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The potential of magnesite for Ocean Alkalinity Enhancement: A delicate interplay of dissolution and secondary precipitation

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Ocean alkalinity enhancement (OAE) is emerging as a promising yet largely untested marine carbon dioxide removal approach. Various methods of implementing OAE include adding solid-powered minerals (carbonates, silicates, hydroxides) and the aqueous solution of hydroxides. We present analyses of mineral-based OAE mesocosm experiments conducted in the coastal waters of the eastern Arabian Sea to explore the potential of magnesite and olivine at four different alkalinity levels (+250, +500, +750 and +1000 µmol kg^{-1}) and track the changes in the carbonate chemistry due to mineral addition. We also present a novel approach to determine the occurrence of secondary carbonate precipitation using dissolved inorganic carbon (DIC) concentration and stable isotope ratios of carbon ($\delta^{13}C$) in DIC pool. No change in alkalinity and pH was observed for olivine additions. This suggests that silicate minerals do not dissolve within the required time scale, and hence, should not be considered an effective mineral for OAE. For 250 µmol kg^{-1} of alkalinity addition via magnesite we saw that enhancement was 88% of the added alkalinity. Similarly for 500, 750 and 1000 µmol kg^{-1} additions the alkalinity enhancement was 92%, 61% and 47% of the added alkalinity, respectively. The pH increased to a maximum of 8.21, 8.4, 8.6 and 8.6 from the initial value of 7.9 for the four alkalinity levels, respectively. The change in DIC along with $\delta^{13}C_{DIC}$ reveals that secondary precipitation begins to dominate at higher alkalinity (>=500 µmol kg^{-1}, Fig. 1) treatments for magnesite, questioning its effectiveness and the need to determine a critical threshold concentration to avoid alkalinity loss via runaway precipitation. We also conducted stable isotope tracer-based experiments to determine the primary productivity and nitrogen fixation rates. Preliminary results show that both carbon and nitrogen fixation rates decrease after the alkalinity addition via magnesite and olivine except for magnesite with alkalinity addition of +250 µmol kg^{-1}. The study underscores the potential influence of these minerals on the carbon and nitrogen fixation rates.

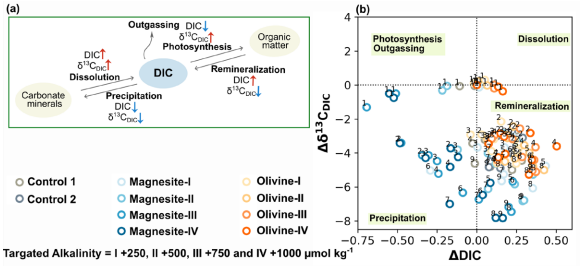

Fig. 1 Variation in the $\delta^{13}C_{DIC}$ and DIC due to various biogeochemical processes. (a) The increase (red arrow) or decrease (blue arrow) in the DIC and $\delta^{13}C_{DIC}$ due to these processes and (b) The change in DIC (ΔDIC) and change in $\delta^{13}C_{DIC}$ ($\Delta\delta^{13}C_{DIC}$) for each mesocosm, and the number on each data point refers to the sampling day.