EPSC Abstracts
Vol. 8, EPSC2013-201, 2013
European Planetary Science Congress 2013

Techniques used in astrobiology to search for past or present extraterrestrial life, in particular on Mars

F. Foucher, F. Westall and the exobiology team
Centre de Biophysique Moléculaire, UPR CNRS 4301, Orléans, France (frederic.foucher@cnrs-orleans.fr / Fax: +33-2-38631517)

Abstract

The search for life on other bodies than Earth implies use of a wide range of techniques from radioastronomy to *in situ* molecular analyses. We have constructed a poster providing an overview of more than 10 observation and more than 30 analytical techniques used in different domains of astrobiology. The physical principle and the kinds of data that can obtained by each technique are describe. The possibility to use these techniques for space exploration, in particular for Mars, is also discussed.

1. Introduction

Astrobiology covers a large range of domains from geology to interstellar chemistry. The aim of this contribution is to provide an overview of the techniques presently used in these different domains to observe and analyse samples of atrobiological interest. Most of the studies concentrate on the solar system and the search for habitable localities, organic molecules, microbes and/or microfossils, in particular on Mars since it is the nearest body to Earth that was (and may still be in the subsurface) potentially inhabited. Present missions to Mars are concentrating on the search for past life, dating back from $\approx$ 4.0-3.6 billion years when the planet was still wet. However, by analogy with terrestrial microbial remains dating back from the same epoch and corresponding to the oldest traces of life known, such traces can be expected to be very subtle and difficult to detect by *in situ* exploration. Indeed, over the last decades, study of the most ancient traces of life on Earth has demonstrated the necessity of using several complementary techniques to demonstrate their biogenicity and syngenicity. This contribution thus also makes an inventory of the techniques presently used in laboratory and their potential used during *in situ* missions is discussed.

2. Traces of life and biosignatures

The detection of life on another body than Earth are all the more challenging the further the body is from the Earth. Thus, using astronomy, it is possible to detect a signal from potential extraterrestrial intelligence in the Milky Way or to find an habitable and/or inhabited exoplanet if it is not too far from our solar system. At the other end of the scale, it is now possible to make *in situ* microscopic investigation on the surface of Mars. However, even on Earth, some of the expected traces of life are very challenging to study. In particular, the oldest traces of life dating back to 3.5 Ga and potentially comparable to Martian microbial remains document prokaryote-like life forms that are sub-micrometric in size [1]. The subtle expression of the fossil remains is accentuated by the degree of degradation of the organic molecules (kerogen). The establishment of biogenicity in these kinds of structures is not easy and requires the use of numerous devices and techniques.

The detection of life can be made without direct observation, based on the impact on the environment (some metabolisms produce biogases or induce the precipitation of particular minerals for example). Moreover, establishing the biogenecity of microbial remains generally requires compositional analyses of the potential biosignatures as well as observation of their morphology. For example, ancient life forms may be preserved as (1) physical structures, including mineral-replaced cells, colonies, biofilms and mats; as bioconstructions, such as stromatolites; and as biominerals, such as carbonate; (2) organic and inorganic chemical signatures including the nanostructure and molecular and elemental composition of the degraded organic cellular components and their isotopic signature; as well as (3) the effects of microbial corrosion on minerals associated with the biosignatures. Since many of these signatures can individually be reproduced by abiogenic processes, biogenicity needs to be

demonstrated by an association of biosignatures that can only be reproduced by living processes.

3. Methods

Many methods and techniques requiring variable sample preparation are employed in the study of biosignatures. They can be classified into those based on observation or analysis.

3.1 Observation techniques

- Optical techniques, from telescopes to microscopes. These techniques provide information about environmental context, geology, petrography, biostructures... The scale of observation ranges from kilometers to sub-micrometers.
- Electron microscopy (SEM and TEM). These techniques use electron instead of photons to make images. They allow observation from sub-milimetric to nanometric scale.
- Scanning probe microscopies, e.g. like SNOM, AFM and STM. These techniques scan the sample surface with a probe (a tip) to make an image. They allow observation from sub-milimetric to sub-nanometric scale.

3.2 Analysis techniques

- Optical spectroscopic techniques permit detection and identification of elements and molecules. They can be made using the whole range of electromagnetic waves from gamma rays to radio waves. The analysed signal can be natural or induced for the measurement, e.g. LIBS or cathodoluminescence.
- Vibrational spectroscopic techniques include IR spectroscopy and Raman spectroscopy. They are used to identify minerals and molecules.
- Mass spectroscopy can be used to determine the molecular, elementary and isotopic composition. Several types of mass spectroscopy exist depending on the sample preparation, ion source and analyzer: GC-MS, ICP-MS, TOF-SIMS, NANO-SIMS...
- Diffraction techniques using X-ray or electron in TEM provide information about the crystallography of the sample.
- Electron spectroscopic techniques use the X-rays produced or the electrons ejected by interaction with an X-ray or an electron beam. They include EDX, Auger electron, NEXAFS, EXAFS, XANES...
- Finally, there are several other techniques that can be used, such as Chemical Force Microscopy, Mössbauer, MNR, EPR... to provide various types of information.

In this contribution we will provide a short description of more than 40 techniques including the physical and technological principle, the kind of information provided, the resolution... In particular, we will discuss their complementarity and how they can be used to demonstrate the biogenicity of a structure. The possibility of using these techniques in space is discussed and the exploration of Mars is used as an example.

4. Summary and Conclusions

The number of techniques used in the different domains of astrobiology is continuously increasing. In this presentation, more than 40 of them are explained and described, from the significance of their acronym to their physical principle and their resolution limit.

References

[1] Westall, F., Loizeau, D., Foucher, F., Bost, N., Bertrand, M., Vago, J., and Kminek, G.: Habitability on Mars from a microbial point of view, Astrobiology, in press, 2013.

N.B.: This study is based on several tens of articles that could not be mentioned here for practical reasons.