Silicification and the preservation of organic matter on the early Earth: a geochemical approach (SilicaLIFE)

A PhD thesis subject proposed at CNRS-UMR6538 Laboratoire Geo-Ocean Équipe Cycles Biogéochimiques et Ressources (CYBER)

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Context: This thesis subject was recently proposed to ANR as part of the Tremplin-ERC program in March 2023 and was awarded in May 2023 approximately 60k€ of co-funding (project PROTO-ECO, 18 months doctoral salary, CNRS pay scale) in order to launch the subject rapidly and strategically increase the PIs' competitivity for currently ongoing European Commission funding applications.

Earth's most ancient sedimentary rocks preserve abundant physical, chemical, and isotopic evidence of a thriving and evolving microbial biosphere that reigned on Earth *for billions of years*. In the first billion years or so, this primitive biosphere gave rise to the major metabolic pathways that define our living planet today: the diverse forms of photosynthesis, chemotrophy, and respiration that underpin modern global biogeochemical cycling and the biospheric regulation of Earth's climate. Lessons from this early history constitute some of humanity's most profound origin stories and strongly inform the search for life on other planets. Yet many of the details of the earliest history of microbial life on Earth – when exactly in deep geological time particular metabolisms were operational, in which environments, and under which local chemical or environmental conditions – remain poorly understood, in large part due to uncertainties in the fidelity of preservation of Earth's most ancient life traces. This PhD project aims to better understand the preservation of some of Earth's most ancient traces of life, dating back 3.5 to 3.2 billion years ago, using novel geochemical approaches. Almost all of these traces are preserved by rapid mineralization with silica, and this thesis will aim to better understand this process, the sources of silica preserving early life traces, and the effects of silicification on the preservation of organic matter. The first component will involve the silicon stable isotope analysis of ancient silica-rich (chert) rocks preserving early life traces to better understand the Paleoarchean silicon cycle, including the role of continental weathering vs. hydrothermal Si supply, as well as water column processes that led to the deposition of diverse cherts of Paleoarchean age. Second, Raman spectroscopy will be applied to characterize the maturity of organic matter of preserved kerogen in these ancient life traces via Raman spectroscopic analysis of their degree of graphitization. These data will be then interpreted in light of the different sources and generations of silica encasing these ancient fossils identified above in order to better understand the role silica may have in ensuring the rapid preservation and long-term stability of ancient life traces through diagenesis and high-temperature metamorphism. Finally, the carbon stable isotope composition of diverse ancient life traces will be evaluated in regards to the knowledge gleamed above regarding preservation fidelity, in order to better distinguish primary carbon metabolic biosignatures preserved in organic matter from the secondary processes that modify the carbon isotope compositions of ancient organic matter and represent the current limitation on available knowledge of how Earth's earliest microbes acquired their carbon. This subject is entirely hosted by the GO laboratory, but will employ samples stemming from ongoing multi-national collaborations with workers at the U. Jena (DE) and U. New South Wales (AU), as well as the ongoing ICDP-funded *Barberton Archean Surface Environments (BASE)* international drilling project.