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The Four Principal Megabiases in the Known Fossil Record: Taphonomy, Rock Preservation, Fossil Discovery and Fossil Study

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Abstract: The Known Fossil Record represents museum collections and the published literature, and it is subject to multiple large-scale megabiases grouped into four major categories: (1) taphonomy; (2) rock preservation; (3) fossil discovery; and (4) fossil study. Taphonomic megabiases are largescale patterns in the quality of the fossil record that affect paleobiologic analysis at provincial to global levels and at timescales usually exceeding ten million years. Taphonomic megabiases are intrinsic (form and behavior) and extrinsic (biotic and abiotic controls on preservation). Other megabiases are the preservation and exposure of rock strata, kyreonomy (discovery) and concipionomy (study). Kyreonomy megabiases include location of fossil sites, mineral evaluation, mineral extraction and colonialism. Concipionomy megabiases include the Taxophile Effect, language and development and distribution of technology.

Keywords: Fossil record; megabiases; taphonomy; kyreonomy; concipionomy

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1. Introduction

The Known Fossil Record represents museum collections and the published literature (Benton et al, 2011), and it is subject to multiple large-scale biases. The purpose of this paper is to demonstrate that megabiases in the fossil record can be grouped into four major categories: (1) taphonomic megabiases; (2) rock preservation; (3) fossil discovery; and (4) fossil study.

2. Taphonomic Megabiases

Behrensmeyer et al. [2] introduced the term megabiases into taphonomy for largescale patterns in the quality of the fossil record that affect paleobiologic analysis at provincial to global levels and at timescales usually exceeding ten million years. Taphonomic megabiases are intrinsic (form and behavior) and extrinsic (biotic and abiotic controls on preservation). Examples of intrinsic megabiases in the vertebrate-fossil record include body size (larger organisms are better preserved), robusticity of skeleton (e.g., fewer bird and pterosaur fossils), presence of armor (dense osteoderms preserve well such as in the nonmarine Late Triassic) and behavior (e.g., semiaquatic or terrestrial).

One significant extrinsic megabias involves the development of vascular plants and related land surface evolution. Schumm [3,4] first speculated that plant evolution caused changes in fluvial style, and Cotter [5] documented the relationship in the Paleozoic. Essentially, increasing plant cover in the Paleozoic led to increased stabilization of channels and floodplains [6–8]. This had profound effects on the taphonomy of plants, trace fossils and body fossils [7,9–11]. The later evolution of land plants, notably grasses, presumably had additional taphonomic impacts. Thus, Hunt et al. ([11] predicted four distinct temporal phases of vertebrate track preservation: (1) Devonian—few tracks, because terrestrial tetrapods are rare, and lack of plant ground cover resulted in frequent reworking of terrestrial surfaces; (2) Carboniferous-Triassic—many tracks because terrestrial tetrapods are common, and increased ground cover reduced the reworking of terrestrial surfaces; (3) Jurassic-Cretaceous—tracks will be numerous and preserved in more diverse sedimentary environments because terrestrial animals are very large, even though ground cover is increased; and (4) Cenozoic—increased ground cover, especially after the diversification of grasses, resulted in less unvegetated areas where tracks can be preserved (with a few notable exceptions such as lacustrine margins).

Another extrinsic example is the evolution of dentition. Pre-mammalian vertebrates generally lack the dental morphology for fine occlusion. Thus, for example, dentalites are rarer on dinosaur bones than on Cenozoic mammal bones because non-avian theropods lacked the dentition or jaw mechanics to manipulate and modify bones in a similar manner [9,10,12,13]. Fiorillo [13] validated this hypothesis by demonstrating that dinosaur faunas exhibited 4% or less of bones with dentalites, whereas in the mammal faunas he studied the percentages varied from 13.1 to 37.5% (but see 14 for a notable exception).

Other examples of extrinsic megabiases include digestive evolution (e.g., preservational effects of GI tract acidity: 9, 10, 15) and Lagerstätten and Megalagerstätten (e.g., Upper Cretaceous of Western Interior of North America: 16).

3. Rock Preservation

Raup [17] persuasively argued that aspects of the rock record have resulted in systematic biases in the fossil record, notably exposed rock area, available rock volume and intensity of subsequent metamorphism and erosion. Subsequent workers have discussed aspects of this topic with regard to diversity through time [e.g., 18–22]. Sheehan [19] recognized Paleontologic Interest Units as a measure of the effort devoted to acquiring knowledge concerning fossils and concluded that eight times as many palaeontologists (per million years) work on Cenozoic fossils as on Cambrian fossils, reflecting the relative exposure of these ages of rocks [19].

4. Fossil Discovery

The history of the discovery of fossils has been heavily influenced by the prospecting for, and extraction of, mineral resources. For example, the major difference between Moscovian and older/younger Carboniferous tetrapod records has its primary basis in coal mining [22,23]. Thus, the larger Middle Pennsylvanian tetrapod record is biased because almost all of the Moscovian tetrapod assemblages are associated with coal beds [23,25,26]. There is an abrupt decrease in mineable coals across the Middle-Late Pennsylvanian boundary, due to climate change driven by sea-level drop, the drifting northward of Euramerica and changing topography and drainage patterns due to Variscan tectonism [e.g., 27–29]. The tetrapod fossil record diminishes with these changes because of the megabias associated with the coal interval.

We apply the term kyreonomy (from the Greek *kyreo* to find) to address biases caused by discovery. Other kyreonomic megabiases include location of fossil sites (related to human geography, climate and geological context), mineral evaluation (e.g., exploration of Cretaceous coalfields of western USA), mineral extraction (e.g., Late Jurassic-Early Cretaceous lithographic limestones) and colonialism (e.g., Tanzanian dinosaurs, Karoo tetrapods, North African dinosaurs).

5. Fossil study

There are markedly distinct levels of interest, and hence study, of different fossil groups, which Hunt et al. [30] termed the Taxophile Effect [e.g., 17]. This is clearly evident, for example, among dentalites where a single tooth mark on a dinosaur bone warrants a published paper, whereas the numerous occurrences on Cenozoic bones are barely noted until the Quaternary [15]. There is consistent elevated interest in certain groups evident from popular culture to rock shop sales to the scientific literature. Dinosaurs and ammonites are the clear winners among vertebrates and invertebrates, respectively. Intrinsic interest is not the only driver to increased study. Extrinsic factors include the relative abundance of exposure of strata in that "geologic systems with more rock contain more species and this leads to more species being described" [31, p. 328: 19]. Other extrinsic factors include employment possibilities such as the decrease in the number of petroleum company micropaleontologists and the decline of traditional systematists among academic faculty. The burgeoning of paleobiology has benefitted the understanding patterns of the fossil record but has had a detrimental effect on the prevalence of study of the building blocks of the record. Other biases include language (non-English literature is under cited) and the development and availability of technology (e.g., SEM, CT scanning). We propose the term concipionomy (from the Latin *concipio* to comprehend) for the biases introduced by study of the fossil record.

6. Conclusions

The Known Fossil Record is subject to multiple large-scale biases. These megabiases can be grouped into four major categories: (1) taphonomy; (2) rock preservation; (3) kyreonomy; and (4) concipionomy.

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