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The usefulness of a taphonomic approach for studies of Pleistocene mammals

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Abstract

The potential usefulness of taphonomical research for studies of Pleistocene mammal remains is detailed. The required taphonomical research involves two stages. The first one is the biostratinomical stage, which concerns the time between the death of the organism and its burial; for this time-span, the spatial distribution of the remnants is analysed, as well as the weathering marks, the activity of predators (i.e. gnawing and digestion), the influence of temperature, intentional human activity, rodent marks (i.e. gnawing), and trampling. in the second one is the diagenetic stage, which deals with the time-span from the burial of the remnants to their discovery; for this time-span, the influence of physical and chemical processes (including diagenetic alterations of the deposit, the influence of water, and plant-root marks) are considered.

The application of taphonomical analysis provides the possibility of reconstructing the environmental conditions under which the skeleton or bone complex was preserved, as well as the depositional history of the bones (postconsumption remnants, flood remains, accumulation of bones by predators). This opens new possibilities for the study of Pleistocene bones in Poland.

Keywords: taphonomy, Pleistocene, mammals' bones.

Introduction

Bones and teeth are the most common objects of research into Pleistocene mammals. Soft parts – such as skin, fur, and internal organs – may also be well fossilized. More or less complete skeletons are rarely found, a notable exception being the most complete cave lion (*Panthera leo spelaea*) skeleton uncovered from Upper Pleistocene deposits from Central Bohemia (Czech Republic) (Diedrich, 2007).

Skeletons with soft parts are also very rare, although the skeleton, body and organs of a baby mammoth (*Mammuthus primigenius*), referred to as 'Lyuba', was found preserved in the permafrost of the Yamalo-Nenets region (Siberia, Russia) (Rebert, 2008; Mueller, 2009). The six-month-old female had been in the permafrost for some 40,000 years. Another example of a specimen conserved in the permafrost is the 20,380-year old woolly mammoth (*Mammuthus primigenius*), called the 'Jarkov Mammoth', of which the bones were found on the Taimyr Peninsula, Siberia (Mol et al., 2001). In the case of the remains of a woolly rhinoceros and a mammoth that lived 36–14 ka) ago in Starunia (Carpathian Region, Ukraine), supersaturation with petroleum derivatives and sodium chloride (present in the remnants' surroundings) was deduced to be the cause of the preservation of the skeleton, skin, tendons, and muscles (Kubiak, 1996; Kotarba et al., 2008).

Both macroscopic and microscopic methods are used in bones studies (Wiszniowska & Kuryszko, 1998). In macroscopic studies, the species and the anatomical identity of the bones, as well as the age and sex of the individuals, may be determined. It is particularly important to determine the number of identified specimens (NISP) and the minimum number of individuals (MNI), which are measures of the relative frequency of species in the material under investigation. The method for calculating the MNI has been described by White (1953); it was later modified by Bökönyi (1970) and Chaplin (1971). The establishment of the MNI involves determination of the number of elements as well as identification of the elements. It is consequently necessary to first estimate the minimum number of elements (MNE), as described by Lyman (1994b). In turn, the MNE is the basis for calculating Binford's (1984) minimum number of animal units (MAU).

Microscopic examination allows actual pathological states to be distinguished from adaptive states of bone tissue (Baglaj et al., 2001; Ruimerman, 2005; Ruimerman & Huiskes, 2005). This forms the basis for conclusions concerning the physical condition of the animals.

Taphonomic analysis forms a good starting point for palaeozoological studies (Efremov, 1940; Lyman, 1994a). The purpose of the present contribution is to show the potential significance of taphonomical research in studies of Pleistocene mammal remains; such research may help to reconstruct the conditions and depositional history of the bones, as will be shown by means of several case studies.

The taphonomic approach

Taphonomy comprises all processes which act on organic remnants, from the death of the organism through to fossilization (Behrensmeyer & Hill, 1980). According to Efremov (1940), taphonomy is the transition of animal remains from the biosphere to the lithosphere. According to Müller (1951), the transition occurs in two stages: the first is the biostratinomical stage (the time from the death of the organism to the burial of its remnants), and the second is the diagenetic stage (from burial of the remains to their discovery). The spatial distribution of the remnants is analysed for the biostratinomical stage, as well as the weathering marks, the activity of predators (gnawing, digestion), temperature effects, intentional human activity, rodent marks (gnawing), and trampling. For the diagenetic stage, the influence of physical and chemical processes leading to fragmentation of the material are considered.

Taphonomy affects the paleontological record, because it evaluates the processes which lead to the preservation or non-preservation of a fossil. In view of the quality of the record, which may be incomplete (sometimes to different degrees in one single succession or unit), it is necessary to draw conclusions carefully, bearing in mind that commonly several interpretations are possible. An example is the progressive loss of wildebeest carcasses and bones via taphonomic processes, as been detailed by Behrensmeyer (1982) (see also Martin, 1999) (Table 1).

The spatial distribution of bones is affected by the speed of burial, animal activity, and the energy of the environment if the deposition took place subaqueously. An articulated skeleton may indicate a lack of transport or limited transport, deposition in a low-energy aquatic environment, or fast burial. The term 'articulated' comes from the Latin root 'articulus' = joint: the area where two bones are attached for the purpose of motion of body parts is thus called the 'articulation'.

A significant relationship exists between an articulated skeleton on the one hand and transport and orientation of its bones on the other hand. Voorhies (1969) found that most of the bones in 'deep' water (this meant in his flume experiments 7–10 cm deep) were oriented current-parallel. According to Coard & Dennell (1995), articulated bones display in a water depth of 0–26 m a greater transport potential than disarticulated bones, and their rate of movement is also significantly faster. Elongate bones, too, tend to orientate parallel to the current. This also holds for complete skeletons;

Table 1. Influence of taphonomic processes on the loss of wildebeest carcasses. Data from Behrensmeyer (1982), cited by Martin (1999). The numbers are based on field studies in the Amboseli Basin (Kenya, Africa).

taphonomic processes	number of carcasses	number of bones per carcass
initial data	1000	152
weathering, trampling, burial per year with influence of age of individuals, especially infants and juveniles	250	0
after carnivore activity	150	105
stage of moderate weathering (stage 3)	0	52
buried assemblages	50	8

their longest axis tends to be aligned parallel to the paleocurrent. A clear example is the skeleton of a horse, deposited in upper Pleistocene fluvioglacial sands at Sieraków (Fig. 1). The slight degree of bone weathering, the lack of bioerosion traces (gnawing by other animals), and the articulation of the skeleton all point to quick burial.

In the case of slower burial, multi-element skeletons undergo relatively quicker disarticulation, as observed by Hill (1980). He found that, after a few weeks, the remains of a medium-sized recent bovid carcass lying on the surface in Uganda (East Africa) had become largely disarticulated. In other cases of slow burial, the skeleton may remain only partly articulated; an example are the bones of the left manus of the wooly mammoth (*Mammuthus primigenius*) found at Skaratki near Warsaw The problem is that these bones were found in a heap of displaced earth, but it is possible that they were originally deposited in a layer separating deposits from the two cold maxima of the last glaciations (Wojtal, 2007). Another possibility in the case of slow burial is that the skeleton remains are represented by a single bone. Exceptions in the form of excellent preservation, even after slow burial, may result from the specific environmental conditions (e.g. the presence of petroleum derivatives, sodium chloride, or permafrost), as mentioned above.

The longer the time before burial of bones, the more weathered the skeletal elements become, and the longer they are exposed to predators.

Bone weathering is measured on a six-point scale (Behrensmeyer, 1978), which can help to estimate the duration of exposure of the bone. Bones exposed on the surface for up to three years may be unweathered, very slightly weathered, or slightly weathered. After more than four years of surface exposure, bones show slight, medium, heavy, or very heavy weathering.

The marks which show activity of Pleistocene carnivores (such as hyenas and bears) include impactions and uneven edges, as visible, for instance, on a long bone fragment from the Komarowa Cave from a layer accumulated during the Interplenivistulian period (approx. 45 –25 ka BP); this bone showes what are probably cave-hyena gnawing marks (Wojtal, 2007). In the case of a bone deposit at Glaston (England), taphonomic research indicated that a cave hyena gnawed frozen horse meat (Glaston Project, 2000). The evidence came from a tooth that the hyena lost during chewing and that found together with horse bones; if the meat had not been frozen, the hyena would not

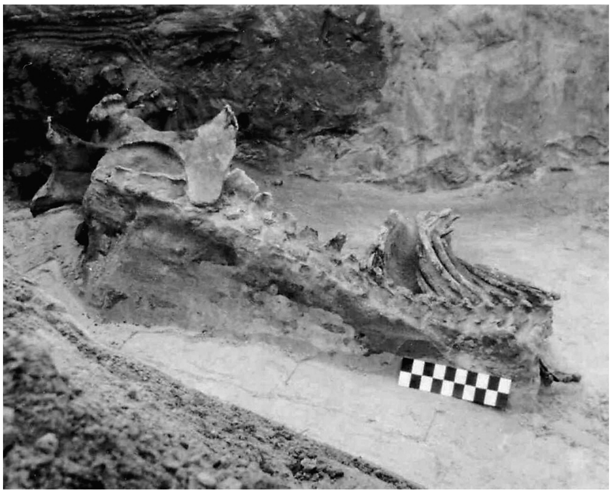

Fig. 1. Sieraków, the upper Pleistocene deposits. The horse skeleton (*Equus caballus*) is oriented in the direction of river palaeoflow. Scale 25 cm.

have needed to apply so much pressure with its jaw that a tooth was lost.

The activities of predators may play a role in bone accumulation. A good example is the Biedensteg site in Germany. This site is an open feeding deposit and a den of hyenas (Diedrich, 2006a,b). Hyenas used this place for a long time, as suggested by the presence of their bones and by gnawing marks on the bones of other mammals, including cave bears. The bear bones are articulated and come from one individual. According to Diedrich (2006b), two scenarios are possible: the elements of the bear's front limb may be derived from a carcass, or they are the results of a successful hunt, after which they were transported to the den. Of the latter possibility would indicate a unique hyena feeding strategy. In addition to the bones, also hyena coprolites were found at Biedensteg. Coprolites may contain small pieces of plant tissue, feathers, hairs, seeds, insect parts, and tiny bones (Bryant & Dean, 2006). Digested bone fragments have usually high degree of polishing, rounded edges, and rounded and concave marks left by the action of the digestive fluids (Fisher, 1995). In general, the size of the digested fragments depends on the size of the consumer; coprolites of large consumers occasionally even contain a complete short bone. In summary, the preservation of bones that have been eaten is affected by the eating behaviour of the animals that consume a prey, the chemistry of the consumer's intestinal tract, and the post-defecation environment (Reinhard et al., 2007).

An interesting depositional reconstructed on the basis of taphonomical indicators concerns Bonfire Shelter (USA), where three layers of bones indicate three acts of driving a bison herd over the edge of a cliff by Pleistocene Paleo-Indians (Bement, 2007). The first stage of dismembering was performed *in situ*, as indicated by the presence of cut marks on the bones. This was done systematically and carefully, as there is no articulation among the bone remains, and so no wasted fat. The decomposition of the mass of carrion was caused by a single fire resulting from spontaneous ignition, at a low temperature, as indicated by the carbonized bone fragments. In general, the temperature effects on the bones may result either from intentional human action, or from something else; the Bonfire Shelter bones are an example of the latter.

Low or high temperatures cause carbonization or calcification of the organic substance in bones (Reitz & Wing, 1999). This changes the colour of the bones from black to white, blue, or green, as the temperature increases. The accumulation of large quantities of burnt bone fragments at the Ciemna Cave (Kraków-Częstochowa Upland) in a Lower Pleniglacial layer and in a Holocene layer with Neolithic artifacts is interpreted by Wojtal (2007) as a possible fuel deposit. Moreover, he found no cut marks (which might indicate food preparation) on the burnt bone fragments.

Cut marks, scrape marks, and chop marks result from intentional human activity. These marks are formed on bones during skinning, removing fat, chopping, filleting, and meat consumption. Particularly cut marks are found to repeat (i.e. they occur as similar marks at the same place on several bones of the same type but dating from different times) due to the anatomical structure of the animal involved.

Analysis of Polish Pleistocene mammals

Analysis of Pleistocene bone material routinely employing taphonomy has yielded good results in Germany, the United States, Russia, and Serbia. Taphonomy-based analysis of Pleistocene bones from Poland has been discussed by Wojtal (2007)(Table 2) for several sites (Kraków-Częstochowa Upland, Skaratek near Warsaw, and the Komarowa and Ciemna Caves). Some earlier works with taphonomical analyses contained material from the Maszycka Cave (Lasota-Moskalewska, 1993), the Obłazowa Cave (Charles, 2003) and Wilczyce (Bratlund, 2002).

Sites with Pleistocene bones, and hence with material lending itself to taphonomical examination, are known so far mainly from southern and eastern Poland (Nadachowski et al., 1989). Some of these sites have been documented well

Table 2. Taphonomical characteristics of material from Poland (Kraków–Częstochowa Upland), upper Pleistocene sites. Data from Wojtal (2007).

site / marks	weathering	predators activity: gnawing	predators activity: digestion of bone	coprolite	burning	human activity: cut marks	rodent activity: gnawing	trampling	plant root marks
Komarowa Cave	–	×	×	×	×	×	×	–	×
Deszczowa Cave	–	×	×	×	×	×	–	–	–
Cave in Dziadowa Skała	–	×	×	–	×	×	×	–	
Łokietka Cave	–	×	×	–	–		–	×	–
Ciemna Cave	–	–	–	–	×		–	–	–
Mamutowa Cave	–	×	×	–		×	×	–	–
Nietoperzowa Cave	–	×	×	–	–	×	×	×	–
Skaratki	–	×	–	–	–	–	–	–	–
Kraków Nowa Huta	–	×	–	–	–		–	–	–
Kraków Spadzista complex	–	×	–	–	×	×	–	×	–
Dzierżysław	×	–	–	–	×	–	×	–	×

× = observed characteristics; – = characteristics not observed.

by stratigraphic descriptions and photos, as exemplified by studies of the Krakow Spadzista site (a.o., Van Vliet 1974; West 1996; Wojtal, 1997).

Palaeontological work in the Polish Lowlands reports only on remains of the European bison (Niezabitowski, 1938) and the forest elephant (Stankowski, 1989). Unfortunaly, much material from central Poland has so far not yet been described. The present author will analyse Pleistocene mammals bones from a prospective research site at Krosinko (near Poznań, Polish Lowlands) on the basis of taphonomy within the framework of a scheduled research project. This analysis will deal with both the bones and the sediments in which they were deposited. The bones occur within the third terrace of the Warta valley, and it will be investigated what was the direction of the bone transport and what environmental conditions (in the old fluvial system) led to the concentration of bone material. The lithofacies and lithofacies associations will be determined, directional structures in the deposits will be measured, and the palaeohydraulic conditions will be reconstructed. The mammals bones will be analysed in this context.

Summary

Taphonomical studies take into account the spatial distribution of bones, weathering marks, the activities of predators (gnawing, digestion), the influence of temperature, intentional human activity, rodent marks (gnawing), and trampling. The analysis of deposits is also important, as is the influence of water on the remains, and of the roots marks of plants.

Standard studies of bones allow identification of the animal that the bones came from, and how they represent an skeletal element or anatomical part of the skeleton. By applying taphonomical analysis, we gain additional information concerning how and at what time the bone or skeletal remains were deposited. We can also find answers to the question of whether the remains were reworked or were still *in situ* when discovered.

Studies of Pleistocene bone material in Poland undertaken so far were limited to assessing the species origin and the anatomical position of the bones, as well as the morphology of the animals. Analysis of taphonomical characteristics from biostratinomical and diagenetic stages represents a good approach to studies of Pleistocene mammals in Poland, and such

studies should be deepened and more widely applied.

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