Deep Time Biogeomorphology 2: Animals as Ancient Ecosystem Engineers

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This thematic set is the second of a pair of volumes delving into the co-evolution of life and sedimentary environments in deep time. Whilst the full gamut of life-sediment interactions is far too vast to cover in its entirety, across both volumes this set provides examples of how different organisms have interacted with sedimentary environments across the entirety of the Phanerozoic. The first thematic set of this pair focussed on plant-sediment interactions from the Carboniferous to the Pliocene (Davies et al., 2022; PALAIOS Volume 37, Issue 6), whereas this second set has a loose running theme of ‘animals’; documenting examples of interactions between metazoans and the environments that they occupied.

In the introduction to first thematic set, Davies et al. (2022) discussed the significant recent advances in biogeomorphology research, both in modern settings and on geological timescales. The natural partner to biogeomorphology is ecosystem engineering – the interplay between
organisms and the bio-physical engineering of their habitats (Jones et al., 1997). In recent years there has been an increased effort to apply the concepts of ecosystem engineering to changes enacted by entire groups of organisms in ancient environments over much longer temporal and spatial scales (e.g., Herringshaw et al., 2017; Cribb et al., 2019). The papers in this issue each contribute to this burgeoning dataset, with case studies dating from the late Ediacaran through to the Late Devonian.

The ecosystem engineering influence of the earliest bioturbators is considered by O’Neil et al. (2022, this issue), who investigate changes in bioturbation intensity and ichnodiversity across the Ediacaran-Cambrian boundary. Using a section of the Wood Canyon Formation from Chicago Pass as a case study, they combine petrographic and bedding plane scale analyses to understand changes in organism-sediment interactions during this evolutionarily significant time interval. Their case study emphasises that the onset and increasing abundance, diversity and depth of burrowing from the Late Ediacaran was a driver of chemical and environmental changes as increased sediment mixing allowed material sequestered at depth to be brought to the surface. This time interval can thus be considered to record some of the earliest instances of ecosystem engineering by animals, where their interactions with the substrate began to change the habitats in which they lived.

The multitude of ways in which ancient ecosystem engineering impact can be quantified is the focus of the study presented by Laing et al. (2022, this issue). They explore and analyse current models for quantifying ecosystem engineering impact and assess how these models can have practical utility for geological studies. Models are necessary to estimate the impact that bioturbation had on ancient environments when it cannot be directly observed. Laing et al. (2022, this issue) consider six multi-parameter models, each of which is interrogated with a suite of questions to ascertain the best practice model for measuring the impact of bioturbation in the rock record.
Bidirectional feedback between animals and their habitats is also crucial to ecosystem engineering. Shillito and Davies (2022, this issue) consider how physical environments determined where ecosystem engineering by bioturbators could take place by showing how sediment type affected the invertebrate-substrate interactions during the Silurian-Devonian colonization of non-marine habitats. Investigating more than 50 sedimentary formations from across the world, they compare the ichnological record in sandstones and mudstones from shallow marine and terrestrial strata deposited during this interval and demonstrate how substrate composition affected tracemaker behaviour.

Lithological controls remain important after lithification, variably impacting preservation of sedimentary structures and body fossils and potentially obscuring the record of ancient life and environment. This issue is investigated by De Baets et al. (2022, this issue), who consider how sedimentary facies, genus, collection style and region are related to the mean size of ammonoid fossils reported from a given formation. Using a data set of Late Devonian ammonoids recorded from different lithologies, palaeolatitudes, and depositional environments they compare the distributions of conch sizes, and how the shapes of these distributions differ.

Together, these four papers highlight the inseparable nature of life and environment in the rock record, demonstrating that while habitats have long shaped the organisms living in them, equally those organisms have long shaped the world around them. Along with the first thematic set on the theme of plants (Davies et al., 2022), as well as many other papers recently (and regularly) published in PALAIOS, the papers here underline that palaeontology and sedimentary geology are separated only by an artificial subject boundary. For over half a billion years, Earth has been an unusually complicated planet, rife with interactions between the biosphere, lithosphere, hydrosphere and atmosphere. The ongoing evolution of eukaryotic life has meant that many of these interactions have become increasingly complex, and have affected the planet at all scales, from the production of individual sedimentary surface textures
to global scale ecosystem engineering. Further understanding how ancient ‘alternative Earths’
(Beerling and Butterfield, 2012; Davies et al., 2020) have differed from modern Earth and other
known planets will be fundamental to understanding the significance and influence of life as a
major force in the universe.

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