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The taphonomy of unmineralised Palaeozoic fossils preserved as siliciclastic moulds and casts, and their utility in assessing the interaction between environmental change and the fossil record

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The enhanced preservation potential of biomineralised tissues in fossil organisms is a key factor in their utility in the investigation of palaeoenvironmental change on fossil ecosystems. By contrast, the considerably lower preservation potential of entirely unmineralised organisms severely reduces the utility of their temporal and spatial distribution in such analyses. However, understanding the taphonomic processes which lead to the preservation of such soft-bodied fossils may be an under-appreciated source of information, particularly in the case of specimens preserved as moulds and casts in coarser siliciclastic sediments.

This information potential is well demonstrated by fossil eldonids, a Cambrian to Devonian clade of unmineralised asymmetrical discoidal basal or stem deuterostomes, with an apparently conservative biology and no clear palaeoenvironmental or biogeographical controls on their distribution. We investigated the taphonomic processes involved in the preservation of fossil eldonids as moulds and casts on bedding surfaces and within event beds from sandstones of the Ordovician Tafilalt lagerstätte in south-eastern Morocco, and from siltstones of the Devonian West Falls Group of New York, USA. Laser Raman microspectroscopy, SEM BSE imaging and EDS elemental mapping of fossil specimens reveals that moulded biological surfaces are coated by a fossil surface veneer primarily consisting of mixed iron oxides and oxyhydroxides (including pseudomorphs after pyrite), and aluminosilicate clay minerals. Moreover, comparison to fossil eldonids preserved as carbonaceous compressions in the Burgess Shale reveals that the biological structures preserved in the Tafilalt and New York specimens – the dorsal surface and a coiled sac containing the digestive tract – represent only specific portions of the anatomy of the complete animal.

We suggest that the preserved remains were the only parts of these eldonid organisms composed primarily of complex organic biopolymers, and that these tissues were preferentially fossilised by the formation of an early diagenic mould directly on the organic surfaces. Excess divalent iron ions, produced during decay of more labile tissues by means of bacterial iron reduction, would have adsorbed to anionic functional groups in the biopolymeric tissues. This would have provided a ready substrate for the formation and growth of such an early diagenic mineralised mould, including aluminosilicate minerals produced via reaction with seawater silica and metal ions, and iron sulphide minerals produced via reaction with hydrogen sulphide and free sulphur produced from seawater sulphate through bacterial sulphate reduction associated with further decay. Subsequent weathering would have oxidised such iron sulphides to oxides and oxyhydroxides.

This taphonomic model supports the lack of utility of the eldonid palaeobiological record in analysing environmental influence on biological communities, due to the lack of preservation of key anatomical components. However, it also suggests that the very occurrence of fossils preserved in this style is dependent on extrinsic palaeoenvironmental factors – including pH, Eh, and the concentration of other ions in the contemporaneous seawater. Analyses of the distribution of fossils preserved in this style may therefore provide information on ambient conditions which may have affected the distribution of contemporaneous mineralised fossils, potentially allowing a more complete analysis of the effects of palaeoenvironmental change on fossil ecosystems.