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Indigenous microbial communities as catalysts for early marine cements: an *in vitro* study

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Rapid early marine cementation is a fundamental process for many characteristics of carbonates, like the formation of steep slopes. The genesis of early cements is often attributed to physicochemical processes but there is evidence for microbial mediation. To elucidate the role of microbes, *in vitro* experiments were undertaken in the presence and absence of indigenous microbiota/organic material in ooids from Schooner Cays, Bahamas and compared with native grapestones from Joulter Cays, Bahamas. Microscopic examinations, assisted by stereomicroscopy, scanning electron microscopy (SEM) and thin section analysis of *in vitro* incubations with native flora document rapid, initial grain fusion, resulting in the formation of grapestones within 30 to 60 days. The initial binding of the grains is primarily facilitated by exudates of extracellular polymeric substance (EPS) and microbial communities acting as catalysts in the formation of micritic bridges, cements and encrusted aggregates. *In vitro* grapestones show similar characteristics as native grapestones from Joulter Cays with intergranular areas infested with EPS, microbes, micritic cements, amorphous calcium carbonate (ACC) nanograins, and micritisized outer surfaces. These similarities suggest that incubations with native flora follow similar mineralization mechanisms as in the natural environment. In contrast, sterilized grains, remain loose with little crystal formation after 60 days and are devoid of microbes and organic exudates. Owing the near absence of precipitates, abiotic precipitation is not the driving force promoting early cements. In contrast, grain fusion is microbially mediated via both a passive mechanism, upon which EPS and cell surfaces function as templates for crystal nucleation and generation of micritic cements, and through an active mechanism by which microbial activities induce chemical alterations of a local environment, facilitating precipitation. This study underscores that microbially mediated cementation can occur at very fast rates and that slope stabilization and firm- to hardgrounds might form shortly after deposition of carbonate grains.

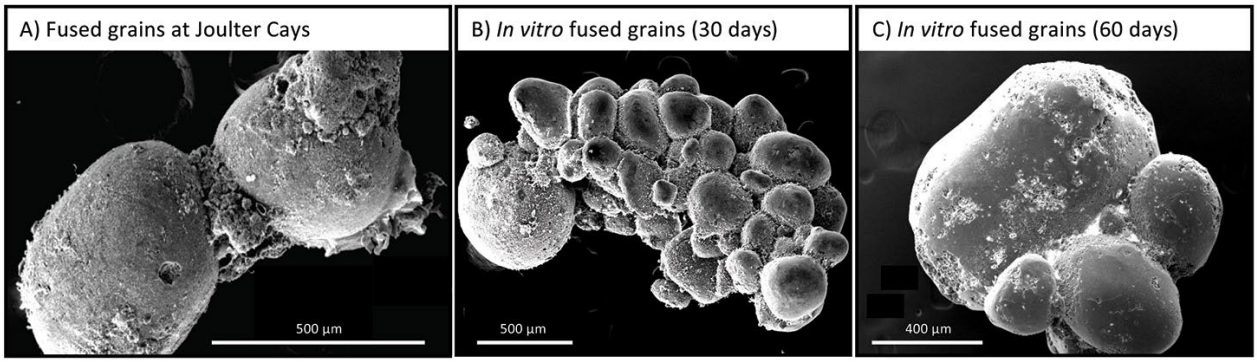

Figure 1. A) Grapestone from the stabilized sand flat of Joulter Cays in the Bahamas. B and C) Grapestone with multiple fused grains after 30 days (B) and 60 days (C) in the *in vitro* experiment; in both samples the indigenous microbial community acted as the catalyst for the micritic cements at grain contact areas. The similarity of fusion of the cements in the grapestones at Joulter Cays indicate a similar microbial mediated origin of the cements.