First Traces of Life

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Astrobiology is the study of the origin, evolution, distribution and future of life in the universe, including the Earth, the only biological planet known so far. The search for life on the early Earth or beyond Earth requires the characterization of "traces of life" or biosignatures. These include fossil molecules produced only by biological activity, isotopic and metal compositions indicative of metabolisms, biosedimentary structures induced by microbial mats, such as stromatolites in carbonates or MISS in siliciclastic rocks, and microstructures interpreted as morphological fossils or biominerals. However, these traces can in some cases also be produced by abiotic processes or later contamination, leading to controversial reports of the earliest record of life on Earth.

Possible traces of life reported in the early Earth rock record suggest the presence of a flourishing microbial biosphere, debatably since 4.3 Ga, the time when Earth became habitable, and more firmly since 3.5 Ga. The first step in the recognition of biosignatures is the determination of the geological context and the environmental conditions of preservation or alteration. Technological advances permit to better constrain the challenges of evidencing the endogenicity (the trace of life is in the rock and not a contamination), syngenicity (the trace of life has the same age as the host rock), biogenicity (biological origin) and interpretation (what kind of life?) of possible biosignatures. Nanoscale analytical instruments investigate the chemical and morphological traces of early life, while experimental approaches attempt to fossilize microbes artificially or to create abiotic structures and organics mimicking life. However, these are not sufficient to remove ambiguities, especially when geological processes such as hydrothermalism (hot fluids) and metamorphism (high temperature and pressure), common in the early Earth record, have altered the rocks. Only a geological context plausible for life, a combination of morphological and chemical evidence, and the lack of abiotic explanations for the observations, will collectively support the authenticity of biosignatures. Advances in fundamental biology are also crucial to help us interpret early biosignatures, as they illustrate the modern diversity of life forms, ecology and metabolisms; the evolutionary relationships or convergence between organisms; and the limits of life. However, early traces are not necessarily comparable to modern signatures. Looking for life beyond Earth is even more challenging, *in situ* on other rocky bodies, or by remote sensing in exoplanet atmospheres.

Resolving these issues is critical if we want to understand in which conditions life may originate (habitability), evolve, and what are the interactions between a planet and life. These interactions leave traces or biosignatures that provide a rationale to tentatively define ways to look for life on Earth or in extraterrestrial environments. The future space missions are now developed based on these early Earth approaches.

This review talk [1] will summarize the challenges linked to deciphering the early record of life, illustrated by examples from the controversial and from the undisputed records. Some research themes to explore further in the frame of the EAI will also be suggested.

[1] E. J. Javaux, The earliest traces of life: challenges and evidence (in review).