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Magnesium carbonate mineralization induced by diurnal microbial metabolic activity: Lessons from natural and laboratory wetlands

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Increasing anthropogenetic carbon dioxide (CO_2) production and impacts of climate change necessitate CO_2 removal from the atmosphere. Microbially-induced carbonate precipitation is an important link between biosphere, atmosphere and lithosphere and leads to the formation of a stable, long-term sink for atmospheric CO_2. Microbial metabolisms and extracellular polymeric substances (EPS) produced by bacteria influence the pH, alkalinity, dissolved inorganic carbon (DIC) of interstitial waters within microbial mats, collectively impacting carbonate mineral precipitation. Alkaline ponds benefit from a large air-to-water surface area for CO_2 diffusion and mineral precipitation facilitated by microorganisms. In this study, microbial mats and sulfate-reducing bacteria (SRB) rich sediments were collected from an alkaline wetland within a hydromagnesite [$Mg_5(CO_3)_4(OH)_2·4H_2O$]–magnesite ($MgCO_3$) playa near Atlin, British Columbia, Canada. Microbial mats were layered on SRB-inoculated sediment in a ~38 L tank that mimicked the geochemical and environmental conditions of the wetland. Over 16 weeks, diurnal water chemistry was monitored by layer with periodic sampling of mineral precipitates. As no dissolved organic or inorganic carbon was added to the tank, cyanobacteria and anaerobic phototrophs were primarily responsible for integrating atmospheric carbon into the system. Alkalinity and DIC increased in the sediment porewater over the 16 weeks, with higher concentrations measured at night, coinciding with SRB activity. Cauliflower-like mineral precipitates in the sediment associated with the EPS were observed using secondary scanning electron microscopy. Geochemical stratification by mat layer was further evident in the dissolved Ca^{2+} and Mg^{2+} concentrations, which remained constant in the overlying water but decreased in the sediment during night over weeks 2–14 (by 8.6 mg/L and 43 mg/L, respectively). This experiment was complemented by a 12 m transect across the playa wetland, where microbial community, mineral precipitates, and water chemistry were measured during the day and night at the surface, photosynthetic mats, and sediment interfaces of the wetland. Alkalinity changed diurnally over depth, suggesting the influence of active microbial metabolisms on carbon cycling at larger scales. Understanding microbial composition and its diurnal impact on water chemistry ensures the success of biomineralization as a CO_2 sequestration solution.