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WHAT IS TAPHONOMY?

Only a small part of what once existed was buried in the ground; only a part of what was buried has escaped the destroying hand of time; of this part all has not yet come to light again; and we all know only too well how little of what has come to light has been of service for our science.
(O. Montelius 1888:5)

Introduction

Taphonomy is the science of the laws of embedding or burial. More completely, it is the study of the transition, in all details, of organics from the biosphere into the lithosphere or geological record. These definitions were given by the Russian paleontologist I. A. Efremov (1940) who coined the term from the Greek words *taphos* (burial) and *nomos* (laws). Taphonomy is, however, important not only to paleontologists, but to archaeologists, especially zooarchaeologists and paleoethnobotanists, who study the organic remains making up part of the archaeological record. That importance has come to be widely recognized in the past 20 or 30 years. Taphonomy is now seen as important because it is often taken to connote that the zooarchaeological and ethnobotanical records are biased if some non-human-related processes have affected the condition or frequencies of biological remains. While that perception is often correct, I will show that this perception is frequently incorrect.

The reason archaeologists should be concerned with taphonomy is that it involves the formation of what is often a major part of the archaeological record. If the archaeological record is those modern traces of past human or hominid behaviors, then the discarded remains of meals such as mammal bones and plant parts constitute a portion of the archaeological record. Thus, taphonomic research involving the zoological and botanical portions of the archaeological record involves "the study of processes of preservation and how they affect information" contained within these parts of the record (Behrensmeyer and Kidwell 1985:105).

Granting the preceding, the reason for this book's existence should be self-evident. What is perhaps not so evident, however, is the reason such a book is appearing now given that archaeology has been practiced within a scientific paradigm for over 100 years (e.g., Trigger 1989). In order to assess why taphonomy is now seen as important, and to help explore why taphonomic research of the late twentieth century appears the way it does, the first part of

Chapter 2 reviews the history of taphonomic research and assesses its current status. The second part of Chapter 2 presents a personal view of the structure of taphonomic inquiry. The history and current status of taphonomic research allow me to take up the topic of Chapter 3, what is variously called actualistic research, ethnoarchaeology, middle-range research, or neotaphonomy, and how this relates to identifying the formational dynamics of a zooarchaeological record from its modern static traces. Chapter 4 is devoted to a review of vertebrate skeletal tissues and skeletons, and a discussion of how to quantify faunal remains. Chapters 5 through 12 are devoted to describing many of the commonly employed taphonomic analytic techniques. In Chapter 13 materials from earlier chapters are integrated and synthesized to provide a framework for performing intensive and extensive taphonomic analyses.

It is important here to introduce some basic terms and concepts that are used throughout this volume. The next few sections of this first chapter, then, are devoted to reviewing some of the basics of zooarchaeological analyses and how taphonomic research contributes to those analyses. That background leads to a consideration of the kinds of contributions taphonomic research can make to archaeology in general. The final topic of Chapter 1 is a discussion of what this book is meant to be, what it is not, and why.

On the analysis of archaeological faunal remains

> We must first eliminate causes of error, and discover what Nature can do to bones submitted to her action.
> (H. A. Breuil 1938:58)

Analyses of archaeological faunal remains have been undertaken at least since the late nineteenth century in North America (Robison 1978), and probably for at least 50 years prior to that time in Europe (Morlot 1861). While once scarcely more than a subsidiary endeavor, archaeological site reports now regularly contain a section on recovered faunal remains, often written by a specialist, and many more independently published and in-depth studies of faunal remains are being prepared by specialists in zoology and archaeologists with zoological training (Lyman 1979a). This reflects the holistic approach of archaeologists trying to understand and explain the totality of human history.

There are two basic goals to analyzing prehistoric faunal remains: reconstruction of hominid subsistence patterns, and reconstruction of paleoecological conditions (Hesse and Wapnish 1985; Klein and Cruz-Uribe 1984). The former has been characterized as an attempt "to explain, in the form of predictive models, the interface that existed between prehistoric human populations and the faunal section of the biotic community" (Smith 1976:284). This goal is anthropological in orientation as it addresses topics such as human diet, animal resource procurement strategies, or predator–prey relationships. Analytic goals are attained using anthropological and ecological principles in analysis and interpretation (Rackham 1983; e.g., Lyman 1992b). Analyses of paleoecological conditions use zoological and ecological data, methods, and theory (Dodd and Stanton 1981; King and Graham 1981) to reconstruct faunal turnover and succession, paleoenvironmental history, and zoogeographic history (e.g., Grayson 1987).

The two distinguished goals are not mutually exclusive. Both require taxonomic identification of faunal remains, which necessitates adherence to zoological method and theory. Data interpretation requires use of ecological principles whether those concern habitat preferences of taxa or determining available biomass or meat. Interpretation of a single assemblage of faunal remains recovered from an archaeological site may accomplish either or both goals (King and Graham 1981) because, in part, analytic techniques overlap. Distinction of the two goals is useful for discussion purposes, but is not mandatory to actual analysis.

Basic concepts

In this volume I focus on vertebrate remains. Research on invertebrate taphonomy is largely, but not entirely, found in the paleontological literature. My remarks are applicable to the remains of virtually all animal taxa, and many are also applicable to plant remains. I restrict discussion and examples in this volume largely to mammal remains for the simple reason that more taphonomic research has concerned mammals than any other vertebrate taxonomic group; non-mammalian vertebrates are covered in some detail in Chapter 12.

Taphonomy is generally construed as focusing on the postmortem, pre-, and post-burial histories of faunal remains. Burial is considered to be a stage intermediate to pre- and post-burial histories due to the potentially destructive and disruptive nature of burial processes (e.g., Dixon 1984; Kranz 1974a, 1974b). Various arrangements of taphonomic agents and processes have been posited in the form of models depicting a general taphonomic history (see Chapter 2). Generally, a bone may be gnawed, buried, exposed, reburied, re-exposed, broken, transported, and reburied prior to recovery (see the Glossary). Realistic sequences of taphonomic factors may therefore require the inclusion of loops. A general chronology of taphonomic agents and processes affecting animal remains is called a *taphonomic history* or *taphonomic pathway*. A *taphonomic agent* is the source of force applied to bones, the "immediate physical cause" of modification to animal carcasses and skeletal tissues (Gifford-Gonzalez 1991:228), such as gravity, a hyena, or a hominid. A *taphonomic process* is the dynamic action of an agent on animal carcasses and skeletal tissues, such as downslope movement, gnawing, or fracturing (relative to the agents listed in the preceding sentence). A *taphonomic effect* or *trace* is the static result of a taphonomic process acting on carcasses and skeletal tissues, the physical and/or chemical modification of a bone. As we will see, taphonomic analysis involves identifying and/or measuring taphonomic effects, and on that basis identifying and/or measuring the magnitude of effects of taphonomic processes and agents.

A taphonomic history begins when one or more members of a biotic community die. Postmortem processes that affect carcasses and skeletal tissues constitute the major part of a taphonomic history. Recovery of faunal remains is a potentially biasing factor because it affects the collected assemblage through differentially moving and sampling it. What the collector perceives as pertinent observations may significantly influence which fossils are collected and which data are recorded, and consequently influence the final analytic results. A large literature already exists on this crucial topic (Gamble 1978). Zooarchaeologists have become much more aware of the stratigraphic and sedimentary contexts of animal remains and the potential taphonomic significance of such geological and contextual data (e.g., Rapson 1990). As a result, more care is taken in the recovery of animal remains today than in the past.

A *fauna* is some specified set of animal taxa found in a geographic area of some specified size, kind, and location at some specified time (Odum 1971:366–367). For example, one can specify a modern intertidal fauna of the Pacific Rim, a prehistoric terrestrial fauna of Europe, and a Pleistocene mammalian fauna of Colorado. Zoologists study faunas by observing living animals. Paleontologists and zooarchaeologists study faunas by analyzing fossils. I have had several zooarchaeologists tell me "fossils are mineralized animal remains," or "fossils are older than 10,000 years." I find neither of these criteria in definitions published by paleontologists (see the Glossary). I use the term *fossil* in this volume to denote any trace or remain of an animal that died at some time in the past (ascertaining the age of animal death is a separate problem).

A *fossil record* is some set of remains of organisms, either or both plants and animals, having a geological mode of occurrence in some defined geographic space and geological context (i.e., with a delineated spatial distribution) (modified from Lyman 1982a, 1987e). A fossil record consists of those observable phenomena such as the particular bones in a particular stratum. A *fossil fauna* consists of those taxa represented by the fossil record at a specific locality. The term fossil fauna serves to emphasize the taphonomic distinction between a living fauna and a fauna represented by fossils. While the term fossil fauna as defined here is virtually synonymous with the terms *local fauna* and perhaps *faunule* (Tedford 1970), the first term emanates from the taphonomic perspective of this volume while the latter two emanate from a paleoecological perspective.

I distinguish two kinds of fossil faunas: those without, and those with, spatially associated cultural materials, or *paleontological faunas* and *archaeofaunas*, respectively. The distinction is not meant to imply whether or not humans had a role in the taphonomic history of a particular fossil assemblage. Analytically categorizing a particular fossil record as constituting a naturally or culturally deposited set of faunal remains is a major part of taphonomic analysis in zooarchaeology (e.g., Avery 1984; Binford 1981b; Potts 1984; Turner 1984). What is meant by these two terms is simply whether artifacts are or are not spatially associated with the faunal remains.

Goals of taphonomic analysis in zooarchaeology

Subsistence studies, by the nature of their research questions, require knowledge of the formation of the archaeofaunal record (Lyman 1982a; Maltby 1985b; Medlock 1975; Rackham 1983). Similar knowledge is important to paleoecological research but for different reasons (Behrensmeyer and Hill 1980; Gifford 1981; Grayson 1981). Subsistence studies require that the fossils constituting the archaeofauna be sorted into at least two categories: those deposited as a result of human (subsistence and other) behaviors, and those naturally deposited (Binford 1981b; Thomas 1971). Culturally deposited fossils must be qualitatively and quantitatively representative of the fauna exploited, and quantification techniques must produce accurate relative abundances of economically important taxa (Grayson 1984; Lyman 1979b). Paleoecological studies need not have representative samples of humanly exploited taxa, but may require representative samples of prehistorically extant faunas. Sample requirements are flexible in the sense that they have certain tolerance limits. For example, a bison kill site probably does not include all taxa exploited by a group of people yet it can be studied and analyzed. Similarly, a zooarchaeologist may focus only on the microfauna and ignore larger taxa in an archaeofauna. Both depend on the research questions being asked. Sample representativeness is relative to some population which in turn is dictated by the research goal. The representativeness of a sample of faunal remains is controlled by the sample's taphonomic history, the sampling techniques used to collect the sample, *and* the research questions being asked of the sample.

Gifford (1981) distinguishes two basic goals of taphonomic research: (1) "stripping away" the taphonomic overprint from the fossil record to obtain accurate resolution of the prehistoric biotic community, and (2) determining the nature of the taphonomic overprint in order to be able to list the precise taphonomic mechanisms responsible for a given fossil assemblage, enabling the writing of taphonomic histories. The latter goal is similar to studying the formation of the archaeological record (Schiffer 1987), and may lead to conclusions regarding the human behaviors that created the fossil record. The former goal is seen as a necessary step towards paleoecological analysis because the target of analysis requires knowledge of the prehistoric biotic community. For example, as Graham and Kay (1988:227) note, "the definition of taphonomic pathways is not the ultimate goal of paleobiological or anthropological studies, but [it is] a means to factor out biases and further our fundamental understanding of past ecosystems and human cultures."

Determination of the exact taphonomic history of a particular fossil assemblage is frequently attempted by zooarchaeologists who wish to know which taxa were exploited by hominids and the relative proportions in which they were exploited. Many interpretations therefore involve outlines of the suspected human behaviors that resulted in the fossil assemblage. For example, Wheat's (1972) description of the hunting and butchery process evidenced at the Olsen-Chubbuck bison kill site is simply a narrative model of the suspected taphonomic history of that site's fossil record.

The two goals of taphonomic research are not mutually exclusive. Stripping away the taphonomic overprint requires that the overprint be known. Once the taphonomic overprint is known, the prehistoric biotic community can, theoretically, be determined by analytically reversing the effects of the taphonomic processes. Of course, this procedure requires the assumption that the sample of fossils is representative of the biotic community, or that it can be analytically made representative of that community. This assumption has been analytically controlled in cases where an archaeofauna is directly compared with a paleontological fauna in close geographic and temporal proximity to one another (e.g., Briuer 1977), and in cases where two or more geographically and temporally adjacent archaeofaunas are compared (e.g., Grayson 1983; Guilday *et al.* 1978). The covert assumption of such comparative analyses is that because each fossil assemblage has undergone a more or less unique taphonomic history, similar but independant interpretive results derived from the assemblages are thought to represent prehistoric reality. That is, the analyst can have greater confidence that taphonomic processes have not totally obscured all indications of a prehistoric biotic community when all examined fossil assemblages indicate the same community.

As we shall see, the goals of taphonomic analysis can be much more finely distinguished. Here I have shown that the two general goals of taphonomic analysis are easily aligned with the two basic goals of zooarchaeological analysis, and that the two kinds of analysis are, and in fact must be, synergistic. That is, determining which animal taxa were eaten by prehistoric peoples, and how much of each animal taxon was eaten, is surely a taphonomic problem. Taphonomy thus presents a challenge to zooarchaeologists that can be simply phrased as "What are these bones doing in this site?"

The challenge of taphonomy

Understanding how taphonomic processes affect quantitative measures of faunal remains is a major challenge facing zooarchaeological research (Gilbert and Singer 1982; Holtzman 1979; A. Turner 1983). Quantitative measures such as taxonomic abundances, meat weights, and frequencies of particular skeletal elements are all affected by taphonomic processes (Badgley 1986a; Grayson 1984). Not only are quantitative data important in many analyses, but so are the distributions of bones and taxa within a site (Grayson 1983; Lyman 1980; Wheat 1972). Taphonomic processes may obscure distributional contexts, unrelated elements may become spatially associated, or related elements may lose their spatial association (Hill 1979b). The second major challenge in zooarchaeological research is, then, ascertaining the meaning of the distributions of faunal remains. The third major challenge is determining how and why the recovered faunal remains differ from the biotic community in which they originated. This question is particularly important to paleoecologists as well as zooarchaeologists. Other, more finely distinguished challenges are easily conceived, but these major ones tend to underpin virtually all of those narrower challenges.

Taphonomy's contribution to zooarchaeology

Examples make clear the nature of the contribution of taphonomy to zooarchaeology. For instance, archaeologists have, beginning in the late 1970s, adopted optimal foraging theory from ecology as an explanatory device (see Bettinger 1991 for a review). Part of that theory demands measuring the breadth of the niche exploited by the subject forager, in this case humans. Typically, niche breadth is measured by tallying the number of plant and animal taxa exploited. Thus, the remains of plants and animals found in archaeological sites must minimally be sorted into two categories: those representing taxa that were exploited, and those representing taxa that were not exploited by people. This entails examining the remains for indications that humans accumulated and deposited certain of the remains and indications that the other remains were naturally deposited. If some of the bones have butchering marks on them, then it is reasonable to suppose that the taxon or taxa represented were accumulated and butchered by people. In this case, the butchery marks are the indication of a human agent in the taphonomic history of those remains. If the nearly complete and partially articulated skeleton of a burrowing animal such as a gopher is found in a krotovina in a site, it is likely that this individual was naturally deposited and did not form a part of the human occupants' diet. Here, the degrees of skeletal completeness and articulation, the behavior of the taxon, and the context of the remains are the relevant taphonomic traces leading to the inference that these animal remains were naturally deposited. These are, as we shall see, simplistic examples. Modern taphonomic analysis is seldom so straightforward.

An archaeologist interested in measuring the dietary breadth of some prehistoric human group must distinguish between culturally and naturally deposited animal remains. If this is not done, then the analyst has simply measured the taxonomic richness (number of species) represented by the sample of animal remains, and not dietary breadth. Inferences that humans broadened their dietary niche, or narrowed it, or did not alter it through time, will surely be inaccurate without such taphonomic analyses.

In paleoecological analysis, animal remains can grant insights to the climatological and floral environment to which a human group adapted. If the remains of an animal taxon that today prefers cool-moist environments is found in a site located in a warm-dry habitat, those remains potentially indicate that the site may have been occupied during a time of cooler and moister conditions (assuming the remains were deposited at the time of human occupation). That indication can, however, be false if the animal remains were not locally derived. Did, perhaps, a far-ranging predator (human or not) collect those remains some significant distance away from the site and then transport those remains and deposit them there? Or, did the taxon in question actually live on or very near, say, < 1 km, from the site? Are the remains corroded from the digestive acids of some carnivore? If so, then perhaps, but not necessarily, the remains came from a significant distance away. Do the remains represent complete skeletons, or selected portions of skeletons? Is the taxon represented so large that it could not have been transported whole to the site? Producing answers to these and related questions involves taphonomic analysis and provides the data necessary to make inferences about the local or distant origin of the remains in question.

One example of how taphonomy has contributed to our understanding of human prehistory involves the debate over whether our Plio-Pleistocene ancestors were hunters or scavengers. The literature on this topic has grown to immense proportions in the last decade (e.g., Binford 1981b, 1984b, 1988b; Blumenschine 1986a, 1986b, 1987; Bunn and Kroll 1986, 1988; Potts 1984, 1988; Shipman 1986a, 1986b). All of that literature involves detailed taphonomic analysis. As a result of that research, the 1950s consensus that early hominids were hunters has been changed to one of perceiving them as individuals who probably hunted small game and scavenged large game, although opinions differ on the precise magnitude of the dietary contribution of both hunting and scavenging. This topic remains one of the most discussed in the literature of the 1990s.

Terminology used in this book

I follow several conventions in describing data used in examples in this volume. These are not formalized but rather are ad hoc conventions. "P" stands for proximal, "D" for distal. Abbreviations for particular skeletal elements vary between investigators, and I have not attempted to be systematic in my use of these; rather I have in many cases applied the original investigator's abbreviations with appropriate definitions. An *assemblage* of fossils is some analytically defined set of faunal remains usually, but not always, from a particular spatiotemporal context. I use the term "bones" frequently as a generic term for bones, teeth, horns, antlers, etc. Finally, I use the terms "hominids" and "humans" interchangeably.

In many cases I employ some very basic statistical tests. Throughout, the significance levels are denoted by P, Pearson's parametric correlation coefficient is denoted by r, Spearman's rank order correlation coefficient is denoted by r_s. Discussion and descriptions of these can be found in any introductory text on statistics. In this age of personal computers, I suspect we will see an increasing number of statistical analyses of taphonomic data. The quantitative aspects of zooarchaeological materials are a subject that could readily fill another volume; many of them are discussed in detail by Grayson (1984). An introduction to the basic quantification units of zooarchaeological research is provided in Chapter 4 of this volume, and additional comments are provided in Chapter 8.

What this book is and what it is not

> The objectives of taphonomic analysis are very varied and its methods are eclectic, being governed in part by disparate characteristics of different types of fossil assemblages, and in part by the nature of [research] problems it is called upon to address.
> (R. D. K. Thomas 1986:206)

This book is meant to review many of the potentially useful and informative analytic techniques taphonomists have developed to help solve particular zooarchaeological problems. It is not meant to provide a set of algorithms for solving conclusively all or any potential interpretive problems; it is not a cookbook in the sense that following a particular recipe will produce a tasteful or even edible product. The heart of the volume lies in the following chapters, which are meant to introduce the novice's mind to, and refresh the expert's memory concerning, the diversity of variables that must be considered and the plethora of analytic techniques that might make up a detailed taphonomic analysis. As the volume's title indicates, only vertebrate taphonomy is considered. For recent synopses of invertebrate taphonomy, see the papers introduced by Thomas (1986) and the volumes edited by Allison and Briggs (1991b) and Donovan (1990). Due to my own limitations, my review of the available taphonomic literature is largely restricted to that portion of it published in English. I took a zooarchaeological perspective in writing this volume, and thus zooarchaeologists will, I hope, find much of value in its pages. I hope as well that vertebrate paleontologists may find some of the material useful.

Nowhere in this volume will a detailed taphonomic analysis of a particular zooarchaeological collection be found, although various collections are described to exemplify the results of particular taphonomic processes or are used to illustrate how a particular analytic tool works. Simply, this book is a review of many of the analytic techniques used in the 1980s and early 1990s to help determine the taphonomic history of bone collections. Because archaeological taphonomy is a rapidly developing field, there is no doubt that some of the techniques reviewed here will not be in use ten years from now, and techniques not yet developed and thus not described here will be developed in the future. As I neared finishing what I thought would be a reasonably complete first draft, I continued to encounter newly published articles and to find references to articles published years ago that I had not previously been aware of. Because it was necessary to the completion of this volume, I stopped reviewing and incorporating new data and ideas in December of 1992. Thus, with few exceptions, the references cited herein were published prior to that date. The volume is in some ways, then, incomplete and in other ways it is out of date. I take these facts alone to indicate that taphonomic research is reaching, and perhaps will continue to enjoy for some time, a period of florescence. This volume is simply one mark of this period.

There is no clearly stated, explicit paradigm for taphonomic research and no rules for how to do it (Thomas 1986), except perhaps those under the umbrella of uniformitarianism. Taphonomic research in prehistoric contexts has few criteria for assessing the validity of a solution to a taphonomic problem. It is not always clear how to determine if a particular analytic technique was the appropriate one for a particular problem. Instead, the results of taphonomic research are often evaluated from the perspective that those results should be replicable if another analyst uses the same data and analytic procedures.

This is not a volume on techniques of zooarchaeological analysis, although it should be clear that much of what is described here often does (and should always) make up major portions of modern zooarchaeological research. Several good volumes on zooarchaeological analysis exist (e.g., Davis 1987; Hesse and Wapnish 1985; Klein and Cruz-Uribe 1984), and these can be consulted in conjunction with use of this volume.

This volume is *not* a pictoral or descriptive essay. There are illustrations here, but I have kept the number of photographs to a minimum because there are now available so many excellent descriptive volumes containing numerous photographs of variously modified bones that I could not hope to replicate the extent or quality of their coverage. The reader is encouraged to study closely the volumes and photographs found in Andrews (1990), Binford (1981b), Brain (1981), Haynes (1991), and White (1992). I have chosen in this volume to focus on what an analyst might do once the modifications have been recognized in a fossil assemblage. Therefore the majority of the illustrations I have chosen to include here are examples of graphs and charts intended to show how various taphonomically modified fossil assemblages may appear when graphed in a particular way. I find it much more mentally stimulating to manipulate taphonomically modified bones analytically than simply to describe some as