THE SETTLING BEHAVIOR OF BRACHIOPOD SHELLS: STRATIGRAPHICAL AND TAPHONOMICAL IMPLICATIONS TO SHELL BED FORMATION AND PALEOECOLOGY

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Brachiopod shells as well as their shell-rich concentrations are noteworthy features of the Phanerozoic sedimentary record. The genesis and environmental distribution of those concentrations are governed by complex taphonomic (e.g. susceptibility to transport and differential destruction) and environmental factors (e.g. sea level). Hence, it is crucial to understand the taphonomic processes, and the potential biases introduced by biostratinomic and diagenetic agents operating in their genesis. However, the manner that these agents operate, and the taphonomic signatures left in the 'products' (fossil concentrations or modern skeletal accumulations) are not always intuitive. In many cases, only through actualistic experimental studies (laboratory and field) can the (a) nature, (b) characteristics and (c) meaning of fossil concentrations be better understood. Since under shallow water conditions brachiopod shells are susceptible to differential rates of transport, fragmentation/abrasion and sorting, it is instructive to examine the comparatively simple hydrodynamic behavior of those shells falling through a column of salt water (see McKittrick 1987, to similar approach with mollusk shells). Hence, the goal of this study is to determine the settling velocities and behaviors of shells of the terebratulid brachiopod *Bouchardia rosea* (Mawe), under laboratory conditions.

B. rosea is a small, epifaunal, free-lying brachiopod with shells fabric similar to some forms of Paleozoic brachiopods. Dead assemblages of *B. rosea* are common in surficial nearshore environments of the São Paulo State, and bouchardiid-rich shell-beds are also common in many Tertiary rocks of South America, Antarctica, and Australia.

Twenty three individual valves (10 dorsal, 10 ventral and 3 articulated), encompassing the typical range of size of *B. rosea* shells were selected to the experiment. Shells were dried and weighted in air to the nearest 0.01g. The diameters of the three major axes of shells were measured to the nearest 1mm. Hydraulic settling velocities were recorded by releasing shells in a 35 cm wide and 56 cm deep column filled with natural salt water. Settling times were measured to the nearest 0.01 second, but falling durations were rounded to the nearest 0.1 second for calculation of settling velocities. Each shell was released just beneath the water surface for ten consecutive runs (230 releases total). In this context, our experiment is methodologically similar to that published by A.M., McKittrick, in 1987. The reason for this is to make our data methodologically comparable to that author, who conversely studied bivalve and gastropod shells.

Our data indicate that the average settling velocities for ventral valves is 15.35 cm/s, and 16.65 cm/s for dorsal ones. Articulated shells have average settling velocities of 26.48 cm/s. During the falling process, no matter the original orientation (concave-down or -up) at release, both dorsal and ventral shells of all studied specimens will quickly roll over. Hence, without exception brachiopod shells will descend and settle in a concave-up (or convex-down) orientation.

The lower average settling velocities of ventral shells indicate that they could stay for longer in the water column. In part, this pattern may be explained by the fact that ventral valves have greater cross-sectional areas than dorsal ones of the same weight. These data have important paleoecological implications, since in comparative taphonomy the proportion of ventral and dorsal valves is used to infer shell transport, environment energy, and residence time in the sediment/water interface. Similarly to clams in which the proportion of left to right valves deviates from a one-to-one ratio, brachiopod-rich accumulations also exhibit biased ratios of dorsal and ventral valves. Unfortunately, for brachiopod shells little is known about the mechanisms causing this phenomenon. However, our data show that the bias between dorsal and ventral brachiopod valves observed in many fossil concentrations and modern environments (e.g., beaches) cannot be viewed as the result of differential resistance to fragmentation and abrasion solely. The lower average settling velocities of *B. rosea* ventral shells may suggest that these could be transported to greater distances than dorsal do. This may help to explain the fact that some modern accumulations of *B. rosea* shells generated under shallow water conditions exhibit a strong bias in favor to convex ventral valves (see Simões and Kowalewski, 2003 for a beach example). This is because the flat dorsal valves with more rapid settling velocities are likely to lag behind. Hence, in this particular case the valve ratio may be one important taphonomic attribute to recognize authochtonous to allochthonous assemblages and to track the history of a given fossil assemblage, especially when combined with other taphonomical and sedimentological/stratigraphical signatures.

Our data can also be used to rank the shells (e.g., disarticulated versus articulated shells) according to their settling velocities. As commented above, the average settling velocities for *B. rosea* ventral valves is 15.35 cm/sec. and 16.65 cm/sec. for dorsal ones. However, closed articulated shells have faster average settling velocities (26.48 cm/sec). Intuitively, in a given shell-bed accumulated through hydraulic processes (and not disrupted by intrastratal biological active) the articulated shells will occur at the base of the bed, as a result of their more rapid falling velocities. For example, brachiopod-dominated concentrations containing terebratulids (*Rhaetina gregaria*), Frata Formation (Upper Triassic, West Carpathians) (see Tomašových 2004), such as bio-floatstones and biointra-packstones with complex internal structures that were generated by high-energy events (storms) show large closed articulated valves at the base of the deposits (sometimes near or at the erosional base) having nested, convex-down brachiopod shells upward (to the top). According to our experiments and the terminal fall velocities between disarticulated and articulated brachiopod shells those fabrics indicate that the shells experienced suspension settling during their deposition. Hence, our experimental data are in strong agreement with the sedimentological and stratigraphical observations of Tomašových (2004). Because bouchardiid-dominated concentrations are common in the Tertiary of South America our data and assumptions may also be directly tested in the geological record.

References

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