***Ichnoentomology: Insect traces in soils and paleosols*.**

Jorge F. Genise, 2017, Springer, Switzerland, Topics in Geobiology no. 37, 695 p., ISBN 978-3-319-28208-4, cloth, $139.

Jorge Genise has been busy. In the past year, in addition to cranking out important journal papers (e.g., Genise et al. 2016a, 2016b; Bellosi et al. 2016) and a dozen or so conference presentations and abstracts, in the work at hand he has shepherded a benchmark masterpiece on trace fossils through to publication. For any relatively new discipline, there necessarily comes a time for the consolidation and reappraisal of the state of our knowledge; for continental trace fossils, and especially those of insects, this is that time, and Genise's remarkable book, *Ichnoentomology: Insect Traces in Soil and Paleosols*, is the vehicle. The comprehensive nature of this unique work, its scholarly detail, brilliant insights, and exhaustive incorporation of earlier research render the volume impossible to effectively evaluate in a few paragraphs.

The significance of trace fossils (ichnofossils) lies in the fact that they are records of ancient animal behavior and, as such, are comparable in detail to the excavations and constructions of their extant animal descendants and collateral relatives. As regards the trace fossils of insects, they are also excellent and reliable indicators of paleoclimate. Genise recognizes that the trace fossils of insects are best known from paleosols—ancient soils. Most soils develop on alluvial floodplains—their ancient counterparts now comprising bodies of rock that—due to the chemical quiddities of their formation—generally do not preserve insect body fossils, but which also preserve detailed records of paleoclimate. As recently as the mid-1980s, the importance of continental ichnofossils was largely ignored by the paleontology community when compared with those of the marine/paralic realm (e.g., Ekdale et al. 1984), despite the prior (yet then recent) publications of several important contributions on traces from fluvial paleoenvironments (e.g., Ratcliffe and Fagerstrom 1980; Laza 1982; Bown 1982; Bown and Kraus 1983; Retallack 1984). The current spate of research on fluvial traces in no way detracts from the seminal work of students of marine traces; rather, it is an expansion of that work for which Genise's *Ichnoentomology* serves as a noble and, in fact, a monumental tribute.

Although continental trace fossils—e.g., Brown (1934), Frenguelli (1938), and Roselli (1939)—and paleosols—e.g., Harvey (1960), Chaleyshev (1969), Freytet (1971), Yaalon (1971), Neasham and Vondra (1972), and Andreis (1972)—were recognized more than half a century ago, the disciplines of continental ichnology and paleopedology only came into their own following the late 1970s, hand-in-hand with a spate of advances in fluvial sedimentology. That interest in the two disciplines would blossom concomitantly reflects: (1) the nature of floodplain deposits, which consist of stacked paleosols from bottom to top (e.g., Bown and Kraus, 1981); and (2) the rich record of insect and other animal activity in both modern and ancient soils.

Most brilliant works are idiosyncratic, and in this regard Genise's refreshingly novel contribution does not disappoint, instructing the reader that his book is concerned principally with the trace fossil record of insects in paleosols and that "… every chapter is linked in different ways with several others and as part of a literary exercise, the book was thought as a circular tale that readers can start in any chapter without losing the thread." The beginning of that thread, Genise cogently instructs us, is *the wall*, for "The wall is the minimal expression of a trace. No wall, no discontinuity with the substrate, no trace." And, therefore "Every trace begins with a wall", the walls of distinct trace-makers are distinctive, and these walls may be defined by their surface morphology, as well as the micromorphology of the wall sediment.

An entomologist, Genise has chosen as his specialty the traces produced by insects. It is estimated that somewhere around 7.7 million described and undescribed species of animals exist in the world (Mora et al. 2011) including, among only the described forms, nearly a million species of insects. Grimaldi and Engel (2013) suggest that the insects alone might have as many as 2.5–10.0 million species. Whatever the ultimate number of insect species, up to 40% of the described species are beetles (Coleoptera), with the bees, wasps, and ants (Hymenoptera) perhaps being nearly as diverse (Stork et al. 2015). The majority of beetles and a goodly proportion of the hymenopterans (especially the ants) are prodigious diggers and, in this activity, to these we must add the termites (Blattodea, Isoptera) and cicadas (Hemiptera, Auchenorrhycha). All of those, and some others, are well documented in the record of described trace fossils. In fact, the behavioral diversity of potential trace-makers among the digging and burrowing insects instructs that we can only expect the number of recognized insect traces to grow and, with enhanced understanding of their trace-making behaviors, their paleoecological significance to grow in proportion.

The book is organized in 22 chapters. Following the Introduction and a chapter on "The Wall", Chapter 3 is devoted to further definition of the micromorphological aspects of trace fossils as well as characteristics of their shape and fillings. Trace fossil morphology is basically simple and consists of two volumetric components; the chamber and its fillings: tunnels, burrows, and galleries are simply unexpanded chambers, and the nature and geometry of the chambers and their fill—as well as any bioglyph on wall or in filling—are simple embroideries useful in determining details in the actions of trace-making as well as in establishing a classification.

Anything can be classified according to any plan, the nature of the classification being limited only by the imagination of the classifier. As "… a morphologically recurrent structure that results from the life activity of an individual organism … which modifies the substrate …" a trace fossil could logically share the classificatory scheme imposed on its creator if, of course, its creator were known. And, in the instances of traces constructed according to simple plans and yielding few morphological details, the likelihood is strong that more than one organism could produce the same trace. Any organism of whatever morphology that moves through sediment produces a tunnel or trail that looks somewhat like the burrow of a worm and, commonly even more so, the worm itself. When I read my first geological studies in the early 1960s, I ran across numerous references to this rock or that impregnated with "worm burrows". Mercifully, we have learned a bit since then. In the work at hand, Genise adopts his (Genise 2000, 2004) ichnotaxonomy, with the ichnofamilies Celliformidae, Coprinisphaeridae, Pallichnidae, and Krausichnidae, utilizing the presence and nature of excavated or constructed chambers to recognize the "… most distinctive features of insect trace fossils in paleosols."

Genise characterizes his Chapters 5 and 6 (keys to the Celliformidae and Coprinisphaeridae and to the Krausichnidae and Pallichnidae, respectively) as "heavy ichnotaxonomy"—chapters that "pretend … to be a practical assistance … to identify trace fossils in the field" [strongly paraphrased]. They are, of course, of immense practical assistance. Chapters 7 and 8 discuss the architecture of dung beetle brood chambers and the considerable and important record of these structures as trace fossils. The nest architectures and trace fossils of the soil nesting wasps and bees (Hymenoptera) are summarized in exquisite detail in Chapters 9 and 10, and the most complex of all insect structures—the nest architectures and gallery systems of the ants (Hymenoptera) and termites (Blattodea, Isoptera) are concisely described and profusely illustrated in Chapter 11, followed by a masterful exposition on the trace fossil record of eusociality in ants and termites (Chapter 12). The trace fossils of other insects (cicadas, chafers, weevils, and sphinx moths) and the traces of insects that invaded the nests of other insects to steal food or parasitize their larvae are unique conspectuses documented in Chapters 13 and 14. The traces and trace fossils of crayfish and other crustaceans, earthworms (Oligochaeta), and other non-insect trace-makers are discussed in Chapter 15, followed by original treatments of the trace fossils of vertebrates and roots (Chapter 16), and the trace fossils, including trackways, of insects in substrates other than paleosols (Chapters 17 and 18). Chapter 19 begins with a pithy yet excellent summary of the history of study of the evolution of behavior and a recap of ethological studies of hymenopterans, followed by the methodological integration of behavioral studies and cladistics and a succinct discourse on the ichnological approach to the evolution of behavior. Superb examples of insect ichnofabrics in paleosols are chronicled in case studies of the Paleogene Asencio Formation of southern Uruguay and the middle Eocene to middle Miocene Sarmiento Formation of Patagonian Argentina (Chapter 20). Association of trace fossils that recur in space and time constitute ichnofacies (Seilacher 1967), and these are named after a prevalent ichnogenus and encompass trace fossils of particular sedimentary environments. In Chapter 21, Genise recognizes the *Scoyenia*, *Coprinisphaera*, *Celliforma*, *Termitichnus*, *Camborygma*, and rhizolith ichnofacies, which are variously typical of alluvial to lake margin paleoenvironments ranging from periodically submerged to open and closed forest/herbaceous communities under warm and humid to cool and or dry conditions. In the final Chapter (22), The Ichnoentomological Synthesis, Genise notes the almost incredible diversity of insects, and observes that "… the true **key** for the dominance of insect trace fossils in paleosols is that they are mostly structures for larval development, either as nest or pupation chambers." The various insects "… provide these structures with elaborated linings … and particular shapes … in order to isolate them from the surrounding soil …" thus increasing their complexity, their capacity to be identified with their trace-makers, their value as paleoecological markers and, ultimately, their recognition as soil-forming factors.

Ichnoentomology is an authoritative work that illuminates all the dark tunnels and chambers of the myriad G*rottes de Chauvet* of insect ichnology and translates the hieroglyphics of the bioglyphs written on their walls. It is a remarkable work that effectively straddles the hostile marchland between a reference volume and a textbook. The writing is highly accessible—at once entrancingly instructive and disarmingly friendly, almost conversational in its presentation. That the author enjoys his subject is clear, and the abundant literary quotations and anecdotal references make reading the book much akin to enjoying a series of lectures by a doting, avuncular professor. Generously illustrated, the numerous superb photographs and schematic diagrams of fossil and modern insect traces set this book apart and effectively portray a wealth of newly illustrated forms that will help to establish Genise's *Ichnoentomology* as an indispensable, nonpareil resource on continental traces and trace fossils for student and professional ichnologists, entomologists, general geologists and paleontologists, pedologists and paleopedologists, and fluvial sedimentologists for decades to come.

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