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Direct carbon measurements in enhanced weathering field experiments using kimberlite residues and olivine powder

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Dissolved inorganic carbon (DIC) in drainage waters is a direct measurement of carbon dioxide (CO_2) removal from the weathering of rock powders applied to soils. To demonstrate this approach, we conducted metre-scale field experiments (2021–2023) in Ontario, Canada, each equipped with soil moisture probes and pore water samplers at 15 and 30 cm depths. Two plots consisted of local calcareous soil to assess background weathering rates, two were amended with 10 and 20 kg of powdered olivine, and two were amended with 10 and 20 kg of kimberlite residues from Gahcho Kué Diamond Mine (Northwest Territories, Canada). Concentrations of Mg and Si in the amended plots, which contained significant abundances of Mg-silicates (olivine: ~89 wt.%, kimberlite: ~31 wt.%), increased relative to the control. However, cation and DIC (42–95 mg C/L) concentrations did not increase in the olivine plots until the second monitoring period. DIC in the pore waters increased with kimberlite dosage (kimberlite: 64–118 mg C/L, control: 56 ±14 mg C/L) and remained elevated, demonstrating CO_2 solubility trapping. Water chemistry data, coupled with a water budget analysis derived from weather and soil moisture data, were used to determine CO_2 removal rates by silicate weathering. The removal rates for the olivine powder were lower (0.01 t/ha/yr) and can be attributed to a lower specific surface area (1.0 m^2/g) than the kimberlite residues (20.6 m^2/g), which removed up to 0.08 t CO_2/ha over 3 yr. Carbonate weathering in the kimberlite residues removed an additional 0.67 t CO_2/ha and were calculated using Ca loadings. These kimberlite residues are geochemically enriched compared to quarried mafic feedstocks commonly used for enhanced weathering field trials (e.g., CaO + MgO; kimberlite, 31.1 ± 13.9 wt.% vs. basalt [1], 17.5 ± 1.9 wt.%), with ~60 billion tonnes made available from diamond mining [2]. Efficient carbon removal by kimberlite residues encourages industries to explore repurposing environmentally safe mine wastes for enhanced weathering while reducing storage and remediation costs [3].

[1] Vanderkloot & Ryan (2023) *Appl. Geochem.* 155, 105728. [2] Kjarsgaard et al. (2023) *Rev. Mineral. Geochem.* 88, 1–117. [3] Power et al. (2024) *Environ. Sci. Technol.* 58, 43–53.