Molecular characterization of micro- and macro-fossils by mass spectrometry at the cellular scale

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The origin of the fossil biomass in ancient rocks remains difficult to assess because of the simple morphology of the fossil microorganisms that compose it. Obtaining molecular signatures at the scale of the individualized fossil microorganism would enable us to better document the evolution of the biodiversity of microorganisms since 3.5 billion years. Similarly, the identification of fossil biomacromolecules at the scale of individual tissues would allow to constrain the nature of the oldest fossil macro-organisms, such as the first land plants.

The secondary ion time-of-flight mass spectrometry (ToF-SIMS) technique has been used to identify biomacromolecules such as melanin or hemoglobin derivatives in macroscopic fossils. This project aims to further develop this type of molecular analysis of fossils down to the cellular level. We will couple information from ToF-SIMS, resolved down to the sub-micrometer scale, and microscale two-step laser mass spectrometry (µL2MS) using an innovative instrument developed in Lille. The analytical parameters of both types of instruments will have to be finely tuned to maximize the molecular information obtained in the mass spectra. On the µL2MS instrument, several choices of laser desorption and/or laser ionization wavelengths will be tested, and a vacuum-UV ionization source will be added to the existing instrument.

We will analyze an exceptional collection of fossils, ~60 to ~460 million year old, including phytoplankton, benthic phototrophic microorganisms, fishes, insects, and plants. The objective is to decipher the composition of individualized (micro)fossils (and their ultrastructures/tissues) in terms of biomacromolecule derivatives (algenan, cellulose, peptidoglycan, chitin, collagen...). Porphyrin enrichments from chlorophylls will also be investigated. This molecular/morphological coupling will constrain the affinity of these organisms and will allow in turn to search for their oldest forms. The techniques applied here to paleontology can be transposed to exobiology (for example, a laser desorption-ionization mass spectrometer will be sent to Mars).

CANDIDATE PROFILES: geosciences with knowledge of paleontology and organic geochemistry with a desire to master advanced instruments; **or physics/chemistry** (mass spectrometry, lasers and applications), with a desire to discover the basics of paleontology/geochemistry.

APPLICATION: send curriculum vitae, letter of motivation (specific to this research project) and e-mails of 2-3 potential referees to kevin.lepot@univ-lille.fr / deadline: 16th of May, 2021 for interviews, 20th for filling full application (see below)

Doctoral school (Sciences de la Matière, du Rayonnement, et de l'Environnement) website and full application file ***(to be filled if the preselection interview is conclusive)***

REFERENCES (et al. omitted ; *: publications of proponent team)

Applications of Time-of-flight Secondary Ion Mass spectrometry to paleontology:
[1] Lindgren (2014) Nature
[2] Greenwalt (2013) PNAS

Development of Time-of-flight Secondary Ion Mass spectrometry at the microscopic scale on fossils and organic matter:
[3*] Vandenbroucke (2015) Nature Communications
[4*] Fadel (2020) Geobiology

Laser-desorption laser-ionization mass spectrometry performed in Lille:
[5*] Duca (2019) Faraday Discuss
[6*] Ngo (2020) Atmos. Meas. Tech.