Bioturbating the oceans and terminating the Proterozoic: Early animals as planetary engineers

N. J. BUTTERFIELD[1]

[1]Department of Earth Sciences, University of Cambridge, Cambridge, UK CB2 3EQ njb1005@cam.ac.uk

Redox geochemistry clearly documents low levels of marine oxygenation through the early-middle Proterozoic, a signal widely interpreted as a measure of correspondingly low levels of atmopheric oxygen. By extension, the relatively late evolution of animals is widely viewed as a consequence of rising atmospheric oxygen levels. Such models, however, have yet to incorporate the compounding ecological and evolutionary feedback effects of early multicellular organisms on marine oxygenation.

Bioturbation is widely recognized as a first-order agent of redox expression. Because of the inertial and viscous properties of the associated media, it is limited to large multicellular organisms – most obviously in motile bilaterian animals and 'sessile' landplants. Almost universally overlooked is the active bioturbation of seawater by sponges. Despite the rapid dissipation of direct physical traces, this behaviour is manifest in the extraordinary capacity of sponges to extract DOC, suppress picoplankton growth, and fundamentally enhance water clarity and oxygen content in modern systems. In the past, such engineering effects can be recognized from paleobiological and geochemical signatures.

It is possible that the early evolution of sponges was constrained by oxygen, but this is difficult to reconcile with the physiology of their unicellular ancestors. In addition to higher mass-specific metabolic rates, these choanoflagellate- like organisms would have had no capacity for turbulent-flow ventilation, thus requiring substantially higher levels of ambient oxygen than their multicellular counterparts. The presence of crown-group eukaryotes (last common ancestor an aerobic flagellate) by at least the late Palaeoproterozoic documents permissive environments for sponge-grade organization roughly a billion years prior to their actual appearance. The first appearance of significant eukaryotic steranes and novel microfossils at ~ 750 Ma (along with geochemical evidence for expanding zones of oxygenation) are consistent with molecular clock estimates for the appearance of sponge-grade animals at this time. Like the subsequent ~ 200 million year 'delay' in the appearance of soft-sediment bioturbation, it was (internally constrained) developments in biological organization that eventually brought the Proterozoic to an end.