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Enhanced weathering of wollastonite and diopside in forest soils for CO_2 removal and exchangeable calcium replenishment

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In addition to carbon dioxide removal (CDR), enhanced rock weathering (ERW) can counteract soil acidification and replenish base cations in forest soils impacted by historic acid deposition, which was prevalent across eastern North America. The effectiveness of ERW depends on dissolution kinetics of individual minerals within applied rock powders, yet mineral weathering rates in soils remain poorly constrained. Wollastonite ($CaSiO_3$) and diopside ($CaMgSi_2O_6$), dominant minerals in the wollastonite skarn (30 and 32 wt.%, respectively) used in this study, have laboratory dissolution rates that differ by approximately two orders of magnitude.[1] However, their relative contributions to CDR under field-relevant conditions remain uncertain. This study employed laboratory column experiments to quantify mineral-specific weathering and CDR rates by assessing changes in pore water and soil chemistry. Soil was collected from Haliburton Forest in central Ontario, Canada and profiles were reconstructed in 50 mL columns prior to amending with coarse- and fine-grained wollastonite skarn, pure wollastonite, or pure diopside, at application rates of 2, 20, and 50 t/ha. The lowest dosage approximates the calcium loss caused by acid deposition,[2] while higher dosages aim for greater CDR. During the 16-week experiment, wetting and drying cycles were conducted; concurrently, the collected soil leachate was analyzed for pH, dissolved inorganic carbon, and major cations. Additionally, the exchangeable cations of the soils after the experiment were analyzed to determine the extent to which released base cations, particularly Ca^{2+} and Mg^{2+}, were adsorbed onto exchange sites versus leached from the soil profile. Results indicate that most of the cations released by ERW were retained on the soil, with minimal corresponding changes in pore water chemistry. Based on the Steinour equation,[3] a 20 t/ha application of fine-grained (D_{50} = 13.54 μm), pure wollastonite yields the highest calculated CDR potential, estimated at 2.55 t CO_2/ha over 16 weeks. This study aims to refine mineral dissolution kinetics under soil conditions, improve CDR estimations, and inform geochemical models bridging laboratory-scale experimentation with *in-situ* weathering processes.

[1] Heřmanská et al., (2023) Chem. Geol. 636:121632. [2] Ott & Watmough (2022) Can. J. For. Res. 52, 3, 372-384. [3] Renforth (2019) Nat. Commun. 10, 1, 1401.