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Organic Matter on Mars: Inventory and Implications

Caroline Freissinet, D P Glavin, Cyril Szopa, A Buch, J L Eigenbrode, Maeva Millan, B Sutter, A Williams, L Chou, C A Knudson, et al.

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ORGANIC MATTER ON MARS; INVENTORY AND IMPLICATIONS. C Freissinet¹, D. P. Glavin², C. Szopa¹, A. Buch³, J. L. Eigenbrode¹, M. Millan¹, B. Sutter⁴, A. Williams⁵, L. Chou², C. A. Knudson², W. B. Brinckerhoff², F. Gómez Gomez⁶, A. Fairén P. R. Mahaffy¹, C. A. Malespin² and the SAM team. ¹LATMOS, CNRS/UVSQ-IPSL, Guyancourt, France, ²NASA Goddard Space Flight Center, Greenbelt MD, USA, ³CentraleSupélec, Gif sur Yvette, France, ⁴NASA JSC, Houston TX, USA. ⁶Centro de Astrobiología, Torrejón de Ardoz, Spain.

Introduction: The ability to detect organic compounds in martian sedimentary rocks is a function of their initial abundance and entrainment as the rock formed as well as the extent of subsequent degradation during diagenesis, exhumation and exposure to the surface and near-surface radiation. Their detection is then subject to the performance, flexibility and robustness of operating instruments. The Sample Analysis at Mars (SAM) investigation on Curiosity rover and the Mars organic molecule analyser (MOMA) instrument on the upcoming Rosalind Franklin rover are both analytical laboratories that seek to detect organic molecules and potential biomarkers in the martian near-surface.

Results and interpretations: SAM has been analyzing Mars' regolith since 2012, with 29 scooped or drilled locations under investigation. Molecules were detected at various locations in Gale crater in the form of chlorinated and sulfurized organic compounds, long-chain hydrocarbons, derivatized molecules, and co-evolving CO and CO₂ at temperatures compatible with oxidation or decarboxylation of organics [1-6] (Figure 1). The origin of the molecules detected on Mars so far remain unclear. Likewise, the exact nature of the precursor molecules is unclear; laboratory experiments are crucial and suggested benzoic acid as the origin of the chlorobenzenes [7], and long-chain carboxylic acids as the origin of the long-chain alkanes [4]. The discovery of organic material in the martian surface means that reduced material with covalent bonds has survived despite the severe degrading conditions. The implications of these results are twofold. Firstly, the Cumberland sample, on which most of the organic compounds were identified, is composed of 20 % of smectite [8]. The detection of up to 300 part per billion of organic compounds in this sample suggests that clays are good candidates for accumulating and preserving organics over geological timescales. This has previously been postulated considering clays' high surface area, negatively charged interlayers and cation associated with water in the interlayers that retards water flow. Secondly, organics are prone to degradation under the high-energy radiation exposure through the thin Mars atmosphere. Preserved samples are thought to be buried < 2-3 m but the CB sample is only 65 mm-deep. The CB sample was found to have a surface exposure age of 78 +/- 30 million years [9], which suggests recently

exposed rocks could contain preserved organic matter and should be targeted for sample return. This view into ancient Mars begins to provide a context for habitable environments and is a first step toward understanding the presence and diversity of possible prebiotic or biotic molecular signatures.

The ExoMars rover is designed to enhance the detection, in abundance and diversity, of organic molecules on Mars. The rover's sampling drill will reach as deep as two meters, accessing increasingly preserved materials. The detection of oxychlorines at two very different locations (Phoenix: polar [10] and Curiosity: equatorial [11] sites) support the hypothesis that those compounds may be widely distributed at the surface of Mars. The drill cores of sedimentary rocks obtained and analyzed from the uppermost 2 m of the martian surface by ExoMars will thus be highly valuable to assess the unknown gradient of oxychlorine vs. depth within the martian regolith. Returning samples from a depth where oxychlorine is less abundant or even absent will provide the potential for better organic preservation and facilitate search for biosignatures in Earth-based laboratories.

The MOMA instrument's complementary combination of laser desorption mass spectrometry (LD-MS) and gas chromatography MS (GC-MS) techniques seek to maximize the scientific return *via* both detection of high molecular weight, non-volatile organics and patterns, and the identification of volatile and semi-volatile lower molecular weight molecules [12].

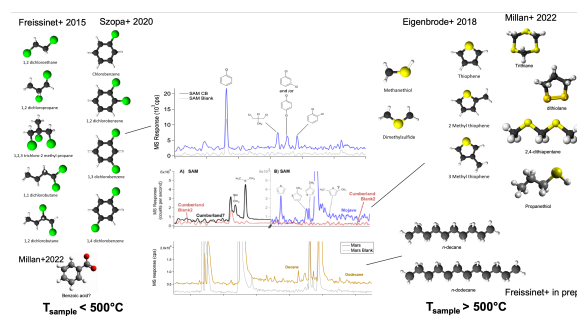


Fig. 1. Detection and identification of organic molecules with the SAM GC-MS sub-system on Mars.

In situ investigations with SAM and MOMA provide significant progress towards mapping out taphonomic windows of preservation for chemically reduced organic compounds. Lessons learned will feed forward to planning of future experiments, increase our ability to select future landing sites in the search for traces of life, and select the best samples to return to Earth for more thorough analyses.

The NASA's Perseverance rover was sent to Jezero crater, selected with biosignature preservation in mind. The Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals (SHERLOC) is a robotic arm-mounted instrument on Perseverance. SHERLOC has utilized deep UV Raman and native fluorescence spectroscopy on natural and abraded targets during the traverse on Jezero Crater, reporting the first direct measurement consistent with 1-ring and 2-ring aromatic organics detection, using Raman and fluorescence spectroscopy on Mars [13]. In comparison to SAM/GC-MS, the emphasis of fluorescence is on *if* organics are present, rather than definitely identifying what they are. This makes intuitive sense for biosignature detection in an exploratory mission and is different than previous approaches.

All the lessons learned from Mars will also feed forward future missions to explore the chemistry and potential biology of further bodies in the solar system such as Titan, Europa or Enceladus. New challenges are facing us in these detections as Mars and the icy bodies are worlds apart.

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