Pyrite and greigite nanocrystals produced by hyperthermophilic archaea

FRANCOIS GUYOT[1] AURORE GORLAS[2] PIERRE JACQUEMOT[1]

[12]Institut de Minéralogie, de Physique des Matériaux et de Cosmochimie, Sorbonne Universités, Université Pierre et Marie Curie, UMR 7590 CNRS, Institut de Recherche pour le Développement, Museum National d'Histoire Naturelle, 75005 Paris, France

[2]Institut de Biologie Intégrative de la cellule, Laboratoire de Biologie Cellulaire des Archaea, UMR8621/CNRS, 91405 Orsay Cedex, France

Interactions between hyperthermophilic archaea and minerals occur in hydrothermal deep sea vents, one of the most extreme environments for life on Earth. These interactions occur in the internal porosity of active hydrothermal chimneys mainly composed of iron sulfide minerals. This study reports the first described mechanism of biomineralisation by hyperthermophilic sulfur-reducing archaea. We show that several species of *Thermococcales* produce Fe_3S_4 greigite nanocrystals at 85°C on extracellular polymeric substances, in a process that is overall oxidizing. Sulfur vesicles produced by the cells, then evolving into pyrite nanocrystals, and intermediate iron (III) phosphate amorphous phases determine this original biomineralization mechanism by which *Thermococcales*, the predominant hyperthermophilic microorganisms inhabiting hot parts of hydrothermal deep sea vents impact the geochemistry of carbon, iron and sulfur cycles in these environments. Measurements of ATP reveal that some of the cells are able to survive after this spectacular biomineralization suggesting an adaptation of life to this hot and heavily mineralized environment. The formation of greigite requiring iron (III) precursors signs the response of the hot hydrothermal ecosystem to an oxidative stress coming from the mixing of the reduced Fe(II)-bearing hydrothermal fluid with the oxidized seawater. Finally, the very specific assemblage of pyrite mineralized vesicles with greigite nanocrystals deposited on extracellular polymeric substances might produce biosignatures of these extreme high temperature environments of life which are so far missing for investigating the temperature frontier of life in the geological record.