Biomarkers detection with the autonomous and remotely operated SOLID-LDChip instrument in a Mars drilling simulating campaign

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Introduction: One of the main goals in Mars exploration is to determine whether life has ever existed on the red planet. To achieve this goal, it is important to verify the performance, robustness, and maturity of instrumentation devoted to life detection, for example through field-testing in Mars analog environments. The Atacama Desert is considered one of the best terrestrial analogs of the surface of Mars due to abrupt temperature shifts, dryness, high UV radiation, and extremely low biomass. This, together with the lack of vegetation and the geochemistry of the regolith, make it an ideal scenario for testing instrumentation, performance, and concepts of operations.

The Atacama Rover Astrobiology Drilling Studies (ARADS) is a NASA PSTAR project conceived for maturing and testing life-detection instrumentation in the Atacama Desert (1). The project is based on the K-REX2 rover equipped with a robotic 1-meter arm that delivers samples to onboard instruments. This includes SOLID 3.1 (Signs of Life Detector), designed as a life-detection instrument for finding complex organic molecules by means of the LDCHip (Life Detector Chip), an antibody microarray sensor (2). The instrument can extract organic compounds from soil, rocks, and sediments into a liquid solvent in the extraction cell (EC), allowing the search for hundreds of microbial molecular biomarkers at once (3). The robustness and reliability of SOLID were tested in the 2019 ARADS Mars drilling simulating campaign and confirmed with other analytical methods.

Methods: Five boreholes were drilled (20 to 80 cm depths) during the ARADS 2019 field campaign at three different locations in a small well-drained Mio-Pliocene alluvial fan (Playa site), located 20 km west of the Yungay region. A subset of five samples, taken at different depth intervals, was selected and autonomously analyzed in-situ with the SOLID instrument. In parallel, samples at 10 cm intervals were manually analyzed with LDCHip in a field lab. Bulk geochemistry (XRD, TOC content, isotopic fractions), ion chromatography (IC), amplicon sequencing, and metaproteomics were also performed back in the lab.

Results: The Playa site was an evaporitic deposit mainly composed of alluvial and colluvial sediments where hydrated sulfates (mainly gypsum) were present at relative abundance (10-12 %). After three sonication cycles, telemetry data indicated that SOLID worked autonomously with similar temperature (30-50ºC) and pressure (2-2.5 bars) values to the EC for all samples. Despite the low content of bulk organic matter detected (TOC and TN values of 0.009-0.036% and 0.002-0.012% respectively), which has been commonly reported in these shallow samples before, the analysis of the fluorescent images captured by SOLID camera showed low-intensity positive signals in three of the five samples: H1b(10-20 cm), H1Ae (40-50 cm) and H3d (70-80cm). In parallel, SOLID results were validated by manually testing every 10 cm intervals with the LDCHip in a field laboratory. Following bacterial composition and metabolic reconstruction of the sediments, two well-differentiated zones could be established: the area between 0-40 cm and the one between 40-80cm deep. Furthermore, we detected the presence of a series of unequivocal microbial biomarkers associated with Actinobacteria, Beta- and Gammaproteobacteria, Firmicutes, Bacteroidetes, and Cyanobacteria, with a changing pattern with depth. Several protein markers, mainly related to ATP synthesis and nitrogen metabolism, were also detected. These findings were corroborated and complemented by other comprehensive analyses back in the lab, including DNA sequencing, and metaproteomics. Thus, the combination of all results allowed us to establish a vertical profile of the bacterial community composition and propose the metabolic reconstruction of the site (4).

Conclusions: We have performed a near real-time biomarker characterization and demonstrated a successful remote life detection and characterization experiment with the SOLID-LDChip instrument in a Mars drilling simulation campaign.

References:

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