Small animals with a big impact: How bioturbators counteract climate change

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The ocean is a major carbon reservoir and holds 40 times more carbon dioxide (CO_2) than the atmosphere. This capacity for CO_2 storage is regulated by the seawater's alkalinity content, which increases the CO_2 solubility. Coastal and shelf sediments contribute approximately 25% of global oceanic alkalinity input, making them crucial for the global carbon budget. Around 80% of the sedimentary n*et al*kalinity production globally stems from calcium carbonate ($CaCO_3$) dissolution.[1] This process 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.[2–4] In contrast, in the deeper, anoxic layers of the sediment, alkalinity is produced through the precipitation of pyrite (FeS_2), accounting for about 20% of the global sedimentary alkalinity release.[5,6] FeS_2 is unreactive in anoxic environments; if undisturbed, it will eventually be buried by downward advection. However, both $CaCO_3$ dissolution and FeS_2 precipitation are influenced by bioturbation, the mixing and flushing of the sediment by animals. Bioturbation can enhance the $CaCO_3$ dissolution by increasing the O_2 availability in the sediment.[4,7,8] 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.[9,10] The overall impact of bioturbation on n*et al*kalinity production through these opposing mechanisms, however, remains unclear.

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, fauna identification 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 precipitation of FeS_2, but bioturbated ponds occasionally displayed high alkalinity effluxes, likely due to $CaCO_3$ dissolution. Interestingly, the presence or absence of bioturbation alone did not account for the variations in sedimentary alkalinity release across the different ponds. The coverage of O_2-producing benthic microalgae and the production rate of reduced compounds in the anoxic sediment additionally impacted the alkalinity release. Hence, these environmental factors must be considered when estimating the sedimentary alkalinity release in shallow coastal systems.

References

1) Krumins *et al.* (2013) *BG* 10. 2) Morse and Mackenzie (1990) *Geochemistry of sedimentary carbonates*. Elsevier. 3) Milliman and Droxler (1996) *Geologische Rundschau* 85. 4) Rao *et al.* (2014) *Estuar. Coast. Shelf Sci.* 148. 5) Hu and Cai (2011) *GBC* 25. 6) Middelburg *et al.* (2020) *Rev. Geophys.* 58. 7) Aller (1982) *J. Geol.* 90. 8) Michaud *et al.* (2021) *J. Mar. Res.* 79. 9) Schippers and Jørgensen (2002) *GCA* 66. 10) Rimstidt and Vaughan (2003) *GCA* 67.

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