

In-situ mineral probes of local fluid-mineral interactions in soils

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The rates of mineral dissolution and precipitation in soil profiles are key variables in the geosciences and environmental geochemistry. For instance, the dissolution of primary minerals coupled to clay formation in deep horizons has been scrutinized for its role in pedogenesis and global biogeochemical cycles, while the interaction of soil solutions with silicate, carbonate, and phosphate minerals in shallower horizons is gaining attention for the development of surficial carbon dioxide removal technologies or sustainable agricultural practices. Our current understanding of these processes, however, mostly rely on bulk fluid measurements (at boreholes, streams, etc.) that may not be fully representative of thin fluid layers actually in contact with minerals in the regolith. In addition, the predictive power of current reactive transport models stands to benefit from more detailed knowledge of local fluid-mineral interaction mechanisms and from benchmarking against local measurements instead of overall mass balances.

In this study, we probed in situ weathering and mineralization processes at a forested site and an agricultural plot located at the Watershed Institute (New Jersey, USA). In particular, we developed a novel approach based on calibrated mineral samples incubated at several depth in soil columns. Olivine dissolution rates were quantified by following the evolution of surface microtopography of forsterite single crystal samples by vertical scanning interferometry and atomic force microscopy, while potential for CO₂ trapping was estimated using carbonate probes. We measured dissolution rates up to 2.4×10^{-10} mol/m² s under the most favorable conditions. These estimates were compared against a mass balance performed on outflow solutions. Other parameters impacting mineral weathering, such as surface colonization by microorganisms, were also quantified.

Overall, this technique should extend our capability to quantify silicate mineral dissolution in soil environments and better assess the sequestration potential of terrestrial enhanced weathering.