Direct measurement of CO₂ 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 [Mg₂SiO₄], serpentinite [Mg₃Si₂O₅(OH)₄], wollastonite skarn [CaSiO₃], 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 CO₂ drawdown and how EW can be used to remove CO₂ 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 m²/g), and contain reactive mafic minerals including serpentine [Mg₃Si₂O₅(OH)₄], diopside [CaMgSi₂O₆], and clinochlore [Mg₅Al(AlSi₃O₁₀)(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 CO₂ gas analyzer with flux chambers to directly measure CO₂ removal. Unweathered kimberlite residues achieved the greatest drawdown rate of -870 g CO₂/m²/yr at 48% saturation, whereas fine and coarse residues, previously exposed to process water achieved fluxes of -150 and -160 g CO₂/m²/yr at 60% saturation, respectively. Brucite mixed with quartz reached -2940 g CO₂/m²/yr at 14% saturation, in comparison to forsterite, serpentinite, and wollastonite that achieved fluxes of -500, -260, and -190 g CO₂/m²/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 CO₂ 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 CO₂ removal.