Goldschmidt 2022 Abstract
https://doi.org/10.46427/gold2022.12169

Enhanced weathering rates of kimberlite residues: Insights from field and laboratory studies

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Enhanced rock weathering (ERW) is a negative emissions technology with the potential to remove gigatonnes of atmospheric CO_2. Accurate carbon accounting is a key challenge of ERW due to the slow reaction of CO_2 with Mg- and Ca-silicates, storage of carbon as either a soluble or solid phase, and spatially and temporally viabilities in soil carbon content in large open systems. The goal of our laboratory and field studies is to develop a scalable methodology for measuring CO_2 sequestration rates through ERW of kimberlite mine residues from De Beers' Gahcho Kué diamond mine (Canada). These mine wastes 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 numerous trace elements, e.g., Ba, Ni, Sr, and Co (1171, 1151, 471, 69 ppm, respectively). Soil-kimberlite mixtures (0–100 wt.% residues; 250 mg total mass) were leached in plastic 250 mL flasks with 100 mL deionized water in a CO_2 incubator (10% CO_2; 35 °C). Principal component analysis of leachate chemical data indicates that the release of Mg, Si, K, Na, Ba, Ni, and Sr were distinct to kimberlite. Field experiments (1 m^2 plots) involved mixing 10 and 20 kg of kimberlite residues into native soil, followed by monitoring of CO_2 fluxes, CO_2 pore gas concentrations, soil moisture, and porewater chemistry for 1 yr. CO_2 fluxes were only negative during the first day of the experiment, removing atmospheric CO_2 at a rate of up to -5.6 kg/m^2/yr. However, CO_2 fluxes quickly became positive and indistinguishable from unamended soil (0–13.5 kg CO_2/m^2/yr). These high soil CO_2 fluxes raise the question of whether ERW is a negative emissions technology or CO_2 avoidance technology, though both are beneficial. Porewaters from the 20 kg residues/m^2 plot were distinguishable from the control soil plot, characterized by higher concentrations of major (Mg, Si, K, Na) and trace (Ba, Ni, Sr) elements, as well as greater alkalinity (8.5 ± 1.5 and 6.6 ± 0.9 mmol/L, respectively). In this ongoing research, monitoring multiple parameters, including distinct trace elements, will aid in developing approaches to assess ERW rates in soil environments.