Development of bioturbation and implications for early Paleozoic biogeochemical cycling

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Bioturbation, the physical and chemical mixing of sediments by burrowing animals, is a critical engineering process in modern seafloor environments and exerts a significant control on not only benthic ecology and sediment properties but also ocean-wide biogeochemical cycling. Well-mixed sediments have long been assumed to appear at the Precambrian–Cambrian boundary with the first occurrence of the index fossil and three-dimensional burrow *Treptichnus pedum*. Recent field-based analyses, however, synthesizing ichnological, stratigraphic, sedimentological and taphonomic data collected from a range of lower Paleozoic siliciclastic successions spanning four paleocontinents, indicates that sediment mixing in marine shelfal environments remained limited until at least the late Silurian, 120 million years after the Precambrian–Cambrian transition. The protracted development of the sediment mixed layer has important implications for contemporaneous biogeochemical (e.g., C, S and P) cycling. For instance, empirically and stratigraphically derived mixed layer depths for the early Paleozoic are consistent with sulfur data and supported by global sulfur model simulations indicating that bioturbation exercised a first-order control upon early Paleozoic sulfur cycling. The delayed development of intensive sediment mixing may also be linked to the anomalous preponderance of exceptionally preserved soft-bodied fossil Lagerstätten characteristic of the lower Paleozoic stratigraphic record. These bioturbation data indicate that, in spite of concurrent advances in infaunalization, mixed layer development was a protracted process and did not occur with the first appearance of three-dimensional burrows, and that evolutionary advances in sediment colonization significantly outpaced advances in sediment mixing. This provides support for the previously hypothesized [1] late onset of infaunal mobile deposit feeding (biological ‘bulldozing’). Ecosystem restructuring caused by the onset of significant bulldozing, unlike other major paleobiological and paleoecological innovations, appears to have occurred well after both the Cambrian Explosion and the Great Ordovician Biodiversification Event.

[1] Thayer, 1979, Science.