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Microbially-enriched solutions drive differential weathering of silicate rock powders: insights from contrasting tropical soils

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Nature-based solutions for carbon dioxide removal (CDR) are gaining traction as scalable climate mitigation strategies. Enhanced rock weathering (ERW) stands out among these approaches, as the dissolution of silicate rock powders releases basic cations that promote inorganic carbon sequestration and creates reactive mineral surfaces with potential for mineral-associated organic matter formation [1]. Yet how microbially-enriched solutions from contrasting soils affect rock powder dissolution kinetics remains poorly understood. This study evaluated the effect of microbiome solutions from a Haplic Ferralsol and a Haplic Nitisol on the weathering kinetics of phonolite, diabase, and granite powders over 225 days. A biodissolution column experiment in a fully randomized 3×3 factorial design crossed three rock powders with three solutions: ionic strength control (1 mM $CaCl_2$), organic buffer with microbial extract from a Haplic Ferralsol, and the same buffer with Haplic Nitisol extract, with four replicates per treatment (n = 36). Elemental concentrations in leachate solutions were quantified by ICP-OES at twelve time points, and cumulative elemental release was calculated by mass balance. Data were subjected to univariate analysis. Microbially-enriched solutions substantially enhanced mineral dissolution relative to the control across all rock types and elements ($p<0.001$ for all elements, Figs. 1 and 2). Solution type was the dominant driver of weathering intensity, while rock type significantly differentiated K and Mg release, reflecting mineralogical differences among the powders. Cumulative calcium release reached up to 46.5, 45.0, and 40.9 mmol kg^{-1} in diabase, phonolite, and granite biotic treatments, respectively, compared to 3.1–21.3 mmol kg^{-1} in controls. Iron and aluminum release were markedly elevated in granite and diabase biotic treatments, with granite exhibiting an exponential increase in aluminum after day 100. Potassium release was notably high in phonolite biotic treatments (22.3 mmol kg^{-1}). Strong positive correlations between Fe, Si, and Mg ($r=0.84$, 0.83, and 0.71, respectively; $p<0.001$) suggest the co-dissolution of Fe-bearing silicate phases under biotic conditions. These findings demonstrate that microbially-enriched solutions from tropical soils substantially accelerate silicate rock powder dissolution, reinforcing the potential of ERW in biologically active agricultural systems as a CDR strategy.

[1] Tao & Houlton (2024), Global Change Biol 30, 17132.

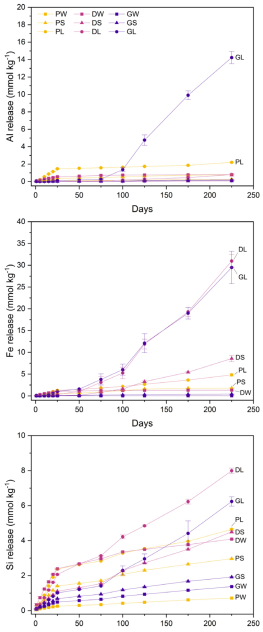


Figure 1. Time-series release of Al, Fe, and Si, tracers of silicate framework dissolution, from rock powders incubated with abiotic and microbially-enriched solutions. D: diabase; P: phonolite; G: granite; W: ionic strength control; S: Ferralsol microbiome; L: Nitisol microbiome.

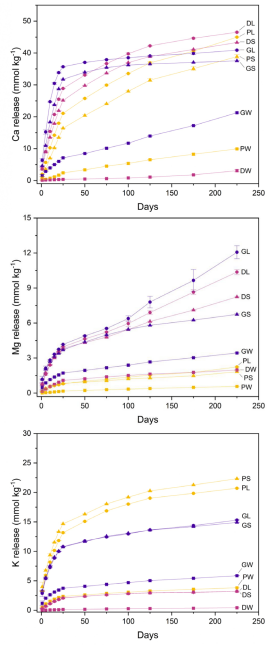


Figure 2. Time-series release of Ca, Mg, and K, base cation indicators of weathering intensity, from rock powders incubated with abiotic and microbially-enriched solutions. D: diabase; P: phonolite; G: granite; W: ionic strength control; S: Ferralsol microbiome; L: Nitisol microbiome.