Magnetite Formation by Iron-Metabolizing Bacteria and its Implementation for the Localization of Hydrocarbon Contamination

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Soil contamination by organic hydrocarbons represents a severe environmental problem, but often the location and extent of contamination is not known. Hydrocarbons or their degradation products can stimulate iron-metabolizing microorganisms, probably leading to the formation or dissolution of (magnetic) iron minerals and an associated change of soil magnetic properties. Therefore, the screening of soil magnetic properties by measuring the magnetic susceptibility of the soil has the potential to serve as an efficient and inexpensive tool to localize such contaminations.
In order to identify under which conditions magnetite (Fe_3O_4), a mixed Fe(II)-Fe(III)-mineral, can be formed microbially, the iron(III)-reducing strain *Shewanella oneidensis* MR-1 and the anaerobic, nitrate-depending iron(II)-oxidizing strain *Acidvorax* sp. BoFeN1 were incubated at different concentrations of iron minerals and in the presence and absence of humic substances or mineral nucleation sites. Iron minerals formed in these incubations were identified by μ-X-ray diffraction and Moessbauer spectroscopy. The changes in magnetic properties of the microbial cultures were followed over time by measuring their magnetic susceptibility.
In our experiments *S. oneidensis* MR-1 formed magnetite at different concentrations of poorly crystalline ferric hydroxide ($Fe(OH)_3$). In presence of humic substances the rate of microbial Fe(III) reduction was higher, though magnetic susceptibility measurements revealed that the formation of magnetite occurred later in comparison to set-ups without humic substances. This suggests that the presence of humic substances (that are known to strongly bind to iron(III) mineral surfaces) inhibits or delays the formation of crystalline iron minerals.
The product of microbial Fe(II) oxidation by *Acidovorax* sp. BoFeN1 was identified as goethite (alpha-FeOOH). However, in presence of magnetite as nucleation site, magnetite was formed additionally to goethite. This suggests that mineral formation is not only controlled by microbial activity and geochemical conditions but also by the presence of nucleation sites.
In addition to the experiments with pure microbial cultures, different soils were incubated in a batch experiment with microbial growth medium and different carbon sources (none, lactate-acetate mixture, gasoline). Increasing magnetic susceptibility over time in microbially active set-ups indicated that additional magnetic minerals were formed. In contrast, no change in magnetic susceptibility could be observed in sterile controls. Therefore, it is evident that in soils the production of magnetic minerals is microbially catalyzed. The results further suggest that the screening of soil magnetic properties can be applied to localize and assess hydrocarbon contaminations.

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Abs. No. **147**
Meeting: **DMG 2008**
submitted by: **Porsch, Katharina**
email: **katharina.porsch@uni-tuebingen.de**
date: **2008-05-29**
Req. presentation: **Vortrag**
Req. session: **S12**