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The life cycle of iron Fe(III) oxide: impact of fungi and bacteria

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Iron oxides are ubiquitous reactive constituents of soils, sediments and aquifers. They exhibit vast surface areas which bind a large array of trace metals, nutrients and organic molecules hence controlling their mobility/reactivity in the subsurface. In this context, understanding the "life cycle" of iron oxide in soils is paramount to many biogeochemical processes. Soils environments are notorious for their extreme heterogeneity and variability of chemical, physical conditions and biological agents at play. Here, we present studies investigating the role of two biological agents driving iron oxide dynamics in soils, root-associated fungi (mycorrhiza) and bacteria.
Mycorrhiza filaments (hypha) grow preferentially around, and on the surface of nutrient-rich minerals, making mineral-fungi contact zones, hot-spots of chemical alteration in soils. However, because of the microscopic nature of hyphae (only $\sim$ 5 μm wide for up to 1 mm long) and their tendency to strongly adhere to mineral surface, in situ observations of this interfacial micro-environment are scarce. In a microcosm, ectomycorrhiza (Paxillus involutus) was grown symbiotically with a pine tree (Pinus sylvestris) in the presence of freshly-cleaved biotite under humid, yet undersaturated, conditions typical of soils. Using spatially-resolved ion milling technique (FIB), transmission electron microscopy and spectroscopy (TEM/STEM-EDS), synchrotron based X-ray microscopy (STXM), we were able to quantify the speciation of Fe at the biotite-hypha interface. The results shows that substantial oxidation of biotite structural-Fe(II) into Fe(III) subdomains occurs at the contact zone between mycorrhiza and biotite.
Once formed, iron(III) oxides can reductively dissolve under suboxic conditions via several abiotic and microbial pathways. In particular, they serve as terminal electron acceptors for the oxidation of organic matter by iron reducing bacteria. We aimed here to understand the role of Fe(III) mineral properties, in particular the influence of solubility, in the kinetics of microbial iron reduction. We used the facultative anaerobic gram-positive bacterium Shewanella putrefaciens as model iron reducing bacterium, with several ferrihydrite, hematite, goethite or lepidocrocite as electron acceptor, and lactate as electron donor. Maximum microbial Fe(III) reduction rates and solubility of Fe(III) phases were found to positively correlated in a Linear Free Energy Relationship suggesting a rate limitation by the electron transfer between iron reductases and a Fe(III) center, or by the subsequent desorption of Fe2+ from the iron oxide mineral surface.