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Direct measurement of CO_2 fluxes into kimberlite residues and powdered rocks: Implications for enhanced weathering

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As part of De Beers' Project CarbonVault, kimberlite residues from Venetia Mine in South Africa, as well as powdered forsterite [Mg_2SiO_4], serpentinite [$Mg_3Si_2O_5(OH)_4$], wollastonite skarn [$CaSiO_3$], and 10 wt.% brucite [$Mg(OH)_2$] mixed with quartz sand, were tested as potential feedstocks for enhanced weathering (EW). The goals of this study were to examine parameters that affect CO_2 drawdown and how EW can be used to remove CO_2 at mines. Venetia generates 4.74 Mt of residues per year that are a valuable feedstock for EW. These residues vary in grain size from fine (<1 mm) to coarse (1–8 mm), have high surface areas (6.8–13.4 m^2/g), and contain reactive mafic minerals including serpentine [$Mg_3Si_2O_5(OH)_4$], diopside [$CaMgSi_2O_6$], and clinochlore [$Mg_5Al(AlSi_3O_{10})(OH)_8$; 1]. An arid climate drives evaporation leading to mine waters being saturated with respect to calcite [2], which is likely a carbon sink, yet cannot be distinguished from primary calcite. Experiments utilized a CO_2 gas analyzer with flux chambers to directly measure CO_2 removal. Unweathered kimberlite residues achieved the greatest drawdown rate of -870 g $CO_2/m^2/yr$ at 48% saturation, whereas fine and coarse residues, previously exposed to process water achieved fluxes of -150 and -160 g $CO_2/m^2/yr$ at 60% saturation, respectively. Brucite mixed with quartz reached -2940 g $CO_2/m^2/yr$ at 14% saturation, in comparison to forsterite, serpentinite, and wollastonite that achieved fluxes of -500, -260, and -190 g $CO_2/m^2/yr$, respectively, at higher saturations of 53–60%. Experiments demonstrate that mineralogical composition and reactivity have the greatest effect on EW rates, followed by water content which affects permeability. Total inorganic carbon increased in the brucite, wollastonite, and unweathered kimberlite indicating that CO_2 was stored via mineral trapping as opposed to solubility trapping, which dominated in the other experiments. Modifying the management practices at Venetia by increasing the exposure of unweathered residues, expanding total dispersal area, and creating optimal water saturation would lead to greater CO_2 removal.

[1] Mervine et al. (2018), Mineral. Petrol. 112 (Suppl 2), S755–S765. [2] Paulo et al. (2021), Appl. Geochem. (*in review*).