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Evolution of Microbial Carbonates During Early Burial: A Multi-Proxy Approach

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This study provides a geochemical and textural characterization of modern, Holocene, and Pleistocene palustrine microbial muds and associated organic matter along the low-energy shoreline of the Florida Everglades, USA.

Dense organic-rich, light brown carbonate muds are deposited above karstified Pleistocene limestone. Deposited in shallow freshwater, the palustrine mud is a result of precipitation induced by cyanobacterial photosynthesis, and reflects local water chemistry and hydrologic conditions. The microbial community forms a dense mat, and excretes exopolymeric substances (EPS) and other labile organic constituents, in which texturally complex, fine-grained low-Mg calcite (LMC) crystals precipitate. Geochemically, this deposit is characterized by high amounts of TOC (up to 12%), a depleted organic δ^{13}C signal indicative of microbial activity, and a low range of inorganic δ^{18}O and δ^{13}C values reflecting freshwater deposition.

Within the Holocene microbial mud sequence, depositional and burial environments (freshwater, brackish, and full marine) can be inferred through variation in geochemical signatures, which arise from differences in depositional fluids, vegetation type, and metabolic processes of organic degradation. Stable isotope values indicate that an increased marine influence causes more positive δ^{18}O values, whereas a freshwater source is characterized by more negative values. Inorganic δ^{13}C of the Holocene sequence likely represents biological influence, and shows a fairly large range of up to 5‰ whereas sediments within the marine burial environment have a much lower range ($\sim$1.5%¸). Depending on the method of organic decomposition (aerobic, anaerobic, etc.), different δ^{13}C signatures are recorded in both the organic and inorganic fraction. Holocene cores indicate that the freshwater environment degrades organic material via denitrification during early burial, whereas the mangrove transition zone (greater marine influence) likely breaks down organic material through sulfate reduction, leading to a more negative organic δ^{13}C signature. Early diagenesis of Holocene ($<$4.5 kyr) muds has altered both the texture, as well as geochemical signatures of the microbial carbonates and their associated organic material. The TOC generally decreases with depth, correlating with more negative organic δ^{13}C values as a result of the degradation of labile material, including EPS.

This study implies that microbial signatures of freshwater carbonates are dependent upon the environment in which they were formed and buried. Variation in salinity, as well as vegetation type within the environment alter the original depositional signature, which is also not well preserved. Deviation from modern geochemical signals implies that meteoric and marine diagenesis affects even these dense LMC mudstones and their associated organic matter, and has implications for the use of palustrine carbonates proxies.