2 Río Tinto

Río Tinto (located in SW Iberian Peninsula, in the core of the IPB), is an unusual natural ecosystem with unexpectedly high level of microbial diversity. Due to the underground chemolithotrophic microbial activity, a high concentration of heavy metals is in solution (iron can be found above 20 g/l, maintaining a constant acidic pH of 2.3 as a mean) and iron formations such as hematite or jarosite can be found in the river system. For these reasons, Río Tinto is considered a good geochemical and mineralogical Mars analogue [2].

2. Material and Methods

Samples were analyzed mineralogical and chemically using XRD and ICP-MS, trying to separate the brownish cover from the sedimentary bedrock for the analysis. Also, observations were realized in the SEM, analyzing the microstructure.

DNA extraction using approximately 0.5 g of sample in PowerSoil DNA Isolation kit from MoBio was achieved. PCR using the primers 515F and 806R was done, using a common protocol described in the literature for microbiomes from soil [3]. The PCR products were sequenced by Illumina Mi-Seq and the output was processed by QIIME 1.9 [4].

3. Tables

Table 1: Mineralogy obtained by XRD

Quartz
SiO_2
Illite
$(K, H_3O)Al_2Si_3AlO_{10}(OH)_{16})$

Chamosite
$(Mg_{5.036}Fe_{4.964})Al_{2.724}(Si_{5.70}Al_{2.30}O_{20}(OH)_2)$

Table 2: Main *phyla* detected by Illumina sequencing

Phylum identified	Relative abundance (%)
Firmicutes	43,7
Proteobacteria	19,5
Actinobacteria	12,4
Fusobacteria	10,4
Bacteroidetes	7,5
Saccharibacteria	1,2
Nitrospira	0,3

4. Summary and Conclusions

This is the first study of rock varnish in an extreme acidic environment. With the data obtained, we hypothesize that our sample is a rock varnish 'type V' in a very particular environment, explaining why Mn oxides have no presence but high content of Fe oxides (table 1). The microbial composition (table 2), reveals the presence of microorganism able to oxidize the Fe and Mn. Bacteria groups reported previously in the literature [7, 9] are presents as well.

Acknowledgements

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Danakil Depression Flats as Analogues for RADAR-Smooth Surfaces of Titan, Mars and Venus

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Abstract

Vast, extremely smooth and solid surfaces on Titan, Venus and Mars as seen by RADAR data have been erroneously interpreted as liquids. An analogue site on Earth is the large Danakil Depression of NE Ethiopia. We observed the characteristics and measured the roughness of 16 individual sites in the Danakil in the field and compared the results with satellite RADAR data. The SAR-darkest, or smoothest, regions are dominated by salt flats, firm surfaces generally flat on cm scales, or silty surfaces, while moderately SAR-dark surfaces have smaller salt polygons with rough margins. SAR-bright surfaces in the region are alluvial fans. This reveals the benefit of field studies for interpreting planetary remote sensing observations.

1. Introduction

The solar system has features with improbable characteristics. Radar observations of Titan made with the giant Arecibo radio telescope in 2002-2003 indicated areas on Titan that were tens of km across, but were 'smooth as parking lots' [1]. The simplest interpretation at the time was that these were areas of liquid – i.e. lakes. Subsequent observations by Cassini showed that these areas were solid after all. Additionally, at least one site on Venus showed a quasi-specular reflection in Magellan data [2].

Yet the fact that such large areas of solid surfaces can be so flat can be difficult to explain. An analogue area exists in the inhospitable Danakil Depression of Ethiopia. This region is a deep depression (below sea level) and is the site of rapid sedimentation fed by surrounding alluvial fans. Because it is a closed basin, it cycles climatically between containing ephemeral lakes and evaporite basins, or salt flats. Such regions are relatively flat over many tens of kilometers.

Although there have been in-situ studies of small regions of playas or salt flats (e.g. Death Valley) to compare with imaging radar data (sigma-0, at incidence angles of 15-40 degrees), the Dallol region offers a much larger target area (>10km) of incredibly flat, homogenous terrain that allows meaningful interpretation of nonimaging remote sensing data obtained at much lower spatial resolution, including nadir backscatter, and microwave emissivity. Such data are often obtained on planetary missions (notably, Magellan and Cassini as well as Mars missions) but comparable knowledge of terrestrial analogues does not exist because most locations are heterogeneous on spatial scales smaller than the instrument footprint.

2. Field Methods

We participated in the Europlanet field study of the Danakil and Dallol of Ethiopia in January 2018. Our field measurement campaign entailed the quantification of the microtopography (cm-scale roughness, using digital photography with geometric calibration – e.g. shadow bar and ruler) with a handheld digital camera held at shoulder height, walking around a ~25 m^2 area to obtain an image-derived DEM, at 16 sites in the Danakil. Our measurements also involved characterization of the composition via geological assessment and hand tool trenching. We compared these field measurements with PALSAR 50 m Synthetic Aperture RADAR (SAR) data for the region in L-band, or 15-30 cm.

3. Surfaces of the Danakil

Our field sites were selected based on their appearance in the field (Fig. 1) and their PALSAR characteristics (Fig. 2). Several regions were targeted because they appeared dark in the PALSAR data, which means they are smooth and return little SAR signal. While it is understood that these surfaces may change by flooding, these events are rare enough in this region that we assume the smoothness is a result of the generally present surface that we observed.

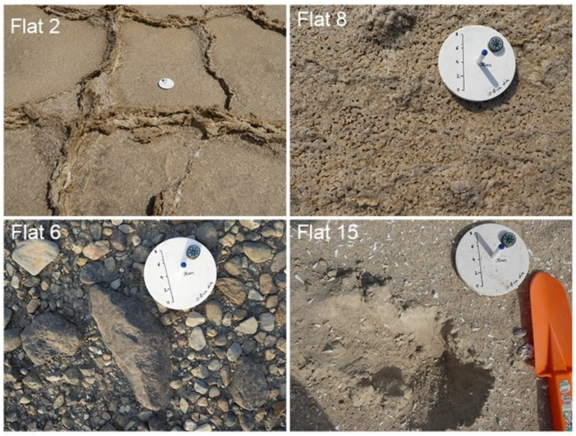

Figure 1: Select field survey regions discussed in text.

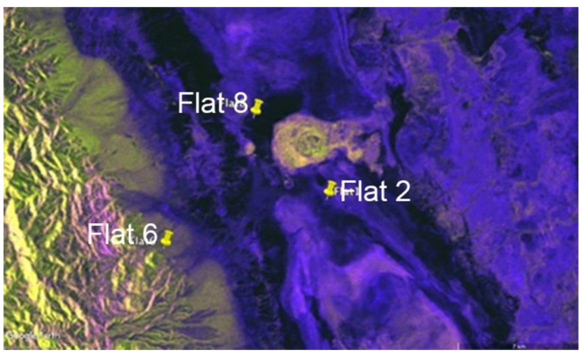

Figure 2: Location of the selected field sites discussed in the text as viewed on PALSAR image (other sites collected here are not shown in this image). Colors are for polarizations of the L-band SAR. Scale bar is 7 km.

Flat 2 was obtained at a salt flat just south of the Dallol hydrothermal area, regionally flat but with some SAR signal return (Figs 1 and 2). Rough edges of salt polygons may affect the signal return, or perhaps there is sub-surface roughness that is seen by the SAR as it penetrates some meters deep at those wavelengths (Fig. 1). Flat 8 was taken in an exceptionally SAR-dark region, where liquids can pond against the valley and the elevated Dallol region (bright circular feature at center of Fig. 2). This site is extremely flat on several to tens of cm scales (Fig. 1). Flat 6 is of an alluvial fan surface, and is noticeably rougher on several to tens of cm scales and is brighter in PALSAR (Fig. 2). Flat 15 was obtained in the south of the Danakil, in the Afdera region. This is a large, SAR-dark region composed of thick, powdery silt related to the retreat of the once larger Lake Afdera.

All regions have characteristics we might predict from a range of possibilities based on the SAR data. We may envision creating a database of possible surfaces that correspond to SAR signal return, so that these could be applied to different geological conditions on Earth and other planets. We are quantifying the roughness of the surfaces using field image-obtained DEMs through elevation profiles and surface height standard deviations [3]. We will quantify the PALSAR signal return sigma0, and will pair each of our 16 measured sites with these data to fully characterize the surfaces in the Danakil.

4. Summary and Conclusions

Our combined study of field measurements and remote sensing observations are providing a set of data against which both simple and sophisticated models of backscatter and emissivity of planetary surfaces can be validated, thereby paving the way for quantitative interpretation of planetary data such as that from Cassini and Magellan but also for potential future missions e.g. Envision.

Acknowledgements

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Intracrystalline geothermometers validated on synthetic clino and orthopyroxenes and applied to a terrestrial analogue

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Abstract

This Ongoing discussion on the application of intracrystalline "geothermometers" to Martian nakhlite samples indicates that the available calibration equations that express the lnk_D as a function of $1/T$(K) for clino- and ortho-pyroxenes (cpxs and opxs) require further validation. This can only be done using crystals grown in rock analogues synthesized under controlled temperature conditions. With these samples, it is possible to compare the closure temperature (T_C) of the intracrystalline Fe^{2+}Mg ordering process for each of both phases (cpx and opx), with the quenching temperature (T_Q) of the synthesis experiments.

1. Introduction

Intracrystalline thermometry records the last thermal event experienced by a single mineral phase if the system remains closed for the entire cooling process, as expected for our synthesized samples, which are subjected to a rapid quenching.

2. Method

For this purpose, we measured by single crystal Xray diffraction the Fe^{2+}-Mg order degree, expressed as the intracrystalline distribution coefficient k_D, on three pairs of synthetic samples containing both clinopyroxene and orthopyroxene as separated crystals. Each of these synthetic samples was experimentally grown from a hydrous nepheline basanite under conditions that ranged from 1050°C at 2.0 GPa to 1170 °C at 3.0 GPa.

3. Results

Our results, obtained by applying for cpx and opx the calibration equations by [1] and that by [2], respectively, demonstrate for the first time the quite remarkable agreement between calculated closure temperatures (T_C) and actual quenching temperatures (T_Q) for synthesis products over which we have complete control. The smallest discrepancy between calculated and actual temperature is of the order of degrees (e.g.12 °C and 4 °C for clinopyroxenes and orthopyroxenes respectively), whereas the largest is of the order of tens of degrees (e.g. 22 °C and 55 °C for clinopyroxenes and orthopyroxenes respectively). These values are well within the intrinsic estimated standard deviations (e.s.d.'s) that arise from the structural refinement (e.g. about 28 °C for the sample with the highest e.s.d. on the Fe site occupancy).

Acknowledgements

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Field work at Ojos del Salado: a new high altitude extreme Mars analogue candidate site in Atacama desert

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Abstract

First report is presented on a candidate Mars analogue site at the highest volcano in Atacama Desert, Ojos del Salado. The low temperature, dryness, strong wind and UV exposure provide ideal locations to survey geology and astrobiology related aspects.

1. Introduction

Field work at Mars analogue sites provide useful information to better understand the Red Planet [1, 2, 3], including astrobiology relevant aspects [4, 5] and logistics connected to future missions [6, 7, 8, 9]. Below a new suggestion site is characterized in Atacama Desert.

2. High elevation at dry Andes

Several aspects of the Atacama desert as range of potential Mars analogue sites have been already analyzed [10, 11, 12] mostly at the lower elevation region, while at locations above 3000-4000 m are also accessible and provide interesting features too. Between 11th February and 3rd March 2018 a five person expedition was realized to the Ojos del Salado region from Copiapo with the stops along the Laguna Santa Rosa (3700 m), Laguna Verde (4328 m), Atacama (5300 m) and Tejos (5837 m) camps route.

Experiences and logistics were available from earlier works by Nagy B. et al. [13, 14, 15] as climate monitoring and biological [16] expeditions there, this year the planetary science and Mars analogue aspects were surveyed of this specific site.

3. Main characteristics

The average annual temperature of this site is around -10 °C, however in summertime around noon could be above +10 °C. The amount precipitation is difficult to estimate because of its stochastic fluctuation, but the region might get almost no precipitation for a year but also could be around 200-300 mm annually. The geological and biological important features to analyse there include: ephemeral water flows, cryokarstic features, hydrothermally heated high altitude lake, wind transported volcanic sand, extreme mineral alteration, salty lakebeds, buried ice and snow masses. Examples of these features will be presented at the EPSC meeting.

4. Future as a Mars analogue site

Beside the described physical conditions, and the range of potential Mars relevant geological processes and extreme organisms, an important advantage of the discussed site is the access. Because of a helicopter accident some years ago bulldozers produced roads up to 5300 m elevation that could be reached by regular cars (with specific preparation driving is possible up to 5800 m elevation). The difficulty is the physiological adaptation that is required for regular work: at least 2 weeks long expeditions should be planned, however important locations (like salty lagoons) could be analysed during this adaptation period. Altogether the site is worth for more detailed analysis, but specific preparation and working methods are necessary there to realize effective research work despite the harsh conditions and physiological challenges.

Acknowledgements

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Figure 1. Example images of the field site. a: drilling at the salty flat of Laguna Santa Rosa, b: debris covered recent snow on the slope of the volcano, c: hot spring at Laguna Verde, d: ephemeral ice melting produced runoff at a channel on the flank of the volcano, e and f: typical scenes of the region with many rock boulders, g: salty lake shoreline and a snow covered volcano.

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MA_MISS and WISDOM on ExoMars: building synergies through fieldwork

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Abstract

The 2020 ESA-Roscosmos ExoMars Rover mission will focus on finding evidences for signs of present or past life on Mars. The WISDOM radar and the spectrometer inside the drill of ExoMars [1] will explore the place where traces of life is most likely to be found: the subsurface of Mars. Data integration between these two instruments is critical, and the two teams are building the experience that will maximize data integration once the actual data will be acquired.

1. Introduction

The Mars Multispectral Imager for Subsurface Studies (MA_MISS) is the spectrometer which will deliver hyperspectral data from the hole drilled in the Martian ground by the ExoMars Drilling system [2, 3]. The experiment has been funded by the Italian Space Agency (ASI) and developed in Italy by SELEX Galileo, a Leonardo Company, Florence. The Water Ice Subsurface Deposit Observation on Mars (WISDOM) is a ground penetrating radar to study and characterize the structure of the Martian underground. It has been funded by the french Centre National d'Etudes Spatiales (CNES) and german DLR and developed at the Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS) in Paris, France[4, 5].

2. MA_MISS / WISDOM synergy

The organization of the digital data delivered from MA_MISS and WISDOM is related to the characteristics of the instruments, the timing and the geometry of acquisition. Integrating these data means locating a common spatial reference frame where we will be able to compare the observations.

Before the actual mission we are planning fieldwork which will build up experience on data integration between these two different instruments.

3. Fieldwork in a quarry

We planned a first fieldwork experiment in Italy on May 2018. This first experiment consists in the acquisition of radar data in the field and returning the rocks back to the spectroscopy lab. We choose to do the test in a quarry as it offers exposed rock walls and interesting data acquisition geometries. The geometry of the first experiment is reported in Figure 1. WISDOM signals will investigate a layered limestone outcrop which is covered by gravel (Figure 1c). The thickness of the gravel layer varies from 0 to about 1.8 meters (see outcrop in Figure 1 from left to right). The limestone layers are 20 to 50 cm thick, interleaved by 5 to 10 cm-thick marly layers (Figure 1d). The layers are dipping about 8 degrees in the direction of the radar survey. This particular geometry creates a variable depth of the gravel-to-bedrock interface which represents an analogue of the martian regolith-to-bedrock contact.

4. Summary and Conclusions

At the time of writing this abstract we are just back from the field and both radar and rock samples are being analyzed. We expect to produce a 1-d subsurface model correlating radar reflections with the subsurface structures exposed in the outcrop. Rock samples have been sent to two different laboratories. Mineralogy of the samples will be analyzed by the spectroscopy lab at the Istituto di Astrofisica e Planetologia Spaziali (IAPS) in Rome, while the dielectric characteristics will be extracted at the Technische Universitat of Dresden.

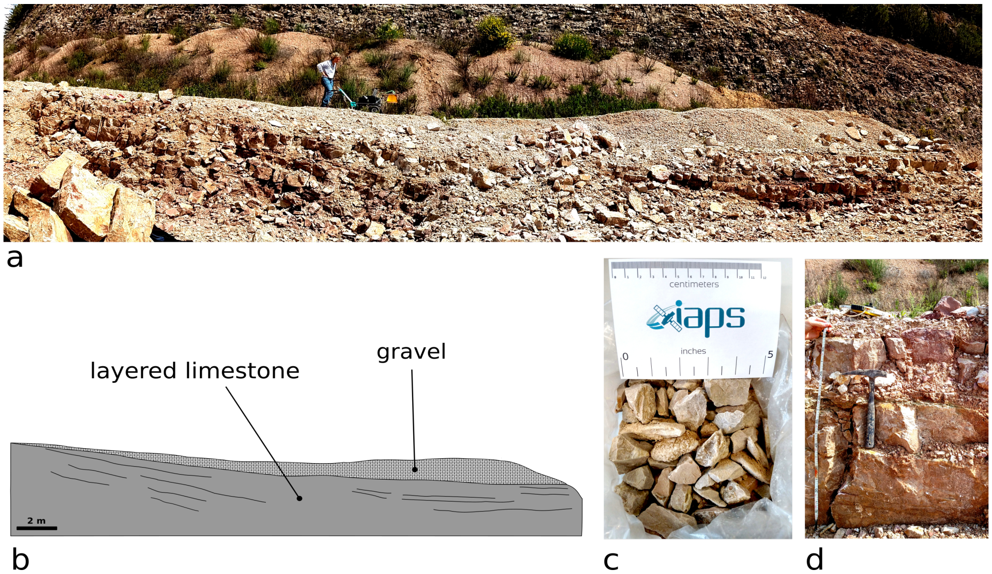

Figure 1: Figure 1: a) A picture of the experiment setup: the radar signals are impinged into a limestone terrain. b) the outcrop shows that we are investigating layered limestones overlayed by a variable thickness limestone gravel. c) the limestone gravel: angular shape in 1 to 5 cm size. d) The layered limestones (hammer height is 33 cm)

The results of this fieldwork will be useful to build a solid base of experience on the data/procedures integration which will result extremely useful during the mission, when quick planning decisions will be made on the basis of data available.

The results of this our first fieldwork experiment will be presented at the EPSC 2018 in Berlin, Germany.

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The ScanMars radar onboard AMADEE-18 analog mission to Mars

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Abstract

Simulated, or analog, planetary missions are putting the base for the forthcoming extraterrestrial explorations, testing new technologies and refining existing operative exploration procedures [1, 2, 3].

In February 2018, the Austrian Space Forum led an international Mars analog mission in the Dhofar region, Oman. Directed by a Mission Support Center in Austria, a small field crew conducted experiments preparing for future human Mars missions in the fields of engineering, planetary surface operations, astrobiology, geophysics/geology and life sciences.

In summer 2017 our ScanMars experiment has been selected to be part of the mission. ScanMars employed a Ground Penetrating Radar to investigate the subsurface by transmitting and receiving radio-wave impulses into the ground. The expected results of the experiment are geophysical images of the underground structures, material differences and the presence of groundwater[4].

Here we present the ScanMars experiment and its results from AMADEE-18 analog mission to Mars, in the Oman desert.

1 Introduction

The instrumental part of the ScanMars experiment onborard AMADEE-18 consists of a Zond-12e Ground Penetrating Radar, developed by Radsys, Latvia. We choose the 500 MHz operative frequency as a good compromise between resolution, penetration depth and maneuverability. The experiment can be divided in three phases: the training, the scientific campaign and the scientific synthesis.

Figure 1: Analog astronauts testing operative procedures during the training at OEWF headquarters in Innsbruck, Austria.

2. Training Phase

The most different element from ScanMars a common radar fieldwork is undoubtedly the fact that the data was going to be acquired by the analog astronauts and not the scientists. Thus the astronauts' training becomes a critical part of the experiment. The challenge of this phase resides in the fact that the analog astronauts have a background which is not specifically trimmed on the experiment, and that they have to acquire a large quantity of diverse information during the training (Figure 1).

3. Scientific campaign

The training efforts have been put into practice during the ScanMars scientific campaign in the field in the Dhofar (Figure 2), where the field crew operated the radar over the planned scientific targets. The experiment explored four different sites with slight different geologic charac-

Figure 2: The analog astronauts during ScanMars experiment data acquisition. The radar sledge is being pulled along the planned profile.

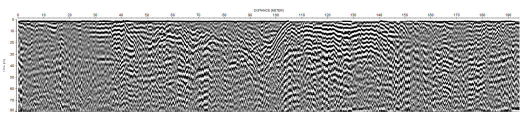

Figure 3: A data frame extracted from the experiment results. The radargram is the visual representation of the radar echoes recorded in the field, representing distance along the profile (horizontal) versus time delay (vertical).

teristics. The analog astronauts acquired about 1400 meters of profiles. A total of about 70000 radar echoes have been recorded and returned to the scientific data archive.

4. Results

Figure 3 shows one of the 25 radargrams which have been acquired in the field. The data quality is very good and the radar echoes show extremely well geologic features typical of the wadi riverbed. The penetration depth of the signals is about 5 meters, and in some case we can extract deeper information.

5. Conclusions

The ScanMars experiment can be considered successful not just because of the data acquired but more importantly we consider ScanMars a success due to the volume of new experience created among the scientific team, the operations' team and the field crew. A good teamwork has been necessary to face the problems which are difficult, when not impossible, to foresee beforehand. With ScanMars and AMADEE-18 in general we are understanding the different aspects of scientific exploration of distant worlds, developing strategies and workflows which will be the building blocks of the future human planetary missions.

Acknowledgements

Thanks to the AMADEE-18 personnel, from the astronauts, the field crew and the mission control, whose efforts turned the ScanMars experiment into a success. We are grateful to the volunteers of the Italian Radio Amateur Association (ARI) who assisted us in laboratory measurements and system optimization of the ScanMars radar hardware.

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The Azorean fumarolic fields as an analog for Mars hydrothermal alteration

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1. Introduction

Hydrothermal environments have long been presumed to exist on Mars based on orbital detections of hydrated minerals, terrestrial analogs studies, and Martian meteorites analyses (e.g., [1] and references therein). The first definitive evidence for volcanic hydrothermalism on Mars is the in situ detection of amorphous silica-rich outcrops (>90% wt opal-A) by the Mars Exploration Rover Spirit, which have been tentatively interpreted as either acid sulfate leaching in fumarolic environments or direct precipitation from hot springs [1,2]. Such hydrothermal spots may have created suitable environments for life and should be a prime target in the search for biosignatures on Mars. The present project focuses on the alteration at the fumarolic fields of the Azorean islands, Portugal, as an analog to some early Martian environments.

2. Geologic Context

The nine Azorean Islands located in the Atlantic Ocean at the triple junction of the Eurasian, North American and Nubian tectonic plates, are thought to originate from the combination of the mid-oceanic ridge activity and a hotspot. They are characterized by the occurrence of frequent seismic activity and volcanic eruptions [3]. In addition to fissural volcanism, large polygenetic volcanoes are also present and sometimes display fumarolic and hydrothermal activity in their calderas and/or along their flanks [4]. Volcanoes and lava flows in the Azores have basaltic to trachytic compositions, which are roughly similar to the Martian surface composition [5,6] (Table 1). Three hydrothermal fumarolic fields emitting various gas species at Furnas Volcano on São Miguel Island (two sites: village and lake) and at Pico Alto Volcano, on Terceira Island, were visited in September 2017. Several fumarolic emissions (Figure 1) and relatively pristine outcrops were sampled for gases, biomaterials, rocks and water (when available) at each site. Bedrock at Pico Alto is made of peri-alkaline lavas (comendites), and is characterized by the presence of riebeckite. Its composition slightly differs from the Furnas Volcano bedrock (Table 1), which is less crystalline and shows traces of phlogopite. Bedrock samples at Furnas are also more porous and show pumice textures. Gas compositions were typical of hydrothermal environments and were found to be roughly similar between the various vents within the same volcano and on the different islands; fumarole temperatures range between 97 and 100 °C. Gas emissions include H_2O and CO_2 as major components with H_2S, H_2, CH_4, CO, Ar, O_2 and N_2 as minor species [7,8]. Water ponds which are present at Furnas, however, show a wide range of temperatures, pH (from 2 to 8) and compositions.

Table 1: Bedrock samples bulk composition at Pico Alto (lava) and Furnas (pumice) volcanoes.

(wt %)	Pico Alto	Furnas
SiO_2	63.94	60.88
Al_2O_3	10.99	16.58
Fe_2O_3	9.14	3.86
MnO	0.27	0.26
MgO	0.18	0.32
CaO	0.46	0.74
Na_2O	6.54	7.74
K_2O	4.32	5.49
TiO_2	0.56	0.46
Total major oxides	98.75	98.42
S	0.02	0.01

Figure 1: Fumarolic vents at Pico Alto (left) and Furnas (right) Volcanoes.

3. Alteration Patterns

Characterization of the collected rock samples performed by in situ VNIR spectroscopy (ASDinc TerraSpec 4), and laboratory XRD and ICP-OES analyses revealed a variety of mineralogical assemblages and alteration patterns on the two islands (Figure 1). At Pico Alto, alteration products include alunite - jarosite, kaolinite, montmorillonite, amorphous silica and hematite, which is responsible for the reddish color of the site. At Furnas, mineralogical assemblages around vents are dominated by aluminum hydroxy-sulfates such as alunite, alunogen, and alum-K, associated to traces of goldichite and copiapite. Mudpots are dominated by amorphous silica. Walls at a distance show surficial alteration into alunite (characterized by yellow tones) and minor jarosite (orange tones). Similar observations were made at two distinct sites, located within Furnas village and at Furnas lake. Clays were not detected at Furnas. Although VNIR spectroscopy is more sensitive to the presence of coatings, its results are in accordance with XRD analyses.

4. Discussion and Perspectives

Despite roughly similar fluid compositions and temperatures, various mineralogical assemblages are observed at Pico Alto and Furnas. Whereas Pico Alto shows the presence of Al-rich clays and hematite, Furnas Volcano is dominated by amorphous silica and sulfates. Both assemblages are observed on Mars, where various hydrated minerals have been detected; however their context is often difficult to infer (e.g., [9,10]). Subtle differences in bedrock compositions are observed, but the bedrock texture and porosity (lava versus pumice) and the surface proximity of the water table could also explain the differences in the resulting alteration patterns. Understanding the context of formation of those alteration minerals and cataloging their occurrences is key to reconstructing Mars paleo-environments; and the first step towards sample-return and astrobiology missions. Future work also includes both defining the microbial communities present at the different vents and hot springs and isolating and characterizing novel thermophilic microbes in the Azores.

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Discovery of a hydrothermal fissure in the Danakil depression

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Abstract

Volcanic rift zones are among the most emblematic analogue features on Earth and Mars [1-2], with expected differences mainly resulting from the different value of a single parameter, gravity [3]. Beyond the understanding of the geology, rift zones provide appropriate hydrothermal environments for the development of micro-organisms in extreme conditions which depend at first order on endogenic processes, and weakly on the planetary climate conditions. The Europlanet 2018 Danakil field campaign enabled identifying a previously unreported 4.5 km long hydrothermal fissure on the Lake Asale salt flats, the Erta Ale - Dallol segment of the southern Red Sea rift and one of the best geological analogues of Martian rift zones. We present the first geologic analysis of this fissure and preliminary data on its hydrochemistry.

1. Introduction

The Dallol-Erta Ale rift, a continental segment of the Red Sea rift, separates the Nubian tectonic plate and the Danakil microplate. Volcanic activity associated with magma centres has been frequent, with magma chamber withdrawal recorded in the last 25 years at the Gada ‘Ale, Alu - Dala Filla, Erta ‘Ale volcanoes and a sub-Dallol magma body [4-7]. A 15 m diameter pond purportedly formed in response to a phreatic eruption next to Black Mountain in 1926 [8]. Magmatic accretion through dyke injection is however intermittent, with the last seismicity-related intrusion in Oct-Nov 2004 [6]. Interferometric modelling inversion suggests that this dyke, injected from beneath the Dallol dome, was accompanied by normal faulting. Seismic normal faulting along the rift margins north of Dallol has been recorded in 1993 [9].

2. Yellow Lake Fissure

A 4.5 km long fissure parallel to the local Danakil rift trend displaying echelon patterns (Figure 1) was identified north and south of Yellow Lake (also known as Oily Lake and Gaet’Ale). It is manifested by (1) salt polygon geometry directly influenced by the underlying fracture; (2) bubbling pools; (3) dead pools; (4) shallow sinkholes; (4) a variety of other micromorphologies related to free or pressurised upflow of gas and fluids; and (5) rare evidence of fumarolic activity. In this context, the Yellow Lake appears as a possible salt karst feature [10] the location and growth of which is controlled by relay zone deformation between the fissure segments.

3. Hydrothermal fluids

The physico-chemistry of fluids and minerals from two small pools located along the Yellow Lake Fissure, as well as the Yellow Lake, have been analysed (Table 1).

Table 1: Characterisation of hydrothermal fluids and main mineral composition. pH and conductivity ($\mu S.cm^{-1}$) are measured in the lab at 25°C.

	Yellow pool	Red pool	Yellow Lake
T (°C)	32.0	35.1	41.2
pH	3.7	3.5	3.4
Conductivity	395	494	598
Minerals	Halite Tachyhydrite	Sylvite Carnalite	Halite Sylvite Tachyhydrite
Dominant cations	$Ca^{2+}>Na^{+}>Mg^{2+}>K^{+}$	$Ca^{2+}>Mg^{2+}>K^{+}>Na^{+}$	$Ca^{2+}>Mg^{2+}>Na^{+}>K^{+}$

The three pools all contain warm bubbling water and are extremely salty. From a chemical point of view, the three pools are quite similar, although small differences are observed for some parameters. Salt precipitations contain Cl^- as the main anion, while various cations (Ca^{2+}, Mg^{2+}, Na^+, and K^+) are present in different proportions from one pool to another, resulting in the precipitation of halite, sylvite, tachyhydrite and carnalite.

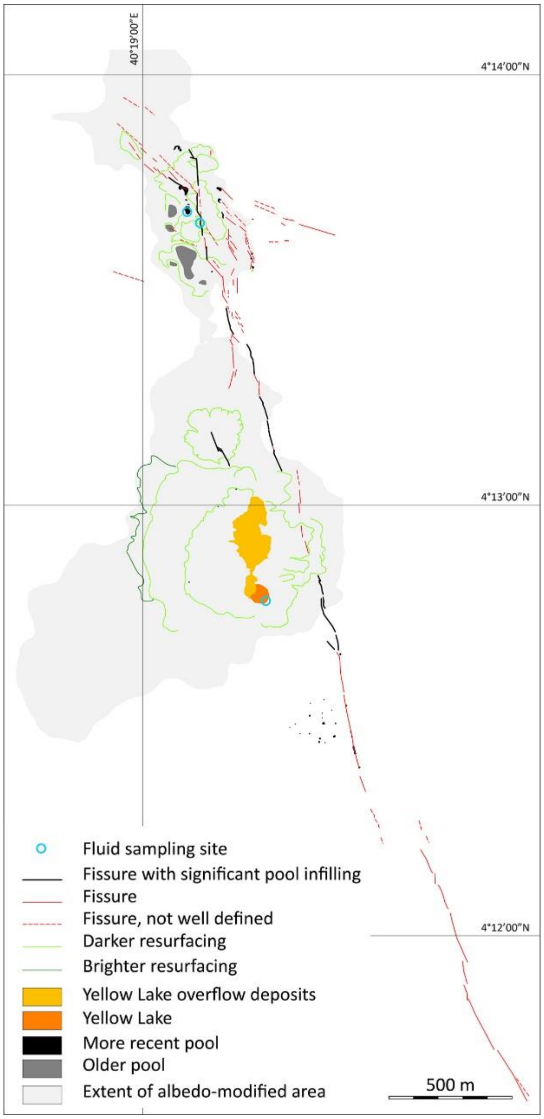

Figure 2. Map of the Yellow Lake Fissure area

4. Timing and origin

The fissure was tracked back using Landsat 7, ASTER, and OrbView-3 satellite images. It is well developed on June 10th, 2005. On February 18th, 2005 it is not apparent on Landsat and ASTER images. Hydrothermal activity increased at Yellow Lake and along the fissure future path in the preceding months. The fissure is parallel to the dyke that propagated in 2004, which is located 2.5 km westward [6].

5. Perspectives

More satellite data are being collected. Systematic time series analysis will be conducted to determine the evolution of tectonic and hydrothermal activity since the early 2000's. A field magnetic campaign is being prepared to determine the evolution of the geometry of the fissure at depth through its influence on surrounding rock alteration, and identify potentially associated magmatic intrusions. The origin and composition of hydrothermal fluids will be determined and compared. Extremophiles have been identified and their

DNA analysis is in progress, shedding light on the possible nature of extremophiles to be sought on similar sites identified on Mars.

Acknowledgements

This work follows field work conducted in January 2018 at the Danakil Planetary Field Analogue Site (TA1-5) of Europlanet 2020 RI, which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654208. Some work is also funded the EXOMHYDR project, carried out within the TEAM programme of the Foundation for Polish Science co-financed by the European Union under the European Regional Development Fund. Chemical and mineralogcal analyses are performed within the ELSIE project of SCK•CEN.

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AGPA: Integrating field Geology and Geophysics for Planetary Analogues

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The exploration of Solar System bodies relies heavily on remote sensing and mapping [e.g. 1]. The approach is complemented by in-situ analyses and sample return. The combination of cross-validating data is of great importance for planetary landing site data analysis as well as for planetary analogues [e.g. 2-4]. Integrating remote sensing and geophysical data can prove useful to constrain surface and subsurface structure of planetary landing sites and their terrestrial analogue counterparts [5-7].

The 2017 ESA astronaut training campaign extension PANGAEA-X [3, 4] hosted several experimental suites. One of them is AGPA [5], standing for **A**ugmented field **G**eology and Geophysics for **P**lanetary **A**nalogues.

AGPA comprises a flexible suite of remote sensing and geophysical experiments including drone photogrammetry and LIDAR [6] as well as geo-electrics [7] and active, passive seismic [8] investigations. AGPA also supported the integration of training data collection and analogue field geology procedures with geophysical in-situ and remote sensing. The resulting technique and data combination is synergistic and can be applied to both science and operational aspects.

Sub-centimetric surface imaging and topographic reconstruction of the main analogue site [6] was obtained. The resulting models, integrating both stereogrammetry and ground-based LIDAR proved useful for the morphometric characterisation of surface materials and structures as well as for constraining the shallow subsurface geometry of vents (Figure 1). These data are being integrated with traditional cave surveying datasets, in order to produce a comprehensive surface-subsurface model.

Subsurface structures and not directly accessible lava tubes have been investigated through concurrent use of surface imaging and subsurface sounding (Figure 2). Results include constraining the position and size of lava tubes (Figure 3) and cross-validation with in-tube lidar as performed by various teams during the PANGAEA-X campaign [see 3].

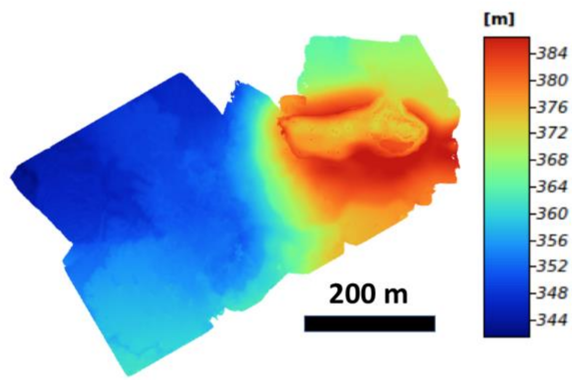

Figure 1: Exemplary result of drone-based stereogrammetric reconstruction of the Tinguaton cone topography [6]

The integrated use of both surface imaging and subsurface geophysics can be synergistic [5], useful for cross-validation and improved geologic interpretation. The approach can be applied on a planetary analogue target, such as lava tubes, or future planetary cases, such as Lunar or Martian landing sites with the need to characterise, map and explore the subsurface, e.g. through lava tubes, collapses and caves.

AGPA raw data are progressively available on public repositories such as Zenodo [9]. Datasets, both raw and processed are going to be shared on public data repositories too, in order to support cooperation, data re-use and reproducibility. The data discovery and access of planetary analogue data is possible via EuroPlanet VESPA (Virtual European Solar and Planetary Access) [10], to be further expanded. The approach could be used also within similar activities [e.g. 11]

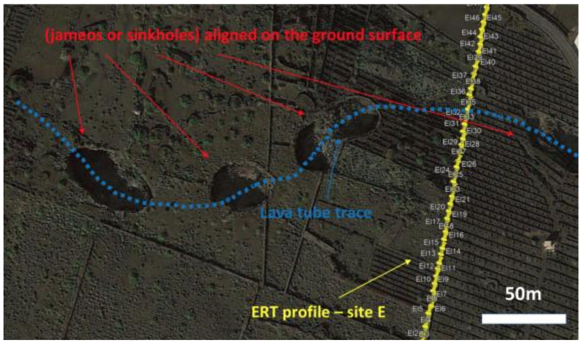

Figure 2: Location of one of the geo-electric profiles over a lava tube system (background imagery Google Earth) [7].

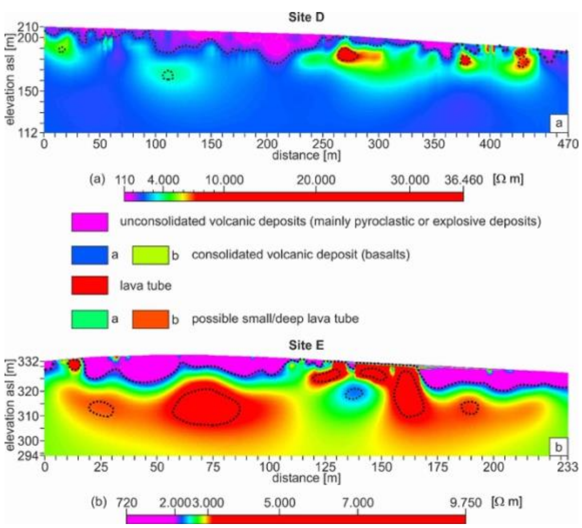

Figure 3: Geo-electric imaging of lava tubes. Surface topography surveyed with RTK-GPS [7].

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Testing Operational strategies for the Mars 2020 Helicopter using a UAV

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Abstract

We utilized a commercial drone to test operational strategies for the Mars Helicopter Scout (MHS), which is expected to be part of the payload for the upcoming NASA Mars 2020 mission. Using the reported capabilities of MHS, we demonstrate that a 3-min flight time at an elevation of 100 m is enough to attain a spatial coverage of 10^4 m^2 (assuming a FOV of ~80°) at an image overlap that is acceptable for building full mosaics and digital terrain models. Despite the apparent short daily flight time, careful planning of the scout path can also result in substantial ground-track coverage of ~200m, which would be enough to provide reconnaissance data for 3–4 sols of rover operations (assuming daily traverse distances similar to that of the Mars Science Laboratory).

1. Introduction

Unmanned Aerial Vehicles (UAVs), commonly referred to as "drones", are fast becoming essential tools in geosciences with variable applications including surveys and mapping, atmospheric and archeological studies, and various monitoring activities. The NASA Mars 2020 mission is expected to include a drone-sized helicopter scout [1]. The drone may aid in mission operations, offer scientific context to the landing site area at higher spatial resolution than what is available from orbit [1], or simply act as a technological proof of concept for future missions. While our results here may be directly relevant to some aspects of the Mars 2020 mission, our main aim is to explore in a general sense optimal operational strategies for utilizing UAV-like instruments in different settings for future planetary missions. During a GeoHeuristic Operational Strategies (GHOST) field test - the latest in a series of field tests organized to test different operational strategies for martian and lunar rover missions [2, 3] we used a commercial drone to test a number of operational strategies for a hypothesized drone utilized in concert with a mobile platform on Mars.

1.1 Study site

The field site that was chosen for the GHOST campaign [4] is located in the Uinta Basin of the Colorado Plateau province in northeastern Utah (39.8058°N, 109.0759°W). The main testing area was a canyon cutting through a 500 x 500 m study region where rock layers are well exposed on both sides of the canyon. The site was chosen because it displays evidence for paleo-habitability that can be detected by in-situ measurements, thereby consistent with being a potential analogue site for ancient Mars in accordance with current goals of the NASA Mars Exploration program.

2. Methods

We used as published capabilities of the MHS as originally proposed for Mars 2020 a baseline [1]. Daily flights would be limited to a short duration of approximately 3 minutes due to power constraints, but it would attain ~100m altitude and ~600m ground track [1]. To simulate these parameters, we used a DJI Mavic Pro drone (https://www.dji.com/mavic/info). The main approach was to carry out multiple 3 minute-flights, each simulating possible MHS constraints for a single sol on Mars to gain better understanding of the nature and extent of scientific reconnaissance that can be carried out on a daily basis. To test reconnaissance capabilities, we used reported data for MHS to design a flight plan that would simulate a 3-min flight. We used Drone Deploy (https://www.dronedeploy.com/) to construct a simulated reconnaissance flight plan with MHS activity constraints. For our flight simulations, we planned for a side overlap (the percentage of overlap between each leg of flight) of 65%, and a. front overlap (the percentage of overlap between one image and the next) of 75%. Finally, we tested additional strategies with no time constraint where we focused on testing methods by which the drone would be able to complement daily rover science operations as opposed to being used as a reconnaissance tool.

3. Results

3.1 Reconnaissance capabilities

Simulated flight plans on drone mapping software demonstrated that an area roughly 10^4 m^2 can be imaged within 3 minutes (assuming a wide-angle FOV of 78.8°, similar to the Mavic Pro), including take-off and landing time, with enough overlap to construct an image mosaic and a DTM.

3.2 Scientific capabilities

In this mode, we utilized the drone to trace vertically stratigraphic packages that would normally be inaccessible to a rover. This would be particularly beneficial in a canyon setting but also applicable for 10s of meter-high outcrops, impact crater walls, etc. In one particular example, the GHOST teams identified an interesting float rock with fossilized ripple marks. The drone was then utilized to trace its stratigraphic origin on the cliff wall.

We also tested an optional mode using the drone's gimbal capabilities to assess the benefits of having such a system in the future, or alternatively two cameras: one nadir-, and another horizon pointing. Our operational plan for a single sol consisted of first launching to maximum height (100m) to take a reconnaissance image, then decreasing the elevation to 20–30 m. The drone would then travel along a potential rover route for 30–50 m, acquire a set of horizontal images over at least a FOV of 180° for panoramic stitching, then repeat the sequence of travelling ahead and acquiring images until there were 30 seconds remaining for the drone to land and finish its simulated martian sol traverse. This mode provided a context image as well as the opportunity to detect a number of regions of interest (e.g., float rocks, interesting outcrops) that would be potential targets for detailed investigation by the rover. Using this technique, we were able to cover a ground track of 150–200 m per operational planning period (i.e., 3 minutes).

4. Implications for future planetary missions

Our analysis is directly applicable to MHS and possibly future missions to Mars. However, certain aspects of our work could be applicable as well to future missions to other planetary bodies. Our testing of having a gimbal system or at least two cameras is directly applicable to the Dragonfly mission proposal to investigate Titan [5, 6]. In particular, our tests here could be applicable to operational strategies of the camera suite [6].

Acknowledgements

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Roughness of Surfaces in the Ethiopian Danakil from Remote Handheld Image Surveys

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1. Introduction

Remote sensing, especially from Synthetic Aperture RADAR (SAR) imaging, can reveal the roughness of surfaces on the Earth and other planetary bodies. Various geological features and terrains are known to have unique small-scale topography and can be identified by their roughness in SAR images at the scale of the RADAR wavelength [1]. Validation of the relationship between radar reflectivity and geometric roughness (also relevant for Aeolian processes [2]) requires measurements in the field. Here we obtain multiple overlapping images with a handheld camera during the Europlanet 2018 campaign [3] to derive a 3D spatial model at several sites a few meters across in a particularly flat arid region, the Danakil desert of Northeastern Ethiopia.

The large area of the salt flats in this region means that the remarkably flat surface may manifest in nonimaging microwave data (such as scatterometer and radiometer observations) to facilitate the interpretation of similar data from planetary missions.

2. Materials and Methods

A fiducial marker was placed on the surface and a series of photos were taken 360 degrees around the marker from shoulder height at two different distances from the marker, ~3 m and ~10 m.

Each image group was then loaded into the software program Agisoft PhotoScan Pro to create elevation models. The shadows that existed in some of the photos were subtracted from the image. The photos were then aligned in Agisoft to position and orient each photo to build a sparse point cloud model, from which a dense point cloud was then built. A coordinate system was created using the image marker, and using the size and shape of the marker, quantitative data could then be extracted from the photos to build an elevation model of each the different surfaces. The dense (x,y,z) point cloud data was exported to MATLAB to calculate the standard deviation of the z positions as a measure of roughness for each flat [1][4].

3. Results and Discussion

The results and data for three of the studied flats analyzed to date are as follows:

Flat 1: A salt flat that appeared to be slightly rougher visually, and that had a height standard deviation of 2.48 cm (Fig. 1).

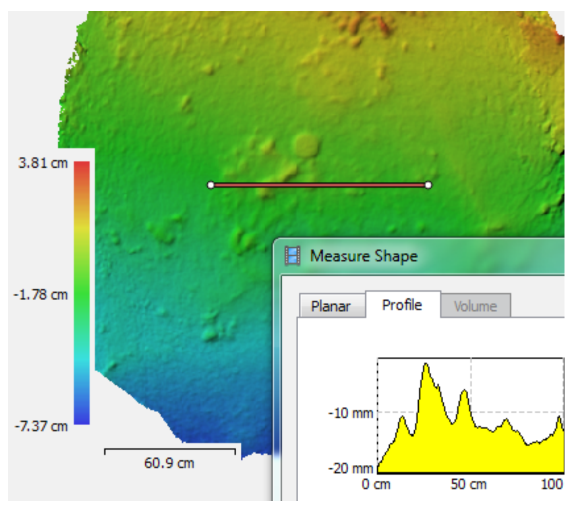

Figure 1: DEM of Flat 1

Flat 2: A salt flat near and similar to Flat 1 with high polygon edges that had a standard deviation of 2.68 cm (Fig 2). Note the remarkably regular spacing of the ridges, and the very flat surfaces between – casual visual observations show strongly specular reflections from these surfaces at low sun elevations.

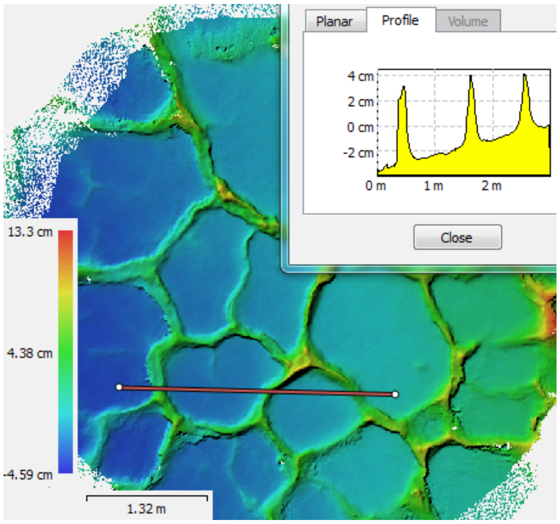

Figure 2: DEM of Flat 2

Flat 6: A rocky, pebbled alluvial fan terrain that had a standard deviation of 5.11 cm (Fig. 3).

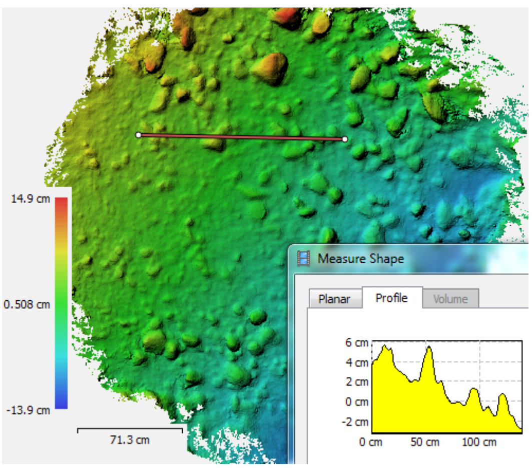

Figure 3: DEM of Flat 6

Flat 11: A sandy flat that is generally smooth (Fig. 4) was found to have a height standard deviation of 1.67 cm. A profile of this flat and the DEM clearly show small-scale ripples (Fig. 5).

4. Conclusions

Preliminary research shows that the elevation models built from images of these flats in Ethiopia represent and quantify the roughness of the area well. If these roughness calculations are relevant to the geological processes of other planets, then this study will give us better understanding of locations on other planets that we see as flat in remote sensing data.

Figure 4: Image of Flat 11

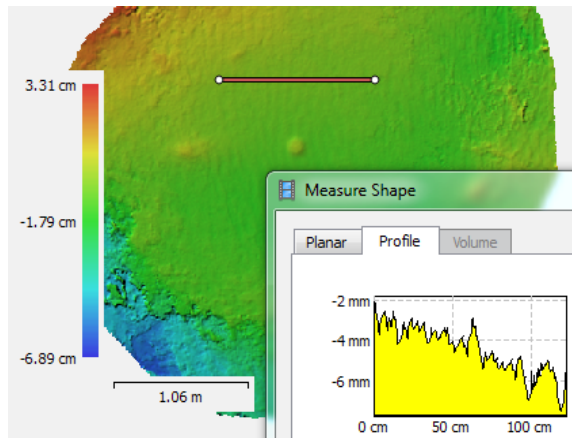

Figure 5: DEM of Flat 11

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Thermal characterisation and mapping of the fumeroles on Vulcano, Italy: Potential analogues for Martian terrains

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Abstract

Vulcano is the southernmost active volcanic island of the Aeolian archipelago linked to back arc spreading of the Sicilian microplate. The four main eruptive phases over the last 120 ka are associated with recurrent hydromagmatic to explosive phases and have resulted in the present day La Fossa Cone crater. Active volcanism on Vulcano is currently confirmed to degassing sites (fumaroles) linked to the underlying volcanic plumbing system. Their location, distribution and temperature have important implications for the state of the volcanic system and are often used as planetary analogues for hydrothermal alterations (e.g. [1]) and potential associations with microbial life.

Our work is based on field data collected in summer 2016, 2017 and 2018 as part of the German ROBEX Project - the Helmholtz Alliance for Robotic Exploration of Extreme Environments. ROBEX aimed to bring together scientists and engineers from different communities of both space sciences and deep-sea research. Data collected during the field campaigns includes high resolution aerial drone photogrammetry, thermal IR and UV camera, UV-VIS-NIR spectrometers, thermocouples and fugacity probes. The drone data was processed to produce high resolution (2cm /pixel) mosaics and textured digital elevation models to map the location and extent of the fumerolic fields. The IR camera was used on more than 300 individual fumaroles in 2016 and 2017.

Preliminary mapping results (Fig. 1) show that the active fumaroles are concentrated in cm to m wide fissures in the northern part of the La Fossa Cone. Temperature variations are present between both a) fumaroles within the same fissure (fissure tip to centre and edge to centre) and b) different fissures in general. The IR data clearly shows a wide spectrum of temperatures ranging from 100°C to excess of 350°C. Detailed mapping will be completed during the campaign this summer and is aimed at linking surface features with the temperature distribution. In addition, comparison with previous thermal surveys (e.g. [2] and [3]) will help to support models such as increased permeability or conduit sealing as mechanisms influencing the location and variability of gas and heat flux from active volcanic sites.

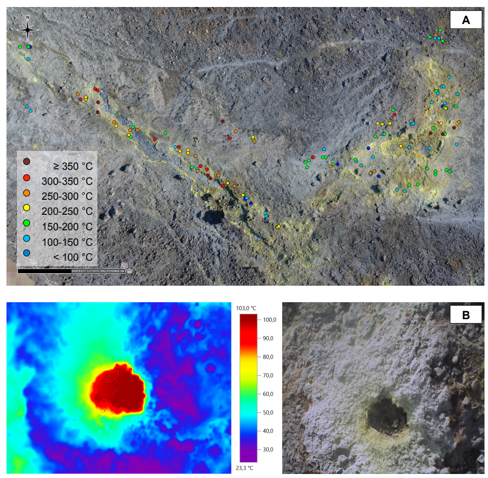

Figure 1: High resolution drone based photogrammetry model and image mosaic with an overlay of the maximum measured temperatures at the mapped fissures, b.) example of an IR image (left) and associated RGB image (right) aquired during the 2017 field campaign.

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ANALOG STUDIES ON ICELAND FOR SUPPORT OF THE MEDA INSTRUMENT OF THE FUTURE MARS 2020 NASA MISSION.

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1. Introduction

The Mars Environmental Dynamics Analyzer (MEDA) instrument is the suite of environmental sensors of NASA's Mars 2020 mission, which development is led by the CAB (Madrid) [1]. MEDA will characterize the weather, radiation, and dust environment of Mars at present and will help to infer martian potential habitability by studying the interaction between atmosphere and substrate, in synergy with other instruments of the mission. Water-related minerals produced by weathering and hydrothermal processes are indicators of potential habitability. Indeed, hydration/dehydration of these mineral assemblages might affect the actual water cycle on Mars, e.g., phase change by absorption /release of water (deliquescence/efflorescence). The Iceland analog is used here to produce unique and valuable data for science and technology teams of MEDA, by characterizing the mineral changes due to substrate-atmosphere interaction, and thermal properties of hydrothermal mineral assemblages.

2. Field survey

We visited two main geothermal areas and some small geothermal patches during the Iceland field campaign in 2017, which shows characteristics significant for comparisons to Mars. The study sites have been selected because of the presence of high-Fe basalts and extensive sulfate and phyllosilicates-rich deposits from basalt weathering, but also according to the acid-sulfate alteration and oxidation conditions of the hydrothermal fluids:

- Krýsuvik + Seltúm area is located in the center of the Reykjanes peninsula, which is characterized by extensive post-glacial lava fields, ridges of pillow lavas, pillow breccias, and hyaloclastite, all basaltic in composition [2]. Alteration mineralogy at the surface is included in the smectite-zeolite zone. We sampled different materials (clays, sulfates, and amorphous silica. See figure 1).

- Hengill-Hveragerði area is located in the extinct Hveragerði volcano region, which connects with the active Hengill volcano by fissures swarms [3]. Rocks are subglacially formed hyaloclastite and interglacial basaltic lava flows. Montmorillonite is referred as the dominant clay at shallow depths. Calcite and zeolites are predicted.

- Small single areas. We also sampled one site close to the Reykjanes coast (Gunnuhver), and others in the way to Hveragerði (Hveradalir to the south of Henhill, and around Nesjavellir to the north).

We sampled active and extinct geothermal sites displaying different colors, textures, and humidity. They represent fresh bedrock, secondary hydrothermal minerals, and fluids from hot springs and mud pools.

Figure 1. Example of a sampling site in Krysuvik

In order to control substrate properties, we used a portable Raman spectrometer (similar to the Mars 2020's SuperCam in its characteristics), which allows replicating synergies of the mission. Few multiparametric physical-chemical sensors and a soil pH-meter helped to constrain the samples' properties. During sampling, MEDA's meteorological observations were simulated using comparable sensors (radiation, temperature, atmospheric pressure, winds).

3. Laboratory analysis

We are doing an analytical study with different settings: 1) Characterize the mineral phases at terrestrial environment (in the field, and at room laboratory conditions); 2) Simulate temperature /pressure /humidity martian cycles to determine the effect on the natural mineral substrate and, ultimately, on the habitability of the surface. The PASC simulation chamber will be used to replicate Mars planetary conditions [4]. This second goal is not the subject of this presentation.

Raman and NIR+MIR spectroscopy were performed before and after sample lyophilization (-70º C, 0.495 mbar). XRD analysis of the samples was used to confirm the mineralogy. After the characterization of the hydrothermal alteration mineralogy, heat capacity (Cp) and thermal conductivity (k) measurements of natural assemblages were done by differential scanning calorimetry. These parameters will help to interpret TIRS (Thermal Infrared Sensor)/MEDA observations from the Mars surface [5].

4. Results

Interesting samples comprise mixtures of several minerals such as Al-clays, opal, alunite, anatase, calcite, and iron oxides. Some assemblages have phases with different crystallinity and thermal behavior.

We use the semi-quantitative analysis of XRD and spectroscopy to determine the mineral ratio for calculations in the calorimetric analysis. Resulting measurements have been compared with particular mineral data [e.g., 6, 7]. Figure 2 shows an example of the temperature dependence of the specific heat capacity of two samples from Krýsuvik. The mineral analysis determines that main compositions are kaolinite, natroalunite, and opal in the case of sample KC_20171029_002; and kaolinite, hematite and opal in sample KA_20171026_001.

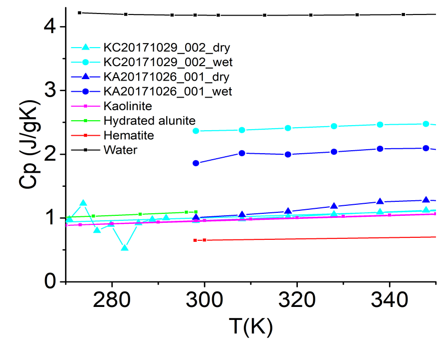

Figure 2. Specific heat of two natural samples from Krýsuvik compared to reference materials [6, 7].

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The loss of negative polarization after depletion of sub-micron-sized particles in regolith simulant

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Abstract

In Escobar-Cerezo et al. (2018)[1], experimental measurements of the scattering matrix of the lunar regolith simulant JSC-1A were presented. In that work, the role of the fraction of smaller particles of the sample was studied as these particles were depleted by a collecting device. By comparing the measurements before and after this depletion, we discovered that the observed negative polarization branch in the original sample disappeared when the smaller particles were removed. This seems to show that the phenomenon that triggers the negative polarization branch is associated with structures smaller than the wavelength.

1. Introduction

The polarization of light can be fully described by the Stokes vector, which represent exactly the polarization state and intensity of a beam of light propagating in certain a direction. The scattering matrix $\mathbf{F}$ in Eq. (1) characterizes the polarimetric response of a particle or an ensemble of particles under incident electromagnetic radiation. This scattering matrix relates the Stokes vector of the incident light into the Stokes vector of the scattered light. The matrix $\mathbf{F}$ depends on the physical properties of the sample, such as size distribution, shape of the particles, and their refractive indices.

$$\mathbf{F} = \begin{pmatrix} F_{11} & F_{12} & F_{13} & F_{14} \\ F_{21} & F_{22} & F_{23} & F_{24} \\ F_{31} & F_{32} & F_{33} & F_{34} \\ F_{41} & F_{42} & F_{43} & F_{44} \end{pmatrix} \quad (1)$$

The IAA-CODULAB apparatus (Muñoz et al. 2010 [2]) is devoted to perform laboratory measurements of the scattering matrices of irregular particles and offer these results to the scientific community through the Amsterdam-Granada light scattering database (http://www.iaa.es/scattering). The device illuminates the sample with an Ar-Kr laser. Thanks to several optical elements that may be arranged in different configurations, the scattering elements of Eq. (1) can be measured. As the sample is under single scattering conditions with random particle orientation and equal amounts of particles and their mirror images, only six of these elements are independent.

2. Degree of linear polarization

The degree of linear polarization under unpolarized incident light equals the ratio $-F_{12}/F_{11}$ where F_{11} as a function of the scattering angle is known as the phase function. In Fig. 1 we show the degree of linear polarization measured for the lunar regolith simulant JSC-1A at three different wavelengths. This plot presents the typical bell shape for irregular randomly oriented particles, with a maximum of polarization near 90° and a small negative branch at backscattering ($\sim$-2 %) (Muñoz et al. 2012 [3]).

In Fig.2, we show the degree of linear polarization of the pristine sample and the sample once have been recovered from the collecting device. During this recovery process, the smaller particles cannot be recovered from the collecting unit as they cling to the walls through electrostatic force or remain stuck in the filters. The effective radius of the size distribution then increases and its scattering response changes. As can be seen, the negative polarization branch disappears, and the maximum of the function increases and moves towards smaller scattering angles.

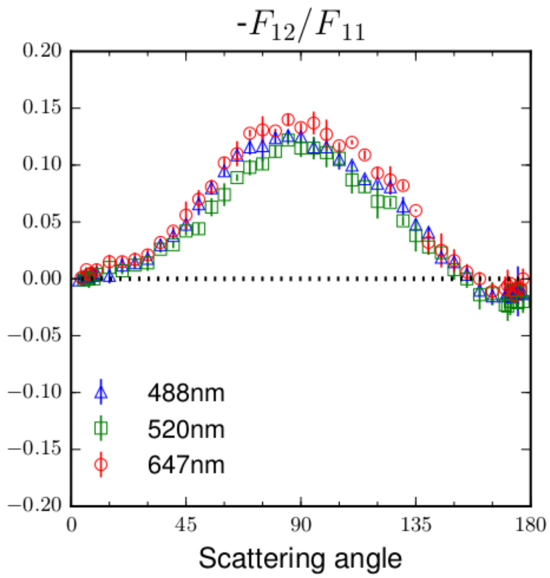

Figure 1: Degree of linear polarization for unpolarized incident light of the lunar regolith simulant JSC-1A at three different wavelengths.

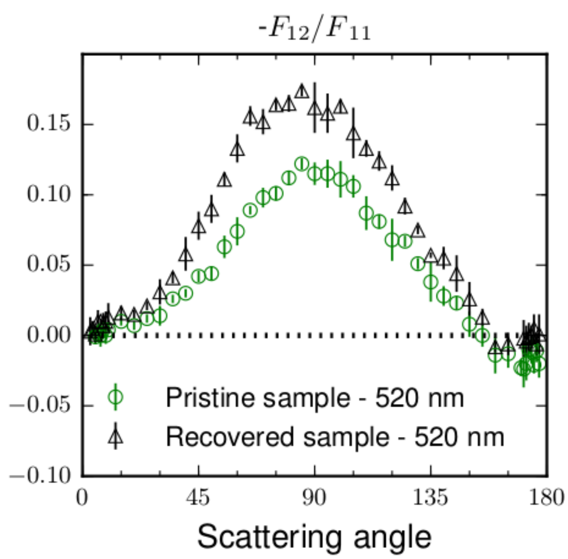

Figure 2: Comparison of degree of linear polarization at 520 nm between the pristine sample and the sample recovered from the collecting device.

3. Summary and Conclusions

This is a very interesting result, as the negative branch has been observed consistently in both comets and asteroids (e.g. Zubko (2012)[4]), and until now there was no proof of the mechanism determining this polarization feature. However, it is still soon to consider this as an answer to this question. Further measurements are planned to test this hypothesis, along with computational simulations to give the theoretical background necessary.

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A physico-chemical and geo-microbiological study of ten different lakes located in the Danakil depression

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Abstract

The Danakil depression harbors one of the best representative volcanic rift zone analogue to Martian rift zones. It is also one of the most extreme places on Earth, located in a salt desert at the confluence of three tectonic plates. In the north east of the Danakil depression, the Dallol volcano is surrounded by several very different sized and shaped lakes. Ten of these lakes were extensively characterized during the Europlanet 2018 Danakil field expedition. The *in situ* measurements showed the extreme physicochemical nature of all ten lakes. The laboratory analyses of rock, water and filtered samples confirm the *in situ* observations of the extreme nature and add that the environment of the ten lakes is dominated by salty minerals like halite, sylvite and anhydrite. Samples of six different lakes contain extractable DNA which is currently further investigated. Elucidating the identity of the microorganisms and finding the logic link with their extreme physicochemical habitat might provide better insights on how microbes are able to survive in extreme volcanic rift zones.

1. Introduction

Volcanic rift zones are among the most emblematic analogue features on Earth and Mars [1, 2]. Most of these volcanic rift zones are extreme environments, not only for the physical parameters like temperature and humidity, but also from a chemistry point of view. The region of the Dallol volcano located in the Danakil depression (Ethiopia) is considered as one of the most extreme places on Earth. The water of ponds and lakes in the vicinity of the Dallol volcano evaporates quickly, leading to very extreme physicochemical conditions. So the Dallol region is the ideal place to investigate whether and how microbes are able to survive such harsh physicochemical conditions. To make this investigation of extremes as reliable as possible well designed and robust *in situ* field sampling techniques are required. Not only the preservation of the geochemistry of samples has to be ensured, but it is also necessary to guarantee that samples have not been contaminated with foreign microorganisms.

2. Site location and description

The Europlanet 2018 Danakil field expedition made *in situ* sampling of the rift zone of the Dallol volcano possible. The names, the GPS location and the type of samples gathered, are summarized in table 1.

Table 1: The names and the location of the ten lakes that were sampled during the Europlanet 2018 Danakil field expedition.

	GPS location	rock samples	water samples	filtered samples
Central green pool	14°14'10.8" N 40°18'00.5" E	Yes	Yes	Yes
Left green pool	14°14'10.6" N 40°18'00.2" E	Yes	Yes	No
Right yellow pool	14°14'10.8" N 40°18'00.8" E	No	Yes	Yes
White chimney	14°14'11.5" N 40°17'59.5" E	Yes	Yes	No
Black lake	14°13'18.4" N 40°17'10.6" E	Yes	Yes	No
Yellow lake	14°12'48.1" N 40°19'17.1" E	Yes	Yes	No
Fault zone Yellow lake	14°13'40.4" N 40°19'08.1" E	Yes	Yes	No
Fault zone Red lake	14°13'41.7" N 40°19'06.3" E	Yes	Yes	Yes
Ashalla karst hole	14°06'57.6" N 40°20'53.2" E	Yes	Yes	No
Karum Lake	n.a.	Yes	Yes	No

The first four lakes are lakes located at the main outcrop of the Dallol volcano. Yellow lake, Fault zone Yellow lake and Fault zone Red lake are three lakes located in a previously unreported 4.5 km long hydrothermal fissure on the Lake Asale salt flats, the Erta Ale - Dallol segment of the southern Red Sea rift. It is considered as one of the best geological analogues of Martian rift zones [3]. To our current knowledge we present here the first data of the Fault zone Yellow lake, Fault zone Red lake and the Ashalla karst hole, discovered near a huge diapir in the salt plane of the Danakil depression.

3. Mineralogy

The rock samples, mainly composed out of very hygroscopic minerals, were taken and excellent preserved in heat-sealed Aluminium – Polyethylene coated vacuum bags. All our mineralogical analyses, XRD, SEM-EDX confirm that the geology in the close proximity of the ten lakes is dominated by the mineral salts halite and sylvite. Other observed but less dominant minerals are gypsum, kutnohorite magnesian, anhydrite, ankerite, bischofite, carnalite, tachyhydrite.

4. Chemistry

All ten lakes show show very high ionic conductivity values (EC), starting from a value of 373 [$mS.cm^{-1}$] for the Ashalla karst hole and going up till a value of 598 [$mS.cm^{-1}$] for the Yellow lake. The latter thus seems to be most salty lake of all ten investigated lakes. pH was the lowest, highest acidity level, in the four major outcrop lakes with values near 0 and not passing 1. The other lakes were a little bit less acidic, but the pH never went up above a value of 4.6. The element analyses performed on representative water samples of all ten lakes are in good agreement with the observed mineralogy. The dominant cations are: $Na^+>K^+>Mg^{2+}>Ca^{2+}$ for the four lakes of the major outcrop of Dallol, $Mg^{2+}>Ca^{2+}>Na^+>K^+$ for the Black lake, $Ca^{2+}>Mg^{2+}>Na^+>K^+$ for the Yellow lake, $Na^+>Ca^{2+}>Mg^{2+}>K^+$ for the Fault zone yellow lake, the Ashalla karst hole and the Karum lake and $Ca^{2+}>Mg^{2+}>K^+>Na^+$ for the Fault zone red lake. The major anion for all the lakes is clearly Cl^-. F^- and Br^- are present in minor, millimolar, concentrations in the major outcrop lakes, the Yellow lake, the Fault zone yellow and red lake. No F^- is detected in the Black lake, the Ashalla karst hole and the Karum lake.

Water samples taken with the newly developed “Closed vial sampling technique” showed identical result than samples taken in open bottles.

5. Microbiology

Until now, detectable DNA was extracted out of rock samples of six different lakes. Further investigation has to be performed to find out whether this DNA originates from surviving microorganisms or has to be considered as an external contamination. Positive identification of surviving microorganisms might provide a better understanding of how microbes are able to survive such extreme volcanic rift zones.

6. Summary and Conclusions

At least two different types of samples, rock and water, could be collected from all of the ten investigated lakes of the Dallol volcano region (Danakil depression, Ethiopia). Rock as well as water samples were excellent preserved during transport and storage. The mineralogy and observed chemistry were found to be in complete agreement with each other and data reported in reference literature. Positive DNA extraction from samples of six different lakes gives a first indication of the possible presence of microbes. Further investigation aims to elucidate whether the DNA originates from real surviving microorganisms.

Acknowledgements

This work follows field work conducted in January 2018 at the Danakil Planetary Field Analogue Site (TA1-5) of Europlanet 2020 RI, which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654208. Chemical, mineralogical and microbiological analyses are performed within the ELSIE research project of SCK•CEN.

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Extremophiles from Tirez and Peña Hueca: Implications for exploring habitability of Mars and Europa

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Abstract

Tirez and Peña Hueca are endorrheic hypersaline lagoons of Villacañas**,** in the province of Toledo, Western La Mancha, Spain. The chloride and sulphate rich environment of endoreic origin of these lagoons potentially serve as Planetary field analogue sites for Martian chloride deposits and oceans of Europa. Extreme halophiles are candidate exophiles to study the adaptation and response of microbial growth in space like conditions [1]. Hence, the objective of the present investigation was to isolate extremophilic halophiles that thrive in brines of Peña Hueca rich in Mg-Na-SO_4-Cl, epsomite and hexahydrate and study its implications for exploring habitability of Mars and Europa.

1. Introduction

Laguna de Peña Hueca is a unique hypersaline ion rich system in La Mancha, central Spain. The salt rich environment of endorreic origin also provides a good analogue for Martian chloride deposits and Europa brines. Studying extremophilic biodiversity from Peña Hueca along with Tirez lake may provide useful insights in plausible exploration of habitability or quest for microbial life in Martian environments

2. Methodology and Observations

A visit to Tirez lake and Pena Hueca field site was conducted from 9 to 13 April 2018 under Europlanet Transnational Access (TA) (17-EPN3-030). Pena Hueca was a unique pink colored lagoon located at 653 m altitude, 39° 30' 56" N 3° 20' 21" W (UTM WGS84) with maximum depth of 40 cm. It was characterized by its bright pink colored water that had a thick layer of pink colored salt crust. Underlying the crust, a typical green mat was observed below which a black anoxic layer was observed. Samples and rocks were collected from the lagoon and analyzed for physicochemical parameters like sodium, potassium, chloride, magnesium content [2].

Fig 1: Pink colored hypersaline Laguna de Peña Hueca.

Laguna de Peña Hueca had a salinity of 12.5 % with a sulphate content of 18.75g/L, magnesium content of 9.04 g/L and a pH range of 7.5-7.9. Extremely halophilic organisms were isolated from rocks collected from Peña Hueca using Sehgal and Gibbons medium [3] containing 1.5 M NaCl and 0.5 M $MgSO_4$. The organism was identified using biochemicals and 16 S rRNA gene sequencing. The organism was exposed to high concentration of salinity, epsomite, sodium sulphate and perchlorate as described earlier [3,4] to explore its potential survival in Martian conditions.

3. Summary and Conclusions

Laguna de Peña Hueca is an interesting hypersaline ion rich system that can be used as a planetary field analogue site for Mars or Europa. The shallow stagnant lagoon has high salinity and sulphur content that metabolically favors combined biogeochemical activities of Sulphur reducing bacteria, purple or green Sulphur bacteria and halophilic bacteria. A distinct gradation of microbial communities can be observed and the black layer indicated biological production of hydrogen sulphide that causes precipitation in sediment. The sulphides are oxidized by photosynthetic bacteria that form a typical green mat and represent photosynthetic bacterial and cyanobacterial communities. The system forms a typical habitat called **“Sulfuretum”** that is Sulphur rich due to biological activities and geological deposits. The rocks present in these sulphur rich brines serve as potential zones for harboring endolithic bacterial communities at the water:rock interface.The survival of micro-organism in high sulphated saline system is imperative to understand the underlying implications of sulphate in microbial growth. Extremely halophilic bacteria *PLR-1* was isolated from a pink rock submerged in the hypersaline sulphate rich brine of Peña Hueca. The extremophile was identified as *Halomonas gomseomensis* PLR-1 and was found to be extremely resistant to high concentration of salinity (upto 4.5 M sodium chloride), epsomite concentration (upto 0.5 M Magnesium sulphate, perchlorate (upto 1M sodium perchlorate) and sulphate (upto 1 M sodium sulphate). The tolerance of this extremophile to high concentration of epsomite, salinity, sulphate and perchlorate demonstrates its ability of growth in Martian soils. The current study highlights the resilience of extremophiles from Planetary field analogues to Martian conditions and its implications and concerns in Planetary protection as these extremophiles may contaminate spacecraft and can thrive in Martian conditions.

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