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Global efficacy of enhancing carbonate weathering

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Carbonate weathering is thought to be a carbon neutral process on geological timescales [1], meaning that it is often overlooked as a mechanism for CO_2 sequestration via enhanced weathering.

However, carbonates react more rapidly than silicates at a range of pH and temperature values, and carbon derived from carbonate weathering can remain in solution for thousands of years in the ocean prior to calcification. This makes carbonate weathering a prime candidate for enhancing alkalinity export from the continents, and studies have shown that the critical zone weathering capacity for carbonates could remove quantitative amounts of CO_2 from the atmosphere e.g., [2]. Whilst carbonate weathering in high pCO_2 semi-confined soil environments can create high DIC concentrations through dissolution, the degassing of waters in the open system river environment (where DIC is transported), coupled to carbonate precipitation, may mean atmospheric carbon is only removed transiently. For enhanced carbonate weathering to be effective, the atmospherically derived DIC needs to be transported to the oceans for successful sequestration.

To understand the net feasibility of enhancing carbonate weathering including riverine transport, we have constructed a global river basin solubility model coupled to PHREEQC v3 to estimate the maximum export of carbonate derived DIC from the continents to the oceans, under varying saturation scenarios (SIc = 0 to SIc = 1). The maximum CO_2 sequestration potential from enhanced carbonate weathering was calculated, and compared to current riverine DIC export and CO_2 consumption to determine a potential transport capacity for DIC to the oceans. Our simulations suggest global rivers have the capacity to transport 10 - 25 % of annual increases in atmospheric carbon (5 Gt yr^{-1}), when DIC is derived from reaction with $CaCO_3$ in these river basins. This model also accounts for logistical concerns such as the amount of lime powder required, and environmental impacts such as changes in soil pH.

[1] Berner, E.K. and Berner, R.A., 2012. *Global environment: water, air, and geochemical cycles*. Princeton University Press.

[2] Zeng, S., Liu, Z. and Groves, C., 2022. Large-scale CO2 removal by enhanced carbonate weathering from changes in land-use practices. *Earth-Science Reviews*, p.103915.