

The limit between biostratinomy and fossildiagenesis

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INTRODUCTION

The history of fossils during fossilization has been a subject of palaeontological interest for the last two centuries. Studies about fossilization have emphasized two aspects of fossils: 1) the diverse environments and detailed processes that occurred during fossilization and 2) their chronological order. As referred by many authors, important events in the history of a given fossil are: death and biogenic production of remains or traces, burial and discovery. Taking into account different criteria, several scientific disciplines concerning processes and phases or stages of fossilization have been proposed during the last century (Fig. 1). Consequently, the meaning of taphonomic disciplines, as well as the quantity and the limits between them, have been modified in different senses by different authors mainly over the last forty years.

Biostratinomy and fossildiagenesis are two taphonomic disciplines, having their own concepts, subjects, application fields, goals and methods, but the limit between these disciplines is not clearly established. The aim of this paper is to analyse the diverse meanings of the terms "biostratinomy" and "fossildiagenesis", determining the most appropriate limit between the application fields of these disciplines in order to solve the current ambiguity.

BIOSTRATINOMY

The term "biostratinomy" was proposed by Weigelt (1927a). This term was, for etymological reasons, changed twenty-seven years later to "biostratinomy" (Wolf, 1954). According to the original meaning, biostratinomy is a scientific discipline between Palaeobiology (concerning life) and fossilization (referring the post-burial fate of biogenic remains). As originally defined, biostratinomy is concerned with death and mechanic changes in distribution of organism remains on the sedimentary surface, as well as the spatial relationships of fossil to each other and to the enclosing sediment. Biostratinomic concepts and methods were mainly developed by Weigelt (1927b), Müller (1951, 1963, 1979) and Schäfer (1962). However, according to a new definition proposed by Lawrence (1968), biostratinomy became a branch of Palaeoecology including certain post-burial changes and referring to a particular phase of the fossilization. In the last years, biostratinomy has been considered a palaeontological discipline or conceptual (sub)system of taphonomy, useful not only in Palaeoecology but also in palaeobiogeography, evolution and biochronology (Fernández López, 1982, 1988, 1991, 1997, 2000; Janin, 1983; Behrensmeyer & Kidwell, 1985; Andrews, 1990; Berger & Strasser, 1994; De Renzi, 1997; Martinell, 1997; Pavia & Martire, 1997; Denys *et al.*, 1997; Behrensmeyer *et al.*, 2000).

Biostratinomy has its own concepts, subjects, application field, goals and methods. The application field of biostratinomy have been considered in two different senses: 1) a type of process or environment of fossilization and 2) a phase or stage of fossilization.

As a type of process or environment of fossilization, biostratinomy has been commonly used to denote the sedimentary history of biogenic remains. Fossils are regarded as sedimentary particles standardized in size and shape to reconstruct sedimentary processes (Seilacher, 1973; 1984: 7; Cadée, 1991). Biostratinomic modifications include physical, mechanical or sedimentary processes, such as disarticulation, abrasion, transport, dispersal, sorting and resedimentation.

As a phase or stage of fossilization, rather than a type of process or environment, biostratinomy would comprise all processes occurring after the death of an organism until its burial. From this point of view, biostratinomy is the study of what happens in the time interval, phase or stage between the death or the biogenic production of a remain or trace and its burial.

FOSSILDIAGENESIS

The discipline named "Fossildiagenese" was proposed and developed by Müller (1951, 1963, 1979). This term was originally defined as the processes acting upon sediment and its constituents from deposition to eventual alteration by metamorphism or weathering. The proper nouns "Fossildiagenese" and "fossildiagenesis", as

Biogenic production - death		Initial burial		Initial exhumation		Final burial		Final exhumation - discovery		Present day			
Fossilization										LYELL, 1833			
Fossilization										ORBIGNY, 1849			
Fossilization										DEECKE, 1923			
Biostratinomy					Fossilization					WEIGELT, 1927			
Accumulation (concentration)		Burial (transport and sedimentation)			Fossilization (mineralization and diagenesis)					EFREMOV, 1940			
Taphonomy													
Necrolysis		Fossil diagenesis		Biostratinomy		"Fossildiagenese" Fossil diagenesis				MÜLLER, 1951, 1963, 1979			
Biostratinomy		Fossilization (Taphonomy)											
Biostratinomy						"Fossildiagenese"							
Taphonomy													
Biostratinomy						Diagenesis Weathering							
Taphonomy													
Biostratinomy		Prefossilization			Fossilization or "Fossil-diagenese"				SEILACHER, 1973				
Taphonomy													
Sedimentation I		Diagenesis I		Sedimentation II		Diagenesis II				SEILACHER, 1984			
Taphonomy													
Biostratinomy		Fossildiagenesis										FERNANDEZ LOPEZ, 1984, 1988, 1989, 2000	
Taphonomy													
Necrology		Biostratinomy					Diagenesis					BEHRENSMEYER & KIDWELL, 1985	
Taphonomy													
Perthotaxic factors (pre-burial)		Taphic factors (burial)				Anataxic factors (weathering- erosion)		Sullegic and trephic factors				HESS & WAPNISH, 1985	
Taphonomy													
Necrolysis		Fossil diagenesis		Biostratinomy 2		Fossil diagenesis					WILSON, 1988		
Biostratinomy 1		Taphonomy											
Necrolysis		Prefossilization		Biostratinomy		Fossilization Weathering					SEILACHER, 1992		
Biostratinomy		Fossil Diagenesis		Fossil Diagenesis									
Taphonomy													
Fossilization													
Taphonomy						Diagenesis						DAUPHIN et al., 1994, 1999	

Fig. 1.- Diverse palaeontological disciplines related to fossilization processes, and different classification systems, as considered by different authors. These disciplines denote distinct intervals during fossilization, from death or biogenic production in the past to discovery or present day.

well as the common nouns "diagenetic studies", "diagenesis of fossils" or "fossil diagenesis", have been employed to define a palaeontological discipline related to fossilization. All these terms have been considered in two different senses: 1) a type of process or environment of fossilization and 2) a phase or stage of fossilization.

As a type of process or environment, the concept of fossil diagenesis is used to comprise all those processes that take place within a sediment or rock to its contained fossils (Müller, 1963, 1979; Rolfe & Brett, 1969: 232; Seilacher, 1995: 24; Cadée, 1991). Diagenetic modifications of fossils include processes of different category, such as mineralization, dissolution, compaction or distortion of remains and traces while they are associated with bioturbation, lithostatic pressure or tectonic deformation of sediments or rocks.

As a phase or stage, fossil diagenesis would begin in a different moment, according to definitions proposed by different authors. For some of them (Müller, 1979: 48; Graham & Kay, 1988: 233) it would begin after deposition; whilst for some others (Rolfe & Brett, 1969; Martinell *et al* 1980; Gifford, 1981; Wilson, 1988; Cadée, 1991), it would begin after burial and associated with the initial burial (Fernández-López, 1984, 1988, 1989, 2000). Finally, for some other authors, it would begin after the final burial (Müller, 1951, 1963; Müller & Zimmermann, 1962; Lawrence, 1968, 1971, 1979; Lyman, 1994) being, hence, associated with permanent burial (Hanson, 1980). The diversity and disparity of these criteria are not justified by theoretical or methodological reasons, and the choice of one of these limits is a question of decision which has to be solved by scientific agreement. Nevertheless, some assertions about these limits involve a mistake among the meanings of terms such as fossil diagenesis, diagenesis, burial and mineralization. For example, Lawrence (1968, 1971) defined fossil diagenesis as starting after final burial, but he remarked that certain diagenetic processes such as mineralization of fossils may occur before final burial. By definition, if fossil diagenesis is defined as starting after final burial, then fossil diagenetic modifications of fossils cannot occur before final burial, although mineralization and other diagenetic modifications of fossils may occur before final burial.

LIMITS BETWEEN BIOSTRATINOMY AND FOSSILDIAGENESIS

"Biostratinomy" and "fossil diagenesis" (or "fossil diagenesis") are terms generally employed to design different palaeontological (sub)disciplines or conceptual (sub)systems. In this respect, they are well differentiated, having their own concepts, subjects, application fields, goals and methods. Problems of limit between both disciplines are rather concerned with their application fields. Preservational features of a fossil can be ascribed to one or more types of process, environment or phase occurred during fossilization. The amount of these categories of processes, environments or phases is a conventional matter that should be justified by practical reasons. The proposed categories, however, must not give rise to arbitrary terms or concepts.

From a theoretical point of view, the limits between the application fields of biostratinomy and fossildiagenesis may be justified by 1) two types of process or environment of fossilization and 2) two phases or stages of fossilization.

- 1) In the first case, if it corresponds to the limit between physical, mechanical or sedimentary processes on the one hand, and chemical or diagenetic processes, on the other, then the terms "biostratinomy" and "fossildiagenesis" show a more general meaning than mentioned above (ordinary or geological) processes. However, these kind of processes do not involve any chronological order. In contrast, if the limit between biostratinomy and fossildiagenesis corresponds to the limit between two successive phases or stages of fossilization, then these two terms imply a chronological order.
- 2) If the limit between biostratinomy and fossildiagenesis corresponds to the limit between two successive phases or stages of fossilization, the criterion to define the limit between these taphonomic disciplines may be based on 2a) a particular fossilization event or 2b) a particular fossilization phase or stage.
 - 2a) In order to distinguish two consecutive phases of fossilization, the event of reference may be the burial and, in particular, either the initial burial or the final burial. If the initial burial would be chosen as event of reference, any evidence of burial would corroborate the fossildiagenetic phase. In contrast, if the final burial is taken as event of reference, it would be necessary to distinguish between diagenetic results of pre-final burial and diagenetic results of post-final burial to corroborate the fossildiagenetic phase. Consequently, the commonly used criterion of final burial give rise to more methodological problems than the criterion of initial burial. According to this sense, biostratinomy is followed by fossildiagenesis and, for methodological reasons, the end of the biostratinomic phase and the beginning of the fossildiagenetic phase should be marked by the start of the burial. From this point of view, for example, taphonomic resedimentation (*i.e.*, removal of taphonomic elements before burial) is a biostratinomic process, whilst taphonomic reelaboration or taphonomic reworking (*i.e.*, exhumation and displacement of taphonomic elements before the final burial) is a fossildiagenetic process.
 - 2b) In order to distinguish successive phases or stages of fossilization, but not necessarily consecutive, a valid criterion may be the difference between buried or non-buried stages. Many authors have distinguished in certain fossilization processes several diagenetic phases separated by sedimentary or biostratinomic phases. When this is the case, "fossildiagenetic phase" and "biostratinomic phase" become respectively synonymous of buried and non-buried phases, or diagenetic and non-diagenetic phases. Consequently, in this respect, these phases can be named using ordinary or geological terms (*e.g.*, burial or diagenesis) and the

terms biostratinomy and fossildiagenesis lack of any particular taphonomic application fields.

In summary, according to the most common use, biostratinomy and fossildiagenesis can be considered as two consecutive phases of fossilization. However, for methodological reasons, the end of the biostratinomic phase and the beginning of the fossildiagenetic phase should be marked by the beginning of the burial. If the fossilization processes are understood as non-linear, then the particular processes of these taphonomic phases, stages or intervals can be considered as non-consecutive and non-successive (Fernández-López, 1984; Seilacher, 1992).

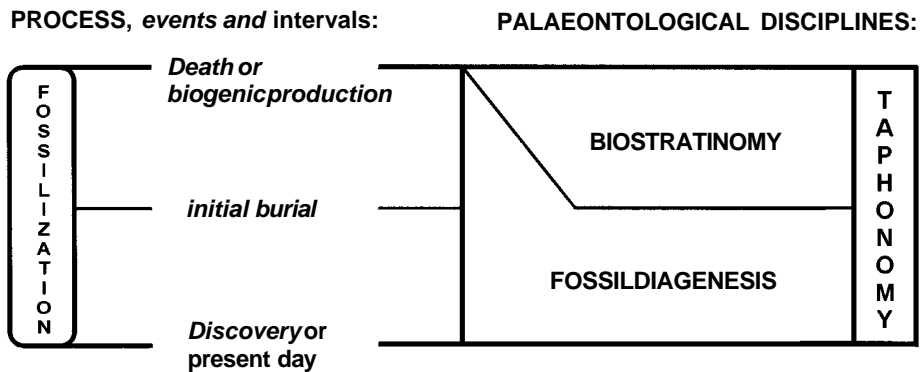


Fig 2 - Scheme of several palaeontological disciplines referring processes, events, phases or intervals of fossilization, as proposed in this paper. In general, taphonomy and taphonomic knowledge may be subdivided in two (sub)disciplines: biostratinomy and fossildiagenesis. However, biostratinomic processes are not necessary in fossilization. There are many fossils, corresponding to remains or traces biogenically produced within sediments or rocks, which have never been affected by any biostratinomic modification. Biostratinomic and fossildiagenetic modifications should be considered as contingent processes during fossilization, although taphonomy is subdivided into biostratinomy and fossildiagenesis.

Dividing the history of fossils during fossilization in several phases, stages or intervals may be useful in many cases, for theoretical and methodological reasons. The terms biostratinomy and fossildiagenesis may be employed to distinguish two taphonomic disciplines, two types of process or environment of fossilization, as well as two phases, stages or intervals of fossilization. In this respect, fossildiagenesis and diagenesis of fossils are not synonymous terms. However, biostratinomy and fossildiagenesis should not be considered as necessary processes, phases, stages or intervals during fossilization. Note, for example, many fossils correspond to remains and traces biogenically produced within deposits or rocks, and have undergone no pre-burial modifications (Fig. 2). Moreover, many taphonomic elements have undergone only biostratinomic modifications before being destroyed. Consequently, biostratinomic and fossildiagenetic modifications should be considered as contingent

processes during fossilization, that may or may not occur, although taphonomy is subdivided into biostratinomy and fossildiagenesis.

CONCLUSIONS

Biostratinomy and fossildiagenesis may be understood as two taphonomic disciplines, having their own concepts, subjects, application fields, goals and methods. They should also denote different and clearly delimited application fields. Biostratinomy deals with the pre-burial modifications of taphonomic elements. Fossildiagenesis, in turn, comprises their modifications after the initial burial. In this respect, fossildiagenesis and diagenesis of fossils are not synonymous terms. However, fossilization processes do not imply the occurrence of biostratinomic and fossildiagenetic modifications, phases, stages or time-intervals.

SUMMARY

The history of fossils during fossilization is a subject of taphonomy. According to the most common classification system over the last forty years, taphonomy may be subdivided in several (sub)disciplines. Biostratinomy and fossildiagenesis are two taphonomic disciplines, having their own concepts, subjects, goals and methods. However, they have not application fields clearly delimited. In order to solve the current ambiguity, biostratinomy should deal with pre-burial modifications, and fossildiagenesis should comprise modifications after the initial burial. Although taphonomy is subdivided into biostratinomy and fossildiagenesis, fossilization processes do not imply the occurrence of biostratinomic and fossildiagenetic modifications, phases, stages or time-intervals. Biostratinomic and fossildiagenetic modifications should be considered as contingent processes during fossilization.

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