



Trace Fossils: Concepts, Problems, Prospects, edited by William Miller III, 2007, Elsevier, Amsterdam, hardcover, 632 p., USD 185.00, ISBN-13: 978-0444-52949-7.

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The year 2007 was extraordinary for ichnology as it was the year when two major works concerning the study of trace fossils were published: *Trace Fossil Analysis*, written by a forefather of the discipline, Professor Adolf Seilacher; and *Trace Fossils: Concepts, Problems, Prospects*, edited by Dr. William Miller III. The latter, which is the focus of this review and contains 36 chapters, was authored by 54 scientists (approximately two-thirds live in North America and approximately one-third live in 9 other countries) and reviewed by 53 referees, 20 of whom are authors and 9 of whom reviewed more than one chapter.

For anyone seeking to comprehend what ichnology is all about and to position this dynamically developing discipline in relation to its past, present, and future, it would be sensible, first of all, to follow Aristotle's advice: "If you would understand anything, observe its beginning and its development." Second, one should read carefully Miller's edited volume. There are several reasons for this, one of which is that the editor's initial promise—to provide a well-timed progress report on the state of the ichnology inclusive of numerous potential growing points in the discipline—has been kept indeed. Another reason would be that in this timely account of the discipline, the chapters are logically sequenced according to common themes lending themselves to a user-friendly layout—a most appealing feature. Furthermore, the very readable individual chapters—a worthy editorial effort considering the multiauthored nature of the book—also have a uniform, scientific-paper format. In each chapter, the encapsulated content is followed by an introduction that, together with the conclusion (or a final summation), sandwich the main body of data and discussion, which are often underscored by case studies. While some chapters recycle previously published concepts and approaches (e.g., Chapters 15–17), each contribution offers a fresh and clear treatment of different topics and an invaluable, up-to-date list of references. With the exception of a very few chapters (e.g., Chapter 18), the book is well illustrated with informative tables, high-quality photographs, and line drawings (although coloring of some figures seems pointless, e.g., 7.2, 11.4, 11.8). Bearing in mind the large number of figures (over 280), there are remarkably few mistakes in the otherwise informative captions (e.g., 11.6 E, F: not Claron but Clarens Formation, Tuli Basin, South Africa). The book also has a well-edited contents page and a functional index comprising 12 pages.

The 611 pages of the volume are partitioned into 3 sections that more or less reflect the subtitle of the book: Concepts, Problems, Prospects. Section I, dedicated to the historical overview of the subject, includes four chapters. While most of this section has a strong bias toward the North American ichnological beginnings, its last chapter (Chapter 4) offers a global perspective on the historical development of the central paradigm in this discipline: the ichnofacies concept.

Section II contains the bulk of the book with 19 chapters centered on established principles, methodologies, and existing applications. Using rather insightful, easy-to-follow and logical diagrams (e.g., Fig. 5.1), chapter 5 presents a topic viewed as a necessary evil by those with a stronger geological inclination and poses some perplexing questions to those with more biological grounding in the hope of resolving some long-standing taxonomical problems. Chapter 6 is a dynamic review of the physical, ecological, and diagenetic controlling factors of postproduction processes that influence the degree of trace-fossil preservation. Chapter 7 hinges its discussion on the key role that substrate-dependent trace-fossil suites play in the evaluation of stratigraphic breaks. In addition, it also presents the genesis and recognition criteria—both sedimentological and ichnological—of some stratigraphic surfaces. Chapter 8 provides a critical account of trace fossils as biostratigraphic tools, a description of some of their major utilities, and a set of guidelines aimed at increasing the reliability of palichnostratigraphy. Chapter 9 concerns the effect of benthic oxygenation levels on trace-fossil diversity and size and critically considers the applicability of ichnotaxa suites of marine mud substrates in the reconstruction of paleoceanographic conditions.

Chapters 10 and 11 discuss how climate, this major allogenic controlling factor, influences the diversity, abundance, and spatiotemporal distribution patterns of trace fossils in especially neritic, marginal marine, and continental settings. In addition, Chapter 10 critically evaluates certain marine ichnotaxa as climate indicators, and Chapter 11 provides a discourse on the climate-driven relationship of media types—in this case, soils—and tiering patterns in terrestrial trace-fossil assemblages. Chapter 12 briefly presents the relevant concepts as well as traces produced by vertebrates due to locomotion, burrowing (for dwelling, breeding, nesting), and feeding activities. It also includes short synopses on hominid trace fossils (the

topic reoccurs later, in Chapter 34), as well as the fossil record of vertebrate burrows and nests. Chapter 13 provides new ichnotaxonomic data on a famous and intriguing complex trace fossil, *Zoophycos*, and reinforces the significance of meticulous assessment (and maintenance!) of type specimens. Based on post-Pliocene carbonate records in the Bahamas Archipelago and southeastern Florida, Chapter 14 reviews the key trace-fossil associations of beach and nearshore settings in some carbonate platforms and points out their importance in paleoenvironmental assessment.

Chapter 15 concerns the trace fossils from the hidden habitat of deep-marine settings by highlighting the history of the relevant concepts, major distribution-controlling factors (e.g., substrate types, trophic levels), the geologic record of deep-sea ichnotaxa and the importance of neoichnology. Chapter 16 looks at continental trace fossils as bioproducts of complex environmental realms with high spatial and temporal heterogeneity and hence a reflection of the interaction and variability of biological and physicochemical processes, ranging from the energy level of the depositional processes to moisture content of media. On the other hand, the chapter emphasizes the value of continental trace fossils in reconstructing and assessing changes in ancient ecosystems. Chapter 17 hinges on the application of the ichnofacies and ichnofabric concepts in aquatic continental settings, provides extensive tabulated inventories of ichnotaxa from fluvial and lacustrine environments, and evaluates the uses of freshwater ichnology in continental sequence stratigraphy. Furthermore, it briefly mentions the specificity of some ichnotaxa and the occurrence of freshwater ichnofaunas in marginal marine settings.

Aiming for an improved understanding of the dynamics and evolution of molluscan predator-prey systems, Chapter 18 is a literature synthesis on selected tropical predatory gastropod groups, their applied feeding mechanisms, and resultant marks left on the victims' shells. Mainly concentrated on the recognition criteria of bioclastrations, a relatively understudied ichnotaxa, generated by the embedding of symbionts in the growing skeleton of the host organism, Chapter 19 also discusses briefly ichnofossil diversity trends of beneficial cohabitation in the Paleozoic. Far from boring, Chapter 20 on macroborings and Chapter 21 on microborings lucidly present some specific tracemakers of these bioerosion features and their spatiotemporal adaptation trends. Chapter 22 is a well-structured review on the formation and geological value of stromatolites as trace fossils, which according to some workers (Bertling et al., 2003, 2006) are not trace fossils at all. Probably assuming a systematically documented and sufficiently robust spatiotemporal database, Chapter 23 highlights the importance of trace-fossil distribution patterns in understanding some major events in the history of life and the processes of ecospace colonization through geologic time.

While a modern perspective on future directions, potential areas of expansion and collaboration between subdivisions of ichnology and with related bio- and geological disciplines is commonly woven into several preceding chapters (e.g., Chapter 8, 9, 12, 15, 21), Section III is the ultimate repository of hot, current, and stimulating topics. Most of the 13 chapters in this section place a strong (and welcome!) emphasis on the processes and mechanics of trace production and preservation and imply

the urgency for further rigorous neoichnological research. At the heart of this section lies the recent transformation in the scope, concepts, and *modus operandi* of ichnology, a directional change toward a more dynamic ichnology already heralded in 2003 in a volume on complex trace fossils, also edited by Miller.

Chapter 24 presents a series of utilities (e.g., estimating the stratigraphic completeness of successions) and adversities (e.g., admixing of high-resolution environmental signals by burrowers) of the ichnological data recorded in Quaternary slope and deep-sea sediments. Chapter 25 evaluates the results of modern animal movement studies from an ichnological perspective with an emphasis on the manifestation of these activities in the ichnological record. Chapter 26 is a particular speculation that approaches the biomechanics involved in infaunal burrowing from materials-science and mechanical-engineering viewpoints and stresses the need for qualifying the physical forces involved (both material and animal strength) in production and destruction of traces. Chapter 27 is an introduction to complex trace fossils that are defined here as traces that record multiple functions or behaviors by organisms. It includes an evaluation of the different views of complexity applied to trace fossils (e.g., compositional, organizational, developmental, operational), as well as proposes a method for the functional interpretation of such intricate biostructures. Chapter 28 describes in detail the characteristics of one type of *Zoophycos* and provides superbly illustrated interpretations of the constructional dynamics of these complex ichnofossils. Challenging entrenched ideas on the identity of the *Nereites* producers, Chapter 29 advocates the arthropod-tracemaker model for this complex trace fossil and bases its argument on the distinctive signature of the anatomy and behavior as well as bioprints—sets of morphologic features recognizable in traces—of some modern intertidal arthropods. Chapter 30 reports on a peculiar composite trace fossil generated by the occupation of older, nutrient-rich ray-feeding traces by younger endobenthic deposit-feeder polychaetes. Chapter 31 concerns the study methodologies, preservation history, and paleoenvironmental value of some informally described, submacroscopic (smaller than 1 mm) trace fossils. This case study, which is presented in conjunction with a detailed sedimentological assessment of the host Middle Triassic carbonates, has potential relevance for the meiobenthic ichnology of other fine-grained Phanerozoic successions as well. Chapter 32 is an ichnotaxonomic contribution dedicated to a common and highly characteristic rosetted microboring observed in shells (e.g., bivalves, brachiopods) and cold-water corals with a Carboniferous to recent occurrence, but with an elusive producer. Chapter 33 elucidates the reasons why the application of the well-developed, marine-based ichnofacies concepts in continental lacustrine settings is limited by reviewing the different environmental controlling parameters, briefly characterizing the common burrowing macrobenthic animals and discussing the differences between marine and lacustrine ichnofacies. Chapter 34 is a detailed description of a suite of biotic and abiotic features observed on late Pleistocene bison bones ranging from insect-feeding traces, weathering, and prehistoric human-food processing and compares them to more recent archaeological excavation marks. The chapter briefly mentions the role of bone-hosted traces and marks in reconstructing not only Quaternary environmental conditions but also finer archaeological details

such as killing season and burial conditions. Chapter 35 defines a new continental ichnofacies (*Entradichnus*) to distinguish those diverse associations of ichnotaxa that occur in minimally vegetated arid landscapes with fluctuating precipitation patterns that can be attributed to shallow-burrowing arthropods. Hinged on the argument that the causes of mass extinction events perturb ecosystems and, thus, ultimately affect the trace-fossil record (e.g., diversity, distribution, tiering patterns, ichnofabric), Chapter 36 reviews these variations in benthic infaunal traces across five major Phanerozoic mass-extinction events with the aim to improve the understating of the causes and effects of such global phenomena.

In conclusion, irrespective of one's tier level in ichnology, the reader may be served by this balanced selection of 36 topics resulting in a book that profoundly treats a large variety of contemporary biogeological concepts, fills gaps on some understudied subjects and topics (e.g., ichnology of carbonates, deep-sea settings), synthesizes information and literature from

the intersection of bio- and geosciences, and provides practical incentives for future expansion of the fascinating subject of trace fossil analysis. I heartily recommend it.

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Emese M. Bordy
Rhodes University
Department of Geology
Grahamstown, 6140
South Africa
E.bordy@ru.ac.za