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Microbially induced clay weathering: Smectite-to-kaolinite transformation

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Abstract

Microbially induced formation and transformation of clay minerals are known to be ubiquitous in nature. This work investigated the smectite-to-kaolinite transformation by *Bacillus mucilaginosus*, a kind of silicate-weathering bacterium. Results showed that the microbe-smectite system doubled protein production compared with the abiotic controls and enhanced dissolved 1.6% of total Si and 0.9% of total Al from smectite after the 25 days experiment. The formation of kaolinite was verified through its distinguished $d_{(001)}$-spacing of 0.710 nm revealed by synchrotron radiation X-ray diffraction (SR-XRD) and high-resolution transmission electron microscope (HR-TEM). HR-TEM analysis indicated some mixed layers of smectite and kaolinite appeared in the form of a super-lattice structure. Moreover, the compositional and morphological changes of the solids suggested the emergence of kaolinite was associated with the formation of amorphous SiO_2 and fragmented clay particles with lower Si/Al ratio and exposed crystal edge. Based on the detection of –C=O species on the smectite surface and the decrease of pH from 8.5 to 6.5, we inferred the organic ligands secreted by *Bacillus mucilaginosus* complexed with cations, especially for Si, which stripped the tetrahedral sheets and promoted the kaolinization of smectite. To our knowledge, this is the first report of microbially induced smectite-to-kaolinite transformation under ambient conditions in a highly-efficient way. This work could shed light on a novel pathway of microbe-promoted weathering of smectite to kaolinite at the Earth surface conditions. Such a robust and efficient transformation from expansive smectite to non-expansive clays as kaolinite may be of great potential in enhancing oil recovery in reservoirs.

Keywords: Smectite-to-kaolinite transformation, clay minerals, *Bacillus mucilaginosus*, super-lattice structure, microorganism