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Analytical techniques for direct identification of biosignatures and microorganisms

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Abstract

Rover missions to potentially habitable ecosystems require portable instruments that use minimal power, require no sample preparation, and provide suitably diagnostic information to an Earth-based exploration team. In exploration of terrestrial analogue environments of potentially habitable ecosystems it is important to screen rapidly for the presence of biosignatures and microorganisms and especially to identify them accurately. In this study, several analytical techniques for the direct identification of biosignatures and microorganisms in different Earth analogues of habitable ecosystems are compared.

1. Earth analogues

There is considerable interest in investigating the microbial forms that thrive in extreme environments, especially under those conditions that can provide a model for potentially habitable ecosystems in other planets. As an example, the Martian surface environment exhibits extremes of salinity, temperature, desiccation, and radiation. By analogy with terrestrial extremophile communities, potential protected niches have been postulated for Mars, such as sulfur-rich subsurface areas for chemoautotrophic communities, rocks for endolithic communities, cold environments and permafrost regions (Onsttot et al., 2009), hydrothermal vents (Shapiro and Schulze-Makuch, 2009) soil, or evaporite crystals (Benison et al., 2008). For instance, there are several similarities between the vast deposits of sulfates and iron oxides on Mars and the main sulfide-containing iron bioleaching products. Further, on Earth, the discovery of cold-tolerant microorganisms in glaciated and permanently frozen environments has broadened the known range of environmental conditions which support microbial life. Terrestrial models of extraterrestrial icy worlds are being intensively studied. Among them, bacterial communities from Arctic and Antarctic permafrost, subglacial lakes and high mountains are considered representative of these environments in which psychrophile bacteria are the unique inhabitants.

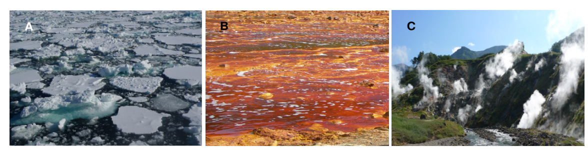

Figure 1: Analogue sites on Earth. (A) Cold environments. (B) Sulfide-containing iron bioleaching products. (C) Hydrothermal sites.

2. Identification of biosignatures and microorganisms

In a search for extant life beyond Earth, biomolecules and microorganisms are the most likely candidates. On Earth, life has developed strategies to cope with the so-called extreme conditions. The successful identification of unknown biosignatures and microorganisms from Earth analogues requires the intelligent use of several different techniques. Among them, some traditional methods include culture on selective medium, microscopy techniques, division into serotypes by specific antibodies, distinction of genotypes by DNA sequence analysis and biochemical tests. These methods provide high sensitivity and specificity, but their efficiency is limited by the complexity of the procedures, they are time-consuming or are completely dependent on the availability of antibodies or the knowledge of genetic sequences of the target bacteria.

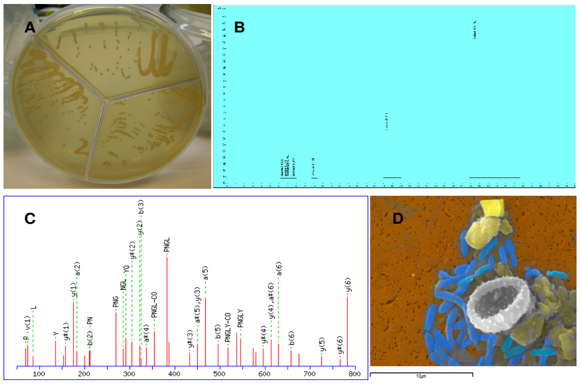

Figure 2: Analytical techniques for identification of biosignatures. (A) Microorganism cultures. (B) Chromatography. (C) Mass spectrometry. (D) Scanning electron microscopy.

3. Analytical techniques for direct identification

In this study, several analytical techniques for the direct identification of biosignatures and microorganisms in different Earth analogues of habitable ecosystems are compared. For example, short-wave infrared (SWIR) spectroscopic instruments such as the Portable Infrared Mineral Analyzer (PIMA) have been tested to investigate sites of paleobiological interest (Brown et al. 2004). RAMAN spectroscopy (Breier et al., 2010) has been used to make a variety of measurements that are only stable under in situ conditions. Gas chromatography-mass spectrometry has been applied to analyze carboxylic acid mixtures, and thermal volatilization coupled to mass spectrometry to the characterization of organics, microorganisms, desert soils, and Mars-like soils. Further, antibody microarrays have been developed for life detection in planetary exploration. At last, matrix-assisted laser desorption/ionization-time of flight mass spectrometry (MALDI-TOF-MS) has enormously contributed to the understanding of protein chemistry and cell biology. Supported by comprehensive databases, MALDI-TOF-MS-based identification could be used for direct bacterial differentiation in earth analogues for habitable ecosystem exploration.

6. Summary and Conclusions

In the last years several analytical techniques for the direct identification of biosignatures and microorganisms in different Earth analogues of habitable ecosystems have emerged. These techniques could be complementary which increase their value and empower their more widespread use. They can be used to identify a wide variety of biosignatures and can even distinguish between closely related ones that have similar chemical structures.

Acknowledgements

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