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Hawaiian beaches as natural analogues for long-term rates and impacts of Coastal Enhanced Silicate Weathering

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Silicate weathering is the primary natural sink for atmospheric carbon dioxide (CO_2) on geological time scales and Coastal Enhanced Silicate Weathering (CESW) aims to accelerate this process as a Carbon Dioxide Removal (CDR) technology for climate stabilization. However, the CO_2 sequestration efficiency and environmental impacts of CESW remain largely unknown as dedicated field studies are lacking and long-term conditions are not yet investigated. However, some natural coastal environments can function as suitable analogues of CESW. Papakōlea Beach in Hawai'i is the world's largest and best example of such a natural coastal analogue, comprising ~90 wt % of olivine, a fast weathering Mg-silicate. As time is the critical factor, these beaches are extremely rare because olivine undergoes rapid dissolution in marine settings. It hence provides an opportunity to study the long-term rate and impact of olivine weathering, as envisioned in CESW applications.

In summer 2022, field investigations were conducted on Papakōlea beach (olivine sand) and the nearby Richardson Bay (carbonate sands). Sediment incubation were done to investigate the dissolution kinetics under natural conditions, the fate of weathering products from olivine dissolution, and to explore the influence of olivine dissolution on biogeochemical cycling and ecology. Our findings reveal alkalinity release from the incubated olivine sand of Papakōlea beach, as well as the calcium carbonate equivalent from Richardson Bay. The alkalinity released during chemical weathering of silicate minerals results in supplementary transfer of atmospheric CO_2 to the coastal ocean, with long-term storage in the form of bicarbonate (HCO_3^-) thereafter. The increase of alkalinity concentrations correlates with the production of dissolved inorganic carbon, indicating atmospheric CO_2 uptake. To characterize the olivine dissolution and reflect surface alteration process on the grain scale, the study included non-destructive scans via electron microscopy (SEM) and high-resolution x-ray diffraction (XRD) of weathered minerals.