MICROORGANISMS AND THE WEATHERING OF SILICATE MINERALS

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Microorganisms are nearly ubiquitous in the environment and can have profound effects on geochemical reactions. Both heterotrophic and lithotrophic microorganisms can dramatically affect both the rates and mechanisms of silicate mineral weathering reactions by producing acids, organic ligands which complex with ions on mineral surfaces or in solution, enzymes, or by changing redox chemistry. We have investigated microbial effects on mineral weathering via a combination of field and experimental approaches in order to understand how rocks are converted to soil. Samples were collected along transects through the essentially inorganic (at distance from the soil zone) and strongly biologically impacted regions of a weathering profile in the Bemboka granodiorite (NSW, Australia). Bulk chemical and mineralogical analyses show that weathering in zones impacted by heterotrophic bacteria and eukaryotes is characterized by more extensive loss of K, Mg, Ti, Mn from biotite, P from apatite, and accumulation of Ce compared to the lower or predominately abiotic weathering zone. Bacterial and fungal effects are localized by insoluble secondary phosphate inclusions in biotite. Mineral dissolution experiments with assemblages of microbes cultured from the rock show that heterotrophic microbes can accelerate dissolution rates of biotite and apatite by one to two orders of magnitude. Under P, Fe, and K-limited conditions, this appears to be due primarily by production of acidic and organic byproducts. The increase in rate and modified reaction stoichiometry observed in biotic laboratory experiments are consistent with the kaolinite-dominated secondary mineral assemblage and composition of the biologically-impacted zone. Iron oxidizing lithotrophs can be sustained by the dissolution of Fe-silicate minerals. Calculations based on measured iron metabolism rates suggest that populations of ~ 10^4 cells could be sustained by alteration of biotite in 1 g of granite. Under closed system conditions, ferric iron accumulates on the Fe-silicate surface and decreases silicate dissolution rates. Fewer microorganisms could be sustained by Fe lithotrophy under these conditions.