Utilization of the trace fossil record to understand bioturbators' ecosystem engineering impact over the last 560 million years

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The trace fossil record of Earth history preserves the activity and behaviours of benthic animals over the last 560 million years. In palaeoecological studies, the trace fossil record has proven particularly useful for understanding how benthic soft-bodied animals – which interacted with the sediment but do not leave robust body fossil records – have evolved and responded to environmental perturbations. Recently, the trace fossil record has been used for understanding ecosystem engineering dynamics throughout Earth history. Ecosystem engineering refers to the behaviours of animals that modify resource availability, and bioturbators are considered key ecosystem engineers in modern oceans. By studying the trace fossil record through the lens of ecosystem engineering, we can better understand the ways in which bioturbators have impacted benthic ecosystem functioning throughout Earth history. Here, I present key studies from two time periods in Earth history that are critical intervals for changes in macroevolutionary processes: the Ediacaran-Cambrian transition (˜541 Ma) and the end-Permian mass extinction event (˜261 Ma). For both time intervals, I have compiled trace fossil data from the literature and my own field work to characterize trace fossils in t̄erms of their ecosystem engineering im-pacts. For trace fōssils from the Ediacaran-Cambrian transition, I have used μXRF analyses to identify geochemical characteristics of different bioturbation ecosystem engineering behaviours. I also have incorporated Ediacaran-Cambrian trace fossil data into biogeochemical models to predict the impact that early bioturbators had on benthic ecosystem resources. For trace fossils from the end-Permian mass extinction, I have analysed global trace fossil data to demonstrate that despite global warming, ocean anoxia, and ocean acidification, some shallow marine en-vironments could support complex, metabolically intensive bioturbating ecosystem engineering behaviours which may have contributed to maintaining local ecosystem functioning in the early Triassic. Finally, I present avenues for research in utilizing the trace fossil record for novel macroecological studies, including integrating the trace fossil and body fossil records together in spatially-explicit palaeoecological analyses to better understand how bioturbators have been fundamental ecosystem engineers in benthic ecosystems throughout Earth history.

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