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Scientific results and lessons learned from an integrated crewed Mars exploration simulation at the Rio Tinto Mars analogue site ☆

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ABSTRACT

Between 15 and 25 April 2011 in the framework of the PolAres programme of the Austrian Space Forum, a five-day field test of the Aouda.X spacesuit simulator was conducted at the Rio Tinto Mars-analogue site in southern Spain. The field crew was supported by a full-scale Mission Control Center (MCC) in Innsbruck, Austria. The field telemetry data were relayed to the MCC, enabling a Remote Science Support (RSS) team to study field data in near-real-time and adjust the flight planning in a flexible manner. We report on the experiences in the field of robotics, geophysics (Ground Penetrating Radar) and geology as well as life sciences in a simulated spaceflight operational environment. Extravehicular Activity (EVA) maps had been prepared using Google Earth and aerial images. The Rio Tinto mining area offers an excellent location for Mars analogue simulations. It is recognised as a terrestrial Mars analogue site because of the presence of jarosite and related sulphates, which have been identified by the NASA Mars Exploration Rover "Opportunity" in the El Capitan region of Meridiani Planum on Mars. The acidic, high ferric-sulphate content water of Rio Tinto is also considered as a possible analogue in astrobiology regarding the analysis of ferric sulphate related biochemical pathways and produced biomarkers. During our Mars simulation, 18 different types of soil and rock samples were collected by the spacesuit tester. The Raman results confirm the presence of minerals expected, such as jarosite, different Fe oxides and oxi-hydroxides, pyrite and complex Mg and Ca sulphates. Eight science experiments were conducted in the field. In this contribution first we list the important findings during the management and realisation of tests, and also a first summary of the scientific results. Based on these experiences suggestions for future analogue work are also summarised. We finish with recommendations for future field missions, including the preparation of the experiments, communication and data transfer – as an aid to the planning of future simulations.

1. Introduction

Mars analogue research is an important topic both in the preparation and result interpretation of robotic exploration, as well as to support future manned Mars missions. Below we present some results from the Rio Tinto field campaign

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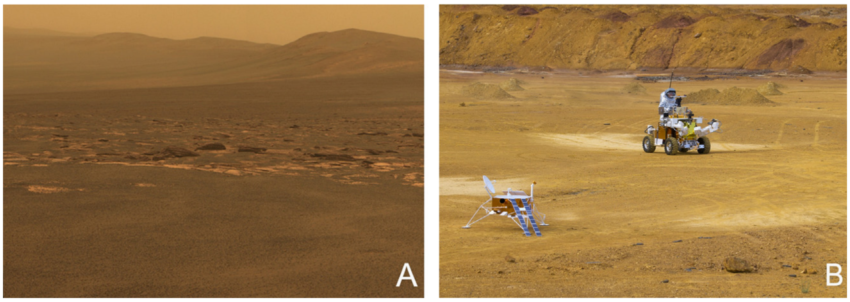

Fig. 1. Comparison Earth with Mars. (A) MER "Opportunity" at the west rim of Endeavour crater, Meridiani Planum, Mars (PIA14508). (B) Rio Tinto Mining Area, SW Spain, Earth. Aouda.X spacesuit tester uses the ESA's Eurobot Ground Prototype rover, in the foreground, the lander demonstrator Mock-up of the Google Lunar X Prise's (GLXP) White Label Space Team can be seen. Image: OeWF/P. Santek.

that was organised by the Austrian Space Forum (OeWF). OeWF focuses on Mars analogue research, the flagship research programme "PolAres" [14] is an interdisciplinary research programme of OeWF preparing exploration strategies for human-robotic Mars surface exploration with a focus on planetary protection [19]. The PolAres project includes the following elements: a planetary surface rover ("Phileas"), a spacesuit simulator ("Aouda.X") and a drill for contamination vector analysis in regard planetary protection studies.

In 2006 a simulated Mars surface operation in the Mars Desert Research Station of Utah was conducted by the team of AustroMars mission [13]. Based on these experiences, and seven other planetary analogue research field simulations by the OeWF, and a Dress Rehearsal, the Rio Tinto Mission 2011 was a cornerstone mission of PolAres (Fig. 1) [15].

The preparation of the Rio Tinto field campaign encompassed a three day Dress Rehearsal testing workflows (Fig. 3) and staff training with artificial data. Every major mission element was tested in this event. During the actual simulation, the field crew was supported by a Mission Control Center (MCC) in Innsbruck, Austria. The field data telemetry was relayed to the Remote Science Support Team, which in turn, guided the flight planning for the next day. We conducted experiments in the field of robotics, Earth (Ground Penetrating Radar, Raman spectroscopy on the field and in the laboratory, Scaled Observations, rock and water sampling) – and Life sciences (Yeti: Youth Explores Terra Incognita, Microbial Assessment, Drill and CVE (Contamination Vector Experiment)) in an operational environment [15].

1.1. *Geological context*

Rio Tinto is a terrestrial Mars-analogue site (Table 1.) in the Iberian Pyrite Belt in SW-Spain because of the terrain's topography and the presence of various sulphate minerals such as jarosite – a potassium iron sulphate-hydroxide mineral, different Fe oxides and oxi-hydroxides, pyrite and complex Mg and Ca sulphates as well as the effects of fine granular and dusty particles on the surface [11,1] (Fig. 1). The composition and Mars relevance of the mentioned minerals are listed in Table 4. The Rio Tinto deep blood-red colour and the formation of sulphate minerals are linked to acidophilic microbial activity and to the aqueous alteration of iron-rich sulphide minerals of the area. The pH is lower than 3.0 at many locations and contains high amount of iron and sulphur (). Under extreme acidic conditions various sulphate minerals precipitate such as copiapite, jarosite, schwertmannite, halotrichite, gypsum (for their composition see Tables 1 and 4). The world type locality of jarosite is located nearby at the "Jaroso Hydrothermal System" in Sierra Almagrea in the SE Mediterranean margin of Spain [25].

In 1976 the Viking landers have discovered sulphur on the Martian surface, but the host minerals have not been identified until the results of Mars Exploration Rover (MER) and Mars Express (MEX) OMEGA (Observatoire pour la Mineralogie, l′ Eau, les Glaces et l′ Activité) [2]. The presence of jarosite was directly discovered in the Meridiani Planum on Mars by Mössbauer spectroscopy on board MER "Opportunity" as well [30,11]. During the Hesperian age of Mars these minerals precipitated in acidic environment, where periodically active subsurface water-rock interaction played the major role in their formation [5].

This paper focuses on the management and realisation of the science experiments against the rainy and windy weather conditions, presents the first geological results – Scaled Observations and Raman spectroscopic studies from laboratory measurements – and finally summarises the lessons learned gained during the mission and collects some suggestions for future Mars analogue missions.

2. Operations

This section discusses the Extra Vehicular Activity (EVA) planning, which is a surface in-situ analysis working in a high fidelity space suit simulator [17] performed by human explorers. The spacesuit simulator "Aouda.X" is the human factors component of the PolAres programme. Its purpose is to reproduce border conditions a real Mars spacesuit would have, like weight, pressure counteracting forces, limited sensory input etc. The 45 kg spacesuit prototype includes a Hard-Upper-Torso with an ambient air ventilation system, a Panox/Kevlar tissue outer hull and a modifiable exoskeleton to simulate various pressure regimes for all major human joints including fingers. The space suit is designed for 4–6 h field operations including donning and doffing, tested temperature limits range between $-110\,^{\circ}C$ and $+35\,^{\circ}C$ and >1 km W-Lan range for the telemetry [17]. The positioning of the suit was always transmitted during EVA's utilising a satellite device enabling a tracking of