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The relative efficiency of in-situ versus ex-situ CO2 mineralisation

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Natural mineral carbonation on the Earth surface proceeds by the weathering of divalent metal-bearing silicates coupled to carbonate mineral precipitation in the oceans. This process has removed CO_2 directly from the atmosphere over Earth's history. Natural silicate weathering on the continents draws down ~0.5 Gt CO_2 annually [1]. This represents no more than 0.1 % of the CO_2 currently being emitted to the atmosphere by anthropogenic activities. Nevertheless, this natural process has inspired many to explore alkalinity production and mineralisation to capture and store CO_2 [2]. Most of proposed engineering solutions use olivine, ultramafic rocks, or basalt crystalline/glassy as their "feedstock".

In each case, this 'feedstock' is required to dissolve to promote alkalinity production, and in many cases, provide the cations provoking the precipitation of stable carbonate minerals. Examples of engineered ex-situ CO_2 solutions include the addition of "feedstock minerals" to seawater to enhance its alkalinity, the addition of 'feedstock' to cropland soil to raise its alkalinity, and perhaps increasing soil organic carbon storage, and the use of mine ultramafic tailings as feedstock to carbonate this waste material. In-situ CO_2 mineral storage uses permeable subsurface silicates, including basalts and ultramafic rocks as feedstock to promote the mineralization of injected CO2.

The efficiency of any of these engineering solutions depends on the dissolution rates of the "feedstock materials" and the precipitation rates of the reaction products. The dissolution of silicates in general increases alkalinity thereby increasing the solubility of CO_2 in natural waters. In contrast, the precipitation of carbonates, iron oxyhydroxides, and clay minerals can decrease some or all of this created alkalinity, limiting the efficiency of some ex-situ carbon efforts. The impact of secondary mineral precipitation on the overall efficiency of ex-situ CO_2 mineralisation has been challenging to quantify due to the many processes occurring in soils and the oceans, and the short time span of current projects. In contrast, geochemical tools have been developed to assess secondary mineral precipitation during in-situ CO_2 mineralization efforts allowing its quantification.

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[2]. Oelkers and Gislason 2023. Geochem. Perspective 12, 179-349.