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Microbial carbonates

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Synsedimentary microbial carbonates include products of bacterially bio-induced precipitation that form within sediments (e.g., at cold methane seeps), at the sediment–water interface (e.g., in biofilm–mats), and as allochthonous water–column precipitates (e.g., biogenic whitings). They have a long record and wide distribution in aquatic environments. Microbial carbonate development particularly reflects: (i) environmental controls (e.g., carbon dioxide, light and nutrient availability; carbonate saturation); (ii) evolution of bacterial metabolisms that promote precipitation (e.g., sulphate reduction, oxygenic photosynthesis and carbon dioxide concentrating mechanisms, CCM); and (iii) interactions with eukaryotes (e.g., grazers, mat– and reef–builders). Key questions include microfabric and macrofabric development, controls on spatial and secular abundance, and the record of metabolic development and seawater carbonate saturation state reflected in microbial carbonates.

Precambrian stromatolites reflect the rise of bacterial mats and metabolisms that influenced microfabric development, and progressive decline in abiogenic seafloor crust precipitation. Suggestions for investigation include: (i) millimetric dark–light couplets are seasonal alternations of abiogenic crust and lithified microbial mat (Hybrid Stromatolites); (ii) clotted–peloidal microfabrics increased with sulphate availability that promoted bacterial sulphate reduction; (iii) cyanobacterial in vivo sheath calcification was triggered by CCM induction in response to decline in carbon dioxide. These latter filamentous fabrics contributed to thrombolite development that transformed macrofabrics in the mid–Proterozoic. Phytoplanktic CCM induction at this time could also have increased whiting precipitation, contributing to carbonate mud substrates in which 'molar tooth' structures developed. In addition, increase in background sedimentation would have reduced stromatolite relative accretion rate, promoting late–Proterozoic diversification of digitate forms.

In the Early Palaeozoic, cyanobacteria and other calcimicrobes contributed significantly to thrombolite–dendrolite formation. Domes and columns declined in the Ordovician as algal–metazoan reefs increased. Subsequently, these morphotypes only developed extensively in marine environments when or where skeletal encrusters were reduced, as in the immediate aftermaths of Mass Extinction events and in ecologic refuges. Reefs limited overall microbial carbonate habitats, but provided cryptic substrates where heterotrophic communities developed reefal microbial crusts, often

with distinctive clotted fabrics. Late Devonian decline in carbon dioxide stimulated cyanobacterial sheath calcification, and also whitings that contributed to Late Devonian–Early Carboniferous carbonate mud mound formation. In addition to competition, episodic Phanerozoic decline in microbial carbonate abundance reflects fluctuating reduction in seawater carbonate saturation that slowed lithification and therefore accretion.

Present–day thrombolitic stromatolites with weak initial lithification that largely accrete by grain trapping are grazing prone; but grazing probably has reduced influence on early–lithified mats. Present–day examples provide valuable insights. Cyanobacterial mat calcification is well developed in calcareous streams and lakes but weak in marine environments, reflecting dependence on elevated carbonate saturation. Marine calcification is sustained better by sulphate reducers in more enclosed substrates, as in methane seeps and reefal crusts. Large marine domes are restricted to shallow wave–swept bays and channels, protected from reef encrustation by hypersalinity (Shark Bay) and/or mobile sediment (Lee Stocking Island). Their accretion relies on production of extracellular polymeric substances, stimulated by high illumination, that promote grain trapping and on heterotroph–dominated sub–mat lithification.