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Iron biomineralization by hyperthermophilic archaea

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Sulfur-rich hydrothermal vents are ecosystems characterized by very extreme conditions of life. However numerous hyperthermophilic microorganisms have been isolated from there, mostly archaea whose predominant strains are the sulfur-reducers *Thermococcales*. Therefore *Thermococcales* are deeply involved in hydrothermal vents sulfur cycle and still have a poorly understood geochemical impact.

We studied the mineralization of iron sulfides (FeS, Fe_3S_4 greigite and FeS_2 pyrite) and of iron phosphates related to the metabolic activity of *Thermococcales*, in order to better understand the response of these archaea to a highly mineralizing medium. We have coupled mineralogical methods (X-Ray Diffraction in anoxic conditions, Scanning Electron Microscopy and Energy Dispersive X-Ray Analysis) with gas content measurements and growth monitoring (cell couting and ATP measurements). These multi-scale analyzes were used to feed a thermo-kinetic model (Chess code) of the mineralization induced by *Thermococcales* in these extreme hydrothermal environments.

The metabolic activity of *Thermococcales* leads to an oxidation sequence of the FeS and iron(III) phosphates initially produced, coupled to a progressive reduction of electron acceptors S(0) and disulfide. Significant amounts of greigite nanocrystals are formed by *Thermococcales* at 85°C from a precursor amorphous iron (III) phosphates **[1]**. *Thermococcales* are also able to rapidly induce formation of abundant quantities of pyrite at 85°C when S(0) is directly available as vesicles either intracellularly or at the cell surfaces **[2]**. The formation of greigite and pyrite, destroying many cells and thus inducing the release of bioavailable organic nutrients and phosphates, allow the survival and growth of a non-mineralized *Thermococcales* cell fraction as detected by DNA sequencing and ATP measurements. This suggests that biologically induced iron-sulfide mineralization is involved in an adaptive strategy at the population level, employed by *Thermococcales* to survive in strongly mineralizing high-temperature hydrothermal environments.

[1] Gorlas, Jacquemot, Guigner, Gill, Forterre, Guyot (2018), *PLoS ONE* 13(8)

[2] Gorlas, Marguet, Gill, Geslin, Guigner, Guyot, Forterre (2015), *Biochimie* 118, 356-364.