Elucidating the emergence of life's mechanism in the green rust mineral, a biochemical and physical study.

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Research to understand biological energy conversion has shown that the catalytic centers of the enzymes involved are transition metals cluster that strongly resemble certain minerals, leading to the hypothesis that the emergence of life on our planet may have been initiated by the metals present in minerals. One particularly interesting mineral is the Green Rust, which has intriguing structural similarities to the catalytic site of the vast superfamily of di-iron hydrolase enzymes, including methane monooxygenases, considered to be involved in the earliest mechanisms of free energy needed for life.
These observations have given rise to the idea that GR nanocrystals may have been part of a small number of minerals that carried out chemical and electrochemical reactions on the primitive Earth that were crucial for the emergence of the first biological metabolism.
The project consists in proving that these GR nanocrystals could have been the precursors of the energy mechanisms essential for the emergence of life. This energy is invariably provided by the "Mitchellian" chemosmotic mechanism, i.e. by the conversion of the proton motive force (pmf) through a "bioenergetic membrane" into ATP via the ATPase enzyme. In this project we plan to show that this mechanism can be performed by these GR nanocrystals. The study will consist in incorporating them into vesicles (as it has been done before with proteins) to understand the interaction of GR nanocrystals alone with barriers made of organic molecules (polypeptides, lipids) as proposed in the origin of life's mechanism.
The work during the Master will consist of:
1) to improve the incorporation of these GR nanocrystals into lipid vesicles. This will require the synthesis of these different GR, their characterization by microscopic methods, as well as a method of fixation in a resin for cutting by microtome to finally be characterized by electron microscopy (SEM, TEM) and spectroscopy (IR, XRD, optical).
2) to compare the formation of a pH and potential differential on both sides of the vesicle by changes of absorption of indicators (safranin, oxonol) on vesicles with or without GR. The change of absorption will be perform by optical spectroscopy.
3) In parallel it will be tested the redox reactions that could have taken place during the emergence of life, for example oxidation of methane into methanol. The gases formed will be monitored using gas chromatography, and the liquid products formed will be monitored using liquid chromatography (HPLC).
This internship at the biology/physics interface will be carried out in the laboratory of biology and protein engineering (BIP), experts in biochemical and biophysical studies of biological and mineral systems, in collaboration with the Centre Interdisciplinaire de Nanoscience de Marseille (CINaM), specialized in advanced technologies in nanotechnologies and in particular on minerals.

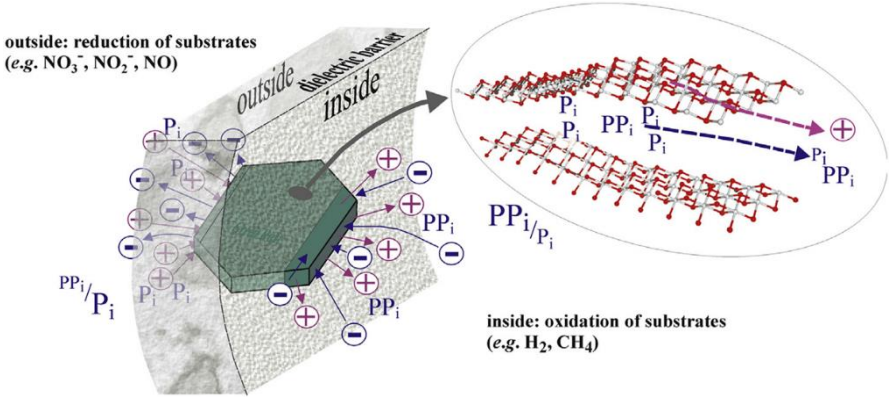

Fig: Schematic representation of a part of the barrier of a hypothetical (dielectrically insulated) compartment in hydrothermal vent chimneys (Russell, 2018) spiked with a Green Rust nanocrystal protruding on both sides of the barrier