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Investigating iron mineral transformations in soils and sediments using ^{57}Fe-labeled minerals and ^{57}Fe Mössbauer spectroscopy

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Iron (Fe) minerals in soils and sediments play important roles in many biogeochemical processes, such as the cycling of major and trace elements and the fate of pollutants in the environment. While most Fe mineral recrystallization and transformation processes have been investigated using synthetic minerals in mixed-suspension experiments, the understanding of kinetics and pathways under natural field conditions remains elusive. New approaches have attempted to follow Fe mineral transformations *in-situ* in soils or sediments. However, diffusion and lack of close contact with the soil matrix are recurrent limitations. Here, we present a novel approach that enables us to follow transformations of Fe minerals in close contact with complex solid matrices, including other minerals, organic matter, and microorganisms. First, we synthesized Fe minerals enriched with ^{57}Fe, mixed them with soil or sediment and incubated the mixture, reproducing the geochemical conditions found in the natural environment. Then we analyzed the solid phase using Mössbauer spectroscopy, which exclusively detects ^{57}Fe and therefore was strongly dominated by the atoms initially added as the investigated mineral. In this work, we conducted a series of microcosm incubation experiments to test our proposed approach. We used ferrihydrite as the initial ^{57}Fe-labeled mineral and a total of four soils differing in chemical and physical properties. Our results reveal the formation of a green rust-like phase in all soils. These results contrast those from traditional Fe(II)-catalyzed ferrihydrite transformation experiments, where formation of lepidocrocite, goethite, and/or magnetite often occurs. Our novel approach can be adapted to different experimental setups and Fe minerals and therefore offers great potential for future investigations of *in-situ* Fe mineral transformations under natural conditions, both in the laboratory and the field.