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Electron Paramagnetic Resonance: a tool for in situ detection, imaging and dating of biosignatures in primitive organic matter

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Electron Paramagnetic Resonance (EPR) spectroscopy and imaging are based on the interaction of a microwave electromagnetic field (typically in the GHz range) with electron spins in presence of an external magnetic field. Contrary to UV-visible and Infrared light, microwave radiation can penetrate in most non conducting materials, so that EPR is sensitive to the bulk (and not to the surface) of samples. All the paramagnetic defects, impurities, point defects in the mineral matrix, radicals in carbonaceous matter of an ancient rock can be detected by this technique. As the most ancient traces of life, as old as 3.5 Gy, are recorded as carbonaceous microstructures in siliceous sedimentary structures (cherts), the radical defects of these microstructures can be probed in situ without sample preparation. By using continuous-wave EPR, the fossilized carbonaceous matter can be mapped at the sub-millimeter scale (EPR imaging)[1], and can be dated with respect to the host rock (evolution of the EPR lineshape)[2]. Thus this method could be used for contamination detection (endolithic bacteria, infiltration etc. . .). By using pulsed-EPR spectroscopy (instead of continuous wave), nuclear magnetic transitions of elements in and around radicals can be detected with a high resolution and sensitivity. We show that specific nuclear transitions for hydrogen (1H and 2D) and 13C (and other nuclei such as 29Si and 31P) can be identified in extraterrestrial carbonaceous matter (meteorites) and in Precambrian and younger cherts. These pulsed techniques provide molecular scale biosignatures for primitive life detection and internal probes to study the history of organic matter in the early solar system [3,4]. Paramagnetic biosignatures are not limited to the organic component of cherts. Specific EPR biosignatures of metal ions can be detected in biominerals such as MnO_2 [5] or in molecular V4+ complexes [6]. EPR is thus a potential technique for the search of primitive life on Earth and Mars.

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