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Enhanced weathering of kimberlite residues in soils: Effects on CO_2 fluxes and drainage chemistry

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Enhanced weathering (EW) field experiments that use a wider variety of soils and rock types are necessary for improving methodologies for monitoring, measuring, and verifying carbon dioxide (CO_2) sequestration rates. We conducted field experiments over two summers (2021 & 2022) in Ontario, Canada, which included a control of local calcareous soil with a history of agriculture, and two experimental plots (1 m^2) that were amended with 10 and 20 kg of kimberlite residues from Gahcho Kué Diamond Mine (Northwest Territories, Canada; denoted K10 and K20). These ultramafic residues contained 30.2 wt.% lizardite [$Mg_3Si_2O_5(OH)_4$] and 9.4 wt.% forsterite (Mg_2SiO_4), nutrients including K (2.12%) and P (0.12%), and numerous trace elements, e.g., Ba (0.12%), Ni (0.12%), and Cr (0.07%). Soil moisture probes, pore water samplers, and CO_2 flux chambers were installed with the goals of measuring CO_2 removal rates and assessing impacts on water chemistry when amending soils with kimberlite residues. The major cation loadings (∑ Ca, Mg, K, P; K20: 11.2–21.8 g/m^2, K10: 14.0–26.0 g/m^2, Control: 8.0–11.6 g/m^2) and alkalinity (K20: 30.6–55 g HCO_3^-/m^2, K10: 41.1–70.1 g HCO_3^-/m^2, Control: 26.7–33.4 g HCO_3^-/m^2) in the pore waters increased relative to the control soil, indicating that more CO_2 was trapped in waters as a result of kimberlite residues weathering. Although the amended plots initially caused CO_2 drawdown, all plots generally had CO_2 emission rates in the 1.3–13.5 kg CO_2/m^2/yr range. These data raise the question of whether EW is a negative emission or CO_2 avoidance technology, though both are beneficial. Pore waters in the amended plots had elevated concentrations of trace elements unique to the kimberlite residues (∑ Ni, Ba, Cr; K20: 2.2–7.2 mg/m^2, K10: 5.3–6.5 mg/m^2, Control: 1.3–2.2 mg/m^2), which could potentially be used to track weathering rates. However, heterogeneous dissolution of the different phases present in kimberlite complicates the determination of kimberlite weathering rates due to the preferential dissolution of more reactive phases. Our field experiment demonstrates that monitoring CO_2 fluxes can assess soil respiration, while unique trace elements and alkalinity can be used as a proxy for kimberlite weathering and to quantify CO_2 sequestration rates.