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Bioturbation as a key driver in the partitioning between alkalinity-generating processes in coastal sediments

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Coastal and shelf sediments account for approximately 40% of the global oceanic alkalinity input, making them crucial for the sequestration of CO_2. Globally, the dissolution of calcium carbonate ($CaCO_3$) and the precipitation and burial of pyrite (FeS_2) are the main processes producing net alkalinity in marine sediments, yet they occur in geochemically distinct environments. Dissolution of $CaCO_3$ occurs in the oxygenated, surficial part of the sediment, where the oxidation of reduced compounds and oxic respiration by animals and microbes lower the pH and increase dissolution rates. In contrast, the precipitation of FeS_2 in the deeper, anoxic layers of the sediment also generates alkalinity. However, both $CaCO_3$ dissolution and FeS_2 precipitation are influenced by bioturbation, the mixing and flushing of sediments by animals. Bioturbation can enhance the $CaCO_3$ dissolution by increasing the O_2 availability in the sediment. Simultaneously, introducing O_2 to anoxic sediment layers can cause the reoxidation of FeS_2, leading to the consumption of the alkalinity generated during its formation. The overall impact of bioturbation on net alkalinity production through these opposing mechanisms, however, remains unclear.

Here, we investigated the interactions between natural alkalinity-generating processes in sediments with and without bioturbation. To quantify the relative importance of these processes in different conditions, we studied salt marsh ponds in Blakeney (Norfolk, UK), where bioturbated and unbioturbated ponds are naturally present just a few meters apart. We conducted in-situ sediment-water flux measurements, detailed investigations of the sediment geochemistry and measurements of bioturbation to explore the interactions between geochemical processes and quantify the net effect of bioturbation on alkalinity production. Bioturbation substantially decreased the burial of FeS_2, but bioturbated ponds occasionally displayed high alkalinity effluxes, likely due to $CaCO_3$ dissolution. In addition to bioturbation, the coverage of O_2-producing benthic microalgae and the production rate of reduced compounds in the anoxic sediment further influenced the alkalinity release. Hence, shifts in benthic fauna communities can significantly affect the alkalinity generation in coastal sediments and should be accounted for when assessing the impacts of changes to coastal systems.