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Potential for atmospheric carbon dioxide removal in mafic quarries via enhanced rock weathering of basalt fines

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Enhanced rock weathering (ERW) is a recognized carbon dioxide removal (CDR) strategy that uses crushed silicate rock (e.g., basalt) to capture atmospheric CO_2, offering co-benefits such as improved soil health and increased crop production [1]. One of the main disadvantages of ERW includes the production of energy needed to crush and transport rocks to their application site [2]. Basalt quarries might be capable of removing CO_2 on-site by optimizing the management of their quarry fines. This approach would reduce transport-related emissions while repurposing valuable and previously underutilized material. To test this possibility, basalt and dolerite fines from Breedon's Orrock Quarry and Tarmac's Cairneyhill Quarry in Scotland are used as potential feedstocks for on-site CDR, respectively. These samples show initial evidence of on-site weathering as secondary minerals are present in some areas of the fines at both the quarries. Thermogravimetric analysis (TGA) on these samples corroborates field observations as 0.75% and 1.76% CO_2 were detected at Orrock and Cairneyhill, respectively. It is estimated that 10 kg CO_2/ t Orrock fines and 23 kg CO_2/ t Cairneyhill fines have been sequestered passively. Based on the CaO and MgO content, the carbonation potential is 190 kg CO_2/ t Orrock fines and 160 kg CO_2/ t Cairneyhill fines. Due to the challenge of accessing this potential under ambient conditions, it's essential to evaluate various on-site basalt management practices. To test this, ex-situ, column-based experiments were performed in the following manner. Fines from both sites were placed into columns with varying thicknesses (1 cm and 5 cm) and grain sizes (bulk and <75 μm). These columns were then subjected to ambient UK conditions (10 °C, 0.04% CO_2) in an environmental chamber and intensified carbonation conditions (50 °C, 20% CO_2) in a CO_2 incubator. Both sets of experiments were in place for three months, with monthly water addition to facilitate natural wetting and drying. Secondary precipitates were visible on the surface of bulk fines from both sites regardless of thickness or chamber conditions with mass increases up to 0.5 g by the end of experiments. Sieved Orrock fines (<75 μm) in the CO_2 incubator exhibit secondary precipitation, irrespective of sample thickness, displaying white patches on the surface and mass increases up to 1.5 g. Energy dispersive spectroscopy reveals that calcite has begun to fill in the pore spaces. Under ambient conditions, the bulk fines generally have the most significant carbon increase at greater depths, while the sieved fines show the greatest carbonation on the surface. This research has important implications for how fines are managed at quarries in the context of CO_2

sequestration and may offer new opportunities for removing CO_2 on-site at quarries.

[1] Beerling, D.J. et al., 2020. Potential for large-scale CO_2 removal via enhanced rock weathering with croplands. Nature, 583(7815): 242-+. [2] Edwards, D.P. et al., 2017. Climate change mitigation: potential benefits and pitfalls of enhanced rock weathering in tropical agriculture. Biology Letters, 13(4).