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The early Paleozoic development of bioturbation—evolutionary and geobiological consequences

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Abstract

Bioturbation, the physical and chemical mixing of sediments by burrowing animals, is a critical engineering process in modern seafloor environments and exerts an important 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*. However, field-based analyses, synthesizing ichnological, stratigraphic, sedimentological and taphonomic data collected from lower Paleozoic successions worldwide, indicate that sediment mixing in marine shelf environments remained limited until at least the late Silurian, 120 million years after the Precambrian–Cambrian transition. In spite of early advances in complex modes of infaunalization, mixed layer development had a much more gradual trajectory and did not occur in step with the first appearance of three-dimensional burrows. The delayed appearance of modern-style intensities of sediment reworking—postdating both the Cambrian Explosion and the Great Ordovician Biodiversification Event—may be due to the late-stage radiation of mobile infaunal deposit-feeders (biological bulldozers)—the organisms which are, in modern marine settings, the most efficient bioturbators. The protracted development of the sediment mixed layer holds important implications for contemporaneous biogeochemical cycling and oxygenation of the ocean-atmosphere system. The delayed development of intensive sediment mixing may have also mediated exceptional preservation of both fossilized soft tissues and shallow-tier trace