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Beachrock: A microbial mechanism for maintaining sand cay stability in the Great Barrier Reef

Beachrock is produced through the lithification of sediments in the intertidal zone of tropical beaches on both continental coastlines and sand cays in reef environments. Beachrock formation through carbonate cement precipitation has the capacity to slow sea-level rise induced erosion of sand cays, islands that host vulnerable habitats, including inhabited cays and sea turtle rookeries. Beachrock formation has been linked to a number of interconnected physicochemical and biological processes, making it difficult to discern the key mechanism responsible for this geological process. This investigation employed synchrotron-based, X-ray fluorescence microscopy (XFM) to characterise beachrock specimens from Heron Island in the southern Great Barrier Reef. High-resolution elemental mapping of beachrock indicated that cementation in part occurs through the internal cycling of cations through microbial dissolution and re-precipitation of carbonate minerals. Boring of endolithic cyanobacteria in carbonate sand grains in the intertidal zone generates elevated concentrations of soluble calcium, magnesium, and strontium in the pore spaces of the sediment. Cyanobacterial photosynthesis produces microenvironments enriched in alkalinity, which, when combined with the high cation concentrations, induces supersaturating conditions with respect to carbonate minerals. Cement precipitation is also aided by the production of nucleation sites in the form of microbial exopolymer. This biogeochemical pathway for beachrock production was verified by synthesising new beachrock in the laboratory. Samples of beach sand and microbial communities from Heron Island were used in aquarium experiments that simulated the conditions typical of the intertidal zone with respect to tidal activity, light, temperature, and water chemistry. The seawater was doped with a strontium enrichment that enabled the identification of new cement precipitates using XFM. When observed using scanning electron microscopy (SEM), the new cements were shown to contain abundant microfossils. Linking high-resolution characterisation of the chemistry (XFM) and structure (SEM) of these cements has elucidated the biogeochemical mechanism that controls the progression from unconsolidated beach sand to lithified rock. Understanding this process, which may be encouraged by stimulating microbial activity, may be critical to maintaining island stability in the face of global sea-level rise.

Keywords or phrases (comma separated)

beachrock, aragonite, cement, exopolymer, nulceation, reef cays, XFM

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