Acidophilic iron and sulfur oxidising bacteria driven primary mineral weathering and secondary mineral formation in Fe ore tailings

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Background

Billions of tons of iron (Fe) ore tailings have been generated from processing and extracting Fe minerals in the mining industry in the world, with a rapidly rising trend due to the insatiable demands for global industrialization. Direct phytostabilisation of Fe ore tailings is unsustainable and infeasible due to the harsh environment of this mine waste, including strongly alkaline pH conditions (> 9.5), deficient available nutrients and organic matter and poor physical structure, hindering microbial and plant colonization. Direct colonization of tolerant plants was reported in moderately alkaline (pH < 9.0) and coarsely textured (> 70% sand fraction) Au-tailings. In contrast, the alkaline Fe ore tailings had different mineralogical composition and exhibited strongly alkaline pH conditions (> 9.5) and highly compacted physical properties due to fine texture (> 80% silt and clay fractions), prohibiting plant survival. Eco-engineering tailings into soils is an emerging technology to convert the hostile tailings into a soil-like substrate (or technosol) for the establishment of sustainable plant and microbial communities, by involving a suite of abiotic and biotic inputs (organic matter, functional microorganisms and pioneer plants).

Abstract

The neutralization of strongly alkaline pH conditions and acceleration of mineral weathering in the alkaline Fe-ore tailings have been identified as the key pre-requisites for eco-engineering tailings-soil formation for sustainable mine site rehabilitation. *Acidithiobacillus ferrooxidans* has a great potential in neutralising alkaline pH and accelerating primary mineral weathering in the tailings, but little information is available. This study aimed to investigate the colonisation of *A. ferrooxidans* in alkaline Fe ore tailings and its role in elemental sulfur (S^0) oxidation, tailings neutralisation and Fe-bearing minerals weathering through a microcosm experiment. The effects of biological S^0 oxidation on the weathering of alkaline Fe ore tailings were examined via various micro-spectroscopic analysis. It is found that: 1) *A. ferrooxidans* inoculum combined with S^0 amendment rapidly neutralised the alkaline Fe ore tailings; 2) *A. ferrooxidans* activities induced Fe-bearing primary mineral (e.g., biotite) weathering and secondary mineral (e.g., ferrihydrite and jarosite) formation; 3) the association between bacterial cells and tailing minerals were likely facilitated by extracellular polymeric substances (EPS). The behaviour and biogeochemical functionality of A. ferrooxidans in the tailings provide a fundamental basis for developing microbial based technologies towards eco-engineering soil formation in Fe ore tailings.

Environmental Implications

This study has confirmed the survival of sulfur oxidizing and Fe-metabolizing bacteria (i.e. *A. ferrooxidans*) in the alkaline tailings and their roles in Fe mineral weathering and transformation, which are consistent with the findings of Sun et al. (2018). Further studies are to be carried out to establish fundamental mechanisms on the SOB driven eco-engineering of technosols, including the role of EPS in mediating SOB colonization, SOB-mineral interactions, Fe(II) minerals oxidation, and organo-mineral associations for organic matter sequestration in the tailings. It is important to point out that the current study is based on microcosm study under controlled experimental conditions, the long-term functions of SOB in the tailings may be influenced by both biotic (plants and microbial communities) and abiotic (Fe mineral changes and S^0 availability, climate conditions such as drought) factors. Therefore, long-term field study is required to evaluate the performance and functionality of SOB in eco-engineering tailings-soil formation under large scale field conditions with variable biotic and abiotic changes. Importantly, the functions of SOB and their interaction with other microbial communities and plant roots in the tailings should be investigated in field soil-plant systems, for establishing sustainable ecosystems in the tailing site.

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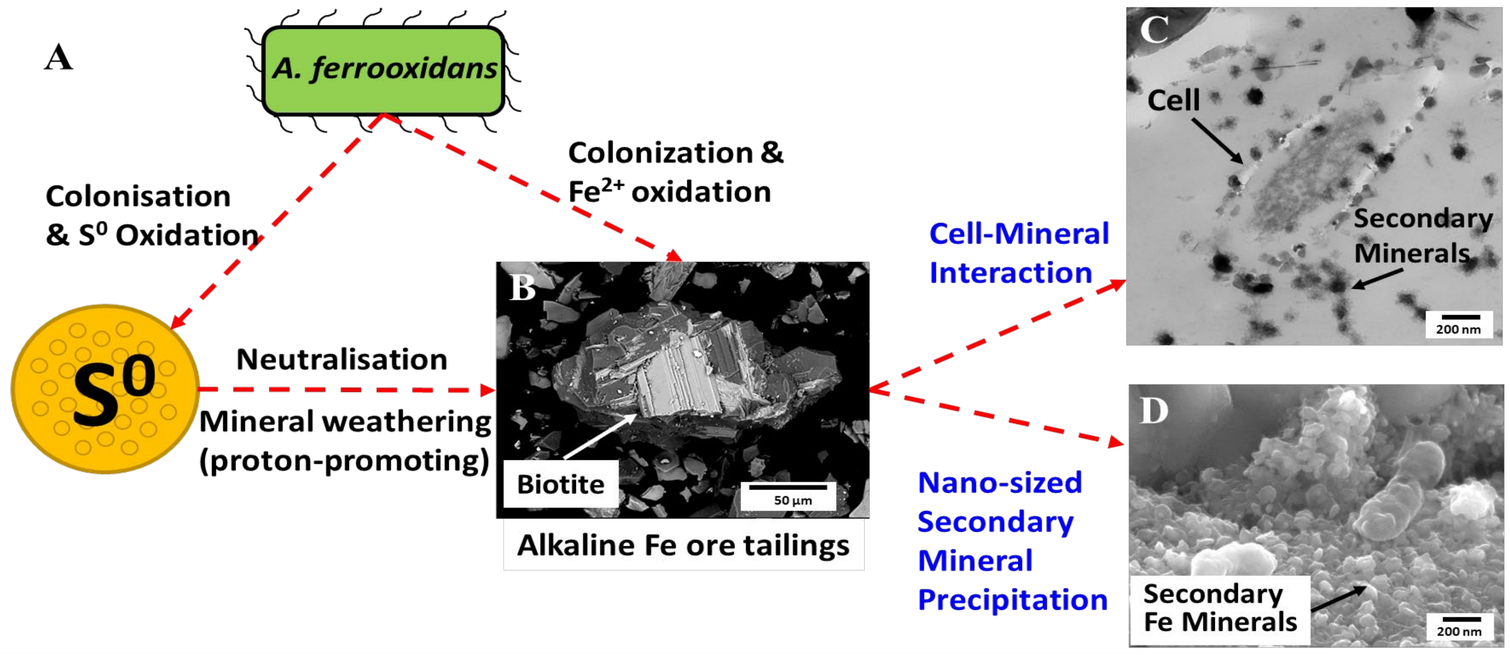
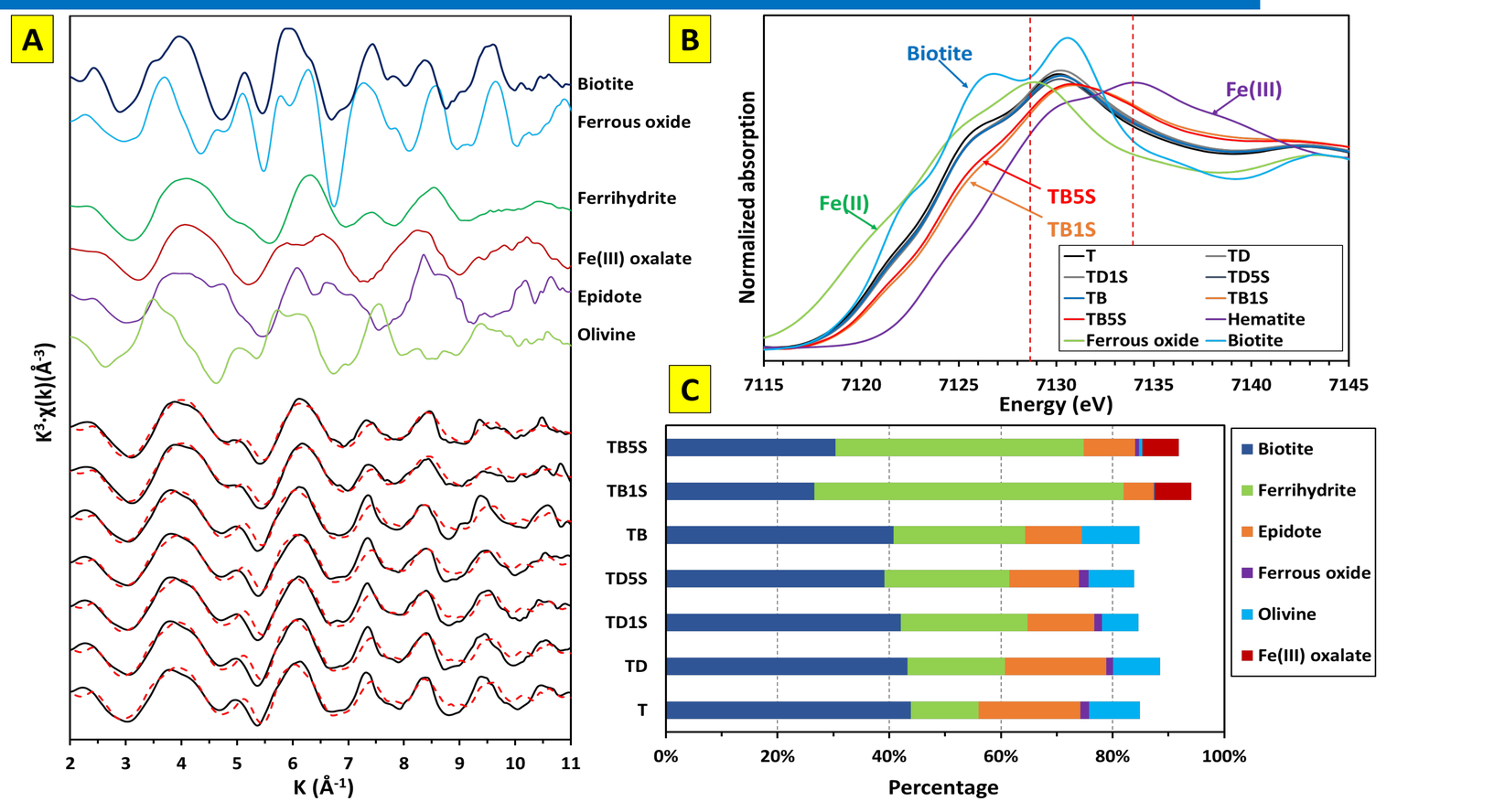
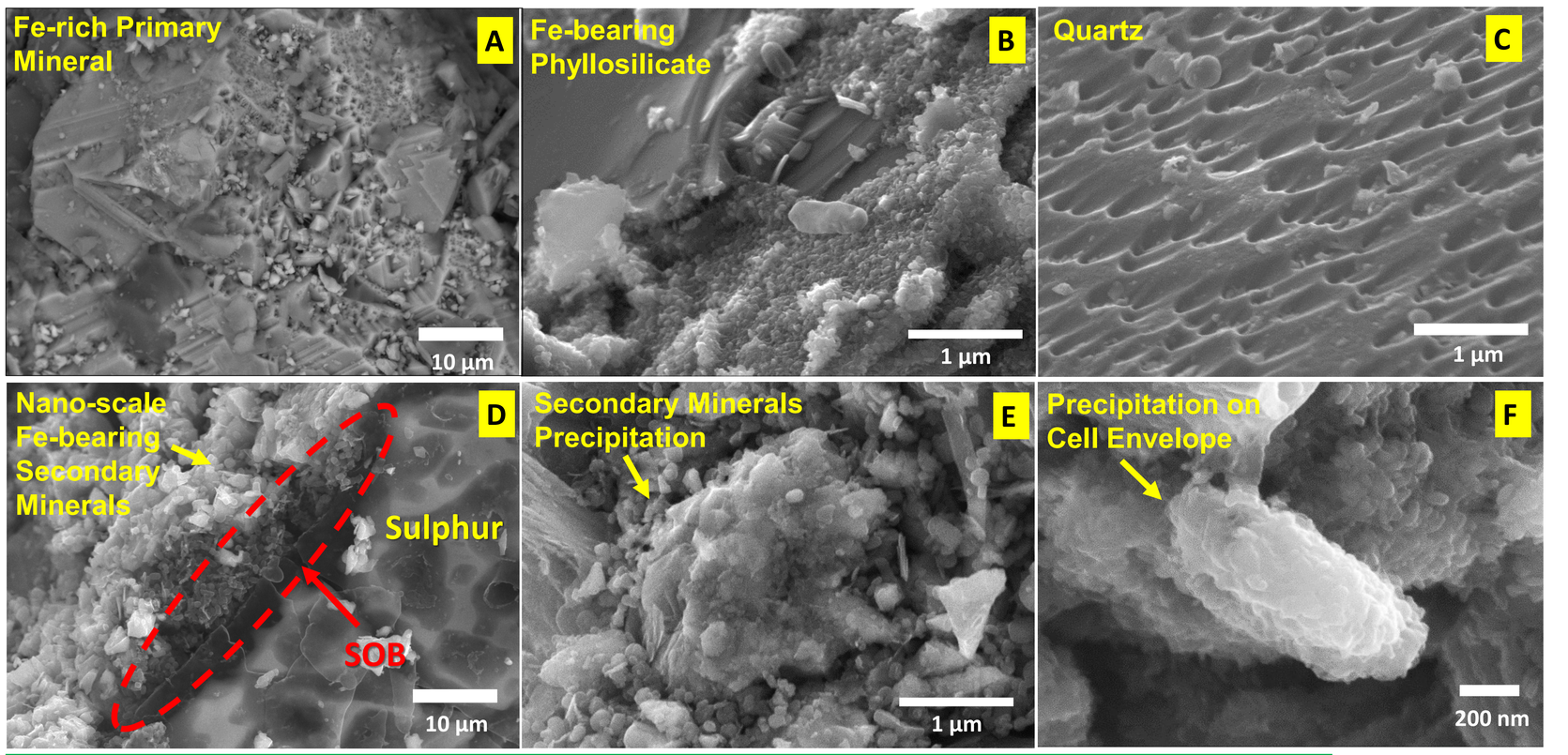


Primary Fe-Bearing Mineral Weathering and Secondary Mineral Formation





Biological S^0 Oxidation and EPS Mediated SOB-Mineral Interactions