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Detecting pyrolysis products from bacteria in a Mars soil analogue

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A primary objectives of the 1976 Viking missions was to determine whether organic compounds, possibly of biological origin, were present in Martian surface soils. The Viking gas chromatography mass spectrometry (GCMS) instruments found no evidence for any organic compounds of Martian origin above a few ppb in the upper 10 cm of surface soil [1], suggesting the absence of a widely distributed Martian biota. However, Benner *et al*. suggested that significant amounts of non-volatile organic compounds, possibly including oxidation products of bioorganic molecules (e.g. carboxylic acids) would not have been detected by the Viking GCMS [2]. Moreover, other key organic compounds important to life, such as amino acids and nucleobases, would also likely have been missed by the Viking GCMS as these compounds require chemical derivatization to be stable in the column [3].

In this study, a Mars soil analogue (serpentine) that was inoculated with ~10 billion *Escherichia coli* cells was heated to 500°C inside a sublimation apparatus for several seconds at Martian ambient pressure and the sublimate, collected by a cold finger, then analyzed for amino acids and nucleobases using high performance liquid chromatography (HPLC) and GCMS. After pyrolysis of the cells, most of the amino acids in the bacteria did not sublime and were completely destroyed when the cells were heated. In contrast, we found that the nucleobases adenine, cytosine, thymine and uracil, were readily sublimed directly from the cells and are much more resistant to thermal degradation than amino acids. Bacterial cell concentrations in a variety of terrestrial samples including deep-sea sediment, seawater and a soil sample from the Atacama Desert were estimated based on the amount of adenine released from the samples during pyrolysis.

Although the Viking GCMS instruments were not specifically designed to search for the presence of living cells on Mars, our experimental results indicate that at the ppb level, the degradation products generated from several million bacterial cells per gram of Martian soil would not be detected [4]. Upcoming strategies for Mars exploration will require in-situ analyses by instruments that can assess whether any organic compounds, especially those that might be associated with life, are present in Martian surface samples.

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AstroBioLab: A mobile in situ subsurface biotic and soil reactivity analytical laboratory

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AstroBioLab is a mobile astrobiology laboratory designed for field campaigns at terrestrial sites that have chemical and environmental characteristics similar to those of the Martian surface. The laboratory uses a complementary suite of in situ instruments that focus on state-of-the-art organic compound detection coupled with determinations of the oxidation chemistry. This allows us to assess the interplay of organic compounds, inorganic oxidants and water in Martian-like terrestrial environments. The AstroBioLab is designed around the Mars Organic Detector (MOD) instrument in combination with a micro-chip capillary electrophoresis system for enhanced analytical capacity. The target compounds are amino acids (the most abundant component of bacterial cells on a dry weight basis) and polycyclic aromatic hydrocarbons (PAHs) (the most abundant class of molecules in carbonaceous chondrites). The instrument package also includes the Mars Oxidant Instrument (MOI) that provides a complementary set of oxidant data. By comparing various sites in the Mojave and Atacama deserts that range from sterile to viable this effort will enhance our understanding of the limits and constraints of life in extreme environments on Earth. In addition, by deploying the AstroBioLab in field campaigns we will carry out experiments under flight–like conditions and thus demonstrate the feasibility of using this instrumentation to explore for signs of organic compounds of possible biological origin during future landed missions to Mars. Preliminary results indicate that at Atacama sites where high levels of oxidants are present amino acids are at or below detection limits (a few ppb). In contrast, when oxidant levels are low, 0.5 to 1 ppm concentrations of amino acids were detected. This demonstrates the critical interplay of oxidants and the preservation of key biomarkers such as amino acids. Analyses carried out on Mars using a similar suite of instruments could enhance the chances of detecting organic compounds possibly derived from life.