Microorganisms are major drivers of the P geochemical cycle in Lake Pavin (Massif Central, France)

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Phosphorus (P) is essential to life but a limiting nutrient in many ecosystems. Therefore, understanding the role of microorganisms in P cycling, especially the formation of mineral phosphate phases, is a major environmental issue. In particular, the processes of P uptake, storage, sorption, and remineralization by microbial cells have received great interest in the context of enhanced biological phosphorus removal and phosphorite formation. Yet, the extent to which they control the geochemical cycle of P over abiotic processes remains poorly determined.

Here, we combine scanning and transmission electron microscopies, confocal laser scanning microscopy and synchrotron-based x-ray microfluorescence to analyze the distribution and speciation of P in particles collected at several depths in the water column of the ferrugineous Lake Pavin (France). Such a correlative combination of high-resolution microscopies with high-sensitivity elemental mapping provides the identification of P hotspots and their carriers, in particular partition of P between organics and mineral phases, while preventing misinterpretation of the elemental correlations due to the superposition of matter.

We show that microorganisms are major drivers of the P geochemical cycle under oxic and anoxic conditions in Lake Pavin, by accumulating P as polyphosphate intracellular inclusions or by templating Fe-phosphate precipitation. In particular, magnetotactic bacteria of the *Magnetococcaceae* family, identified by molecular analyses, accumulate polyphosphates abundantly and are major carriers of P in the particulate fraction at the oxic-anoxic interface in the water column. This high accumulation may be characteristic of this family and also related to the chemical conditions prevailing in this lake. Finally, the fate of these P-rich particles upon sedimentation and diagenesis will be adressed.