TAPHONOMY

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Contents

Summary

Taphonomy is the science of "law of embedding". The term, concept and methodology have recently growing in the research field of palaeontology, palaeoecology, archaeology and palaeoanthropology. We propose here to better explain, through some limited instances, what is taphonomy and the main stakes for many studies to consider it. It is just a glance to point out the importance of Taphonomy which becomes more and more an essential topic developed initially to reconstruct ecology of Past life.

Taphonomy is now used to reconstruct palaeoenvironment as well as palaeoethology, and social life of past human societies. It can pretend too, to be envisioning for the future.

1. Definition and History

Since the XIX century, researchers wonder to know the origin of fossil assemblages as well as site formation processes involved in fossil and artifact accumulations. Most of these queries have been developed in the field of quaternary palaeontology in relation with the presence of prehistoric (*antediluvium*) Cave Man in Europe (*e.g.*, Buckland 1823, Tournal 1833, Schmerling 1833, 1834, Dawkins 1874, Fraipont 1896).

This was enlarged in the first half of XX century in palaeontology, archaeology or palaeoanthropology with the discoveries of Early Pleistocene sites from East and South Africa or Asia (China) with fossil human remains (*Australopithecus*, *Homo*), raising up the relationship between lithic artifacts and bones and tooth remains mainly of ungulate (herbivore) species (*e.g.*, Martin 1907, Pei 1938, Breuil 1939, Hughes 1954, Leroi-Gourhan 1955, Dart 1957). If this relation seems mostly trophic (diet), the use of mammal bones as tools stays questionable since the early time of hominids (*e.g.*, "osteodontokeratic" culture of Dart from South-African sites) even if more recent works seem to demonstrate bone use at some extend.

One of the main questions concerns the preservation of biological or cultural signals through a fossil accumulation and the meaning of what it is usually called a "site" or "locality". The palaeontological studies search to understand the cause of death and concentration of fossils, as well as the modification of organic remains in sediments to explain the possible survival of then as fossils. We can mention the pioneer work made by Weigelt (1927) with the concept of "biostratinomy", and also Quenstedt (1927) with the term of "taphocoenosis" and Wasmund (1926) speaking of "thanatocoenosis" (=fossil or death assemblage) (see Boucot 1953).

The final goal of these studies concerns especially a branch of palaeontology, named palaeoecology (see Gifford-Gonzalez 1981) which consists «… *à rechercher les conditions dans lesquelles ont vécu et se sont déposés les assemblages paléontologiques, en rapport avec les sédiments qui les contiennent* » (Fisher 1969), deciphering the intimate relation between environment (climate, physiographic, chemical…) and organisms. In this context the principle of actualism or uniformitarism based on analogy (*e.g.*, geological works of C. Lyell, L. Agassiz) is essential, based on modern observations and process (natural or even ethnographical) as well as experimental studies. They build a rich and diversified referentials, explaining all kind of variation, very useful for comparative purposes to interpret fossil accumulations in terms of life and interactions in the Past.

Such investigations are crucial and bring important issues thanks to the combination of studies in Earth Science, Life Science and Human and Social Science. They start to be greatly developed in palaeontology, vertebrates as invertebrates or flora evolving within terrestrial or humid ecosystems, and more especially for the Quaternary studies and Human evolution.

It is in 1940 that the term "Taphonomy" (from Greek: *taphos*=to bury and *nomos*=law), the science of the laws of embedding, was coined by a Russian paleontologist I.A. Efremov (specialist of palaeozoïc amphibians) as a sister-discipline of palaeontology or palaeoecology, in part due to due to the incomplete nature of the fossil records (but see remarks by C. Darwin, G.G. Simpson or S.J. Gould), in order to compensate for phyletical or palaeoecological reconstructions, and beyond (see Leroi-Gourhan 1984).

According to Efremov, taphonomy is certainly not a separate science. It is important here to quote « *the indissoluble unity of geological-biological analysis* » in this thought on « *the study of the transition (in all its details) of animal remains from the biosphere into the lithosphere*" (p. 85), definition *princeps* of the Taphonomy. Two main stages can be seen: i) pre-burial with many biological interactions and ii) post-burial with strong effects of physic-chemical factors (diagenesis).

Taphonomy, as a word, is recent, but Efremov showed that the studies of the fossilization processes are older. As soon as 1490, Leonardo da Vinci described marine mollusk shells and corals in Italian Alps, far away from the sea. Because floods carry objects from top to bottom, not upwards, da Vinci concluded that organisms had been buried before the mountains were raised, when an ocean was there (Cadée 1991, Baucon 2010).

Combining biological and geological knowledges to understand a site is taphonomy. The association of biology and geology is also stipulated by A. d'Orbigny (1802-1857): "Car la paléontologie, sans les données géologiques les plus rigoureuses, devient simplement de la zoologie fossile, et non de la paléontologie réelle." (*in* Gaudant 2002). The state of preservation of fossils was used by Buckland (1823) to understand the formation of vertebrate sites.

Gressly (1861) compared the left - right valve ratios in modern and fossil bivalve shells to estimate hydrodynamic conditions, a taphonomic method. As soon as 1927, Weigelt described various modes of death and decomposition of modern vertebrates; he noticed the role of insects and compared the data of experimental works with fossils. The monograph was called "the first major work on vertebrate taphonomy" (Lyman 1994), after it was translated in English (1989).

2. Why Study Taphonomy?

As stressed by many authors, taphonomic analysis or the "study of process of preservation and how they affect information in the fossil record" (Behrensmeyer & Kidwell 1985: 105) constitutes a primordial research step on any kind of past fossil assemblages studies in order to reconstruct palaeoenvironment, species ecology and ancient behavior into the fields of palaeoecology (Andrews 1995, Hart 2012, and Figure 1), palaeobiology or palaeoanthropology.

Such approach needs to consider geological and sedimentological parameters in order to better understand the bias in a fossil distribution regarding diversity, density and degree of preservation/fragmentation according to structures or organs. If *"decay processes are responsible for substantial preservational bias in the fossil record*" (Allison 1990), their studies constitute a real gain in palaeobiological information as well as taphonomic agents as humans or carnivores (Palmqvist & Arribas 2001; Figure 2). It becomes a subtle integration and reflection between biological systems (molecular, cells, individuals, population levels) and ecological systems (community, ecosystem, landscape, ecoregion, and biosphere) (Pavé 2007) to be appraised within physical, abiotic context (soil, climate, rocks, etc.).

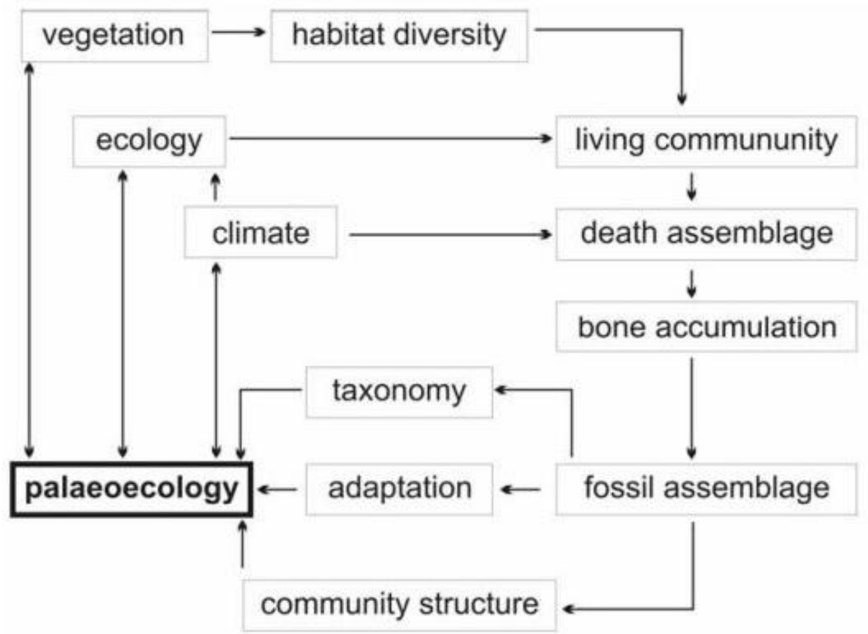

Figure 1. Interrelations between taphonomy and palaeoecology (redrawn from Andrews 1995)

Figure 2. Nineteenth representation of a striped hyena with a carcass (aquatint by W. Daniell)

Living organisms are complex heterogeneous structures, the parts of which differ in size, shape and composition. Because of these differences, the different components of an organism do not behave similarly during the predation and after the death (Figure 3). And because organisms are different, these behaviors also differ when different species are taken into account. Thus, organisms become preserved, fossilized or are destroyed. Actually, probably no fossil biota is preserved bias-free, even those where skins, soft tissues or colors are still visible. Among plants and animals, some organisms have the ability to produce mineral parts; shells as a protection, teeth for eating... These mineralized parts are more likely to be preserved than the organic soft parts, thus the fidelity of the fossil record is highly variable.

Studying taphonomy provide data on the environment of a region through the floristic and faunistic compositions, but also on the geological history of sites. The most difficult problem is to unravel the biological and geological signals in the fossil or archaeological remains to reconstruct the history of the region.

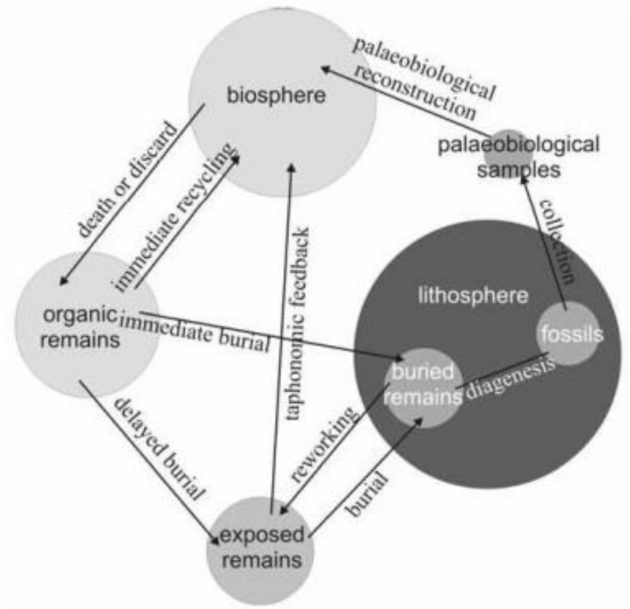

Figure 3. The taphonomic paradigm according to Behrensmeyer (redrawn from http:// www.mnh.si.edu /ete / ETE_People_Behrensmeyer_ResearchThemes_BonesofAmboseli.html). The number of samples decreases at every stage of the taphonomic process.

This new approach of fossil collections and sites show a large expansion for the Quaternary studies with the publication of several books in the early eighties: Binford (1981 « *Bones* »), Brain (1981 « *The hunters or the hunted* »), Behrensmeyer & Hill (1980 « *Fossils in the making* »), Shipman (1981 « *Life history of a fossil* »), followed by some important text-books (ex. Klein & Cruz-Uribe 1984, Lyman 1994, Martin 1999). They are seminal works and they emphasize both on Plio-Pleistocene hominid sites of East and South Africa (respectively open-air and karstic sites) and on modern referentials from natural settings and various biotopes (ex. predator location, natural mortality) as well as from traditional human societies (ex. Nunamiut, Bushman, Hottentots) (*e.g.*, Yellen 1977, Gifford-Gonzalez 1989, Binford 2001).

Since, taphonomic studies show a spectacular growth: first about the “objects” analysed and involving new methodological tools, sometimes sophisticated (*i.e.*, SEM, tomography, synchrotron, see below) and experimental studies (*e.g.*, Voorhies 1969, Behrensmeyer 1978, Schiffer 1976, Yellen 1977, and see Costamagno et al. 2008). The "objects" are of course biological (fauna, flora), from skeletal parts, pollens, or DNA and isotopes …, but also material human production (ex. lithic/metal artifacts, art, potteries…) or waste, both from archeological and historical times. They have generated new disciplines (bioarchaeology, geoarchaeology, micromorphology...) seeking to envision the integrity and meaning of past remains. They have renewed our understanding on many of Past life and dynamic of all ancient environments and, as such, Taphonomy became an essential federative concept.

3. Objects

They concern all kind of natural and cultural materials considered at macroscopic and microscopic scale, and look for the degree of preservation and completeness undergoing time effect.

3.1. Biological Remains

The most part of fossil remains is composed of external (shells, tests...) or internal skeletons. Despite about one hundred of biominerals are known, three categories are dominant: calcium carbonates (corals, mollusks, echinoderms..., calcium phosphates (bones and teeth) and silica (diatoms, radiolaria, sponges). The size, the shape, but also the mineralogy, the structure or histology, the organo-mineral ratios, the chemical composition.... all these parameters play a role in the fossilization processes. As well, organic components (ex. DNA) are subjects to degradation, and soft tissues are also concerned by taphonomy (Aufderheide 2011).

3.2. Artefacts

Into the prehistoric context, the lithic industry used a large variety of raw matter: flint, quartz and quartzite, volcanic rocks...They were used as tools by man and use-wear trace studies (*i.e.*, Keeley 1980) allow inferring their functions and the worked material (bone, skin, vegetal, etc.). The post-depositional alterations constitute strong restrictive factors for the interpretation of prehistoric toolkits (see review Claud & Bertran, Lhomme et al., *in* Thiebault et al. 2010).

Another field concerns cave art painting and engraving with decorated panels showing diverse alterations (physical and/or chemical, biological, anthropogenic) as illustrated by the famous upper Palaeolithic site Chauvet Cave in South of France (Kervazo et al., *in* Thiebault et al. 2010). Indeed, all kinds of cultural productions are concerned by preservation and taphonomy approaches are more and more generalized and basically used by archaeologists *s.l.* which is not a real misuse of the term (Lyman 2010, Dominguez-Rodrigo et al. 2011).

4. Factors of Accumulation and Alteration

Skeletal material can be concentrated by biological and physical processes. Predation, a biological process, has long been recognized as an important mechanism in the concentration of small vertebrate skeletal remains leading to fossil sites (Mellett 1974, Dodson &Wexlar 1979, Andrews 1990). Physical processes are mainly wind or fluvial/hydraulic transports. Some studies have attempted to identify signatures such as fragmentation and skeletal element representation left by different predators (*e.g.*, Dobson & Wetzlar 1979, Hoffman 1988, Andrews 1990), whereas others have investigated the microscopic and chemical modifications induced by digestion on bones and teeth (Rensberger & Krentz 1988, Andrews1990).

4.1. Biological Factors

Depending on the size of predator and prey, data are more or less abundant. Consumption by predators produces damages on all bones and teeth from all sized preys (from micro [rodents], meso [lagomorphs], macro and megafauna). Thus, each identified paleontological remain (species and osteology) provides an interesting taphonomical sketch and contributes to reconstruct successive and different taphonomical histories from one site.

Rodents (Rodentia) are small size-species characterized by continuously growing incisors and are among the more diverse mammal categories. Common rodents include mice, rats, voles and also pets: guinea pigs and hamsters. They are a main source of food for predators, so that their taphonomy is complex.

Three main categories of predators hunt for rodents: reptiles, birds of prey (“raptors”), and mammals (small carnivores), which can also catch other small vertebrates (insectivores, amphibians). Unfortunately, few studies are devoted to reptiles. One of the very rare papers dealing with amphibians is dedicated to the site of Atapuerca (Middle Pleistocene) (Pinto Llona & Andrews 1999). As soon as the capture occurred, alteration begins and differs. Birds of prey use “talons” or claws to catch the prey in flying, while most mammals use their claws to grab the prey and kill it with jaws. For example, a mouse is caught by a cat with claws, and killed with teeth.

Usually, only one small round hole is visible in the skull of the mouse. Differences exist due to the size of the prey and the predator (Haynes 1981, 1983 for large mammals). A second step inducing differences is the ingestion of the prey. Birds have no teeth, but birds of prey have a short and thick tongue to manipulate the food. Then the prey goes through the esophagus and stomach. Acids and enzymes (mainly pepsine) and the muscular contractions of the gizzard (the second part of the stomach) reduce the pieces of flesh in nutrients that are absorbed through intestinal tissues. At the end is the cloaca, for products from the digestive and urinary systems.

Several hours after eating, the indigestible parts (bones, feathers...) are compressed into a pellet in the gizzard, and then go back to the first part of the stomach. It will remain there for up to 10 hours before being regurgitated, so that any more prey can be swallowed until the pellet is rejected. Other birds used a powerful beak to tear pieces of flesh only.

Observations in nature are not easy, so that zoological gardens and reserves are useful to study the habits of various birds and to collect the regurgitation pellets. The grade of digestion differs according to the species (Andrews 1990). It has been shown that for an individual, the acidity of the stomach juice depends on the age of the animal (Smith & Richmond 1972, Raczynski & Ruprecht 1974, Duke et al. 1976, Dodson & Wexlar 1979). Thus, the pattern of preserved bones for a unique predator can vary (Figure 4) (Bruderer & Denys 1999, Gomez 2005).

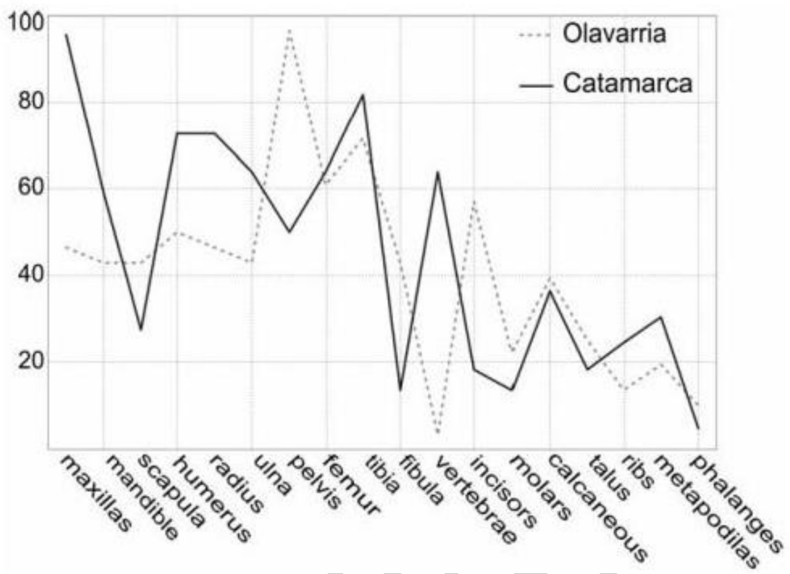

Figure 4. Patterns of bone preservation (% elements) for a single predator in two sites (data from Gomez 2005).

Comparisons based on the prey species found in regurgitation pellets show that some predators are opportunists, whereas some birds eat only one or two species. Thus, studying the pellet contents provide data on the predator, but also on the faunal composition of a zone. The type and number of bones and teeth in a pellet are also a source of information, despite some variability. Beyond quantitative data, qualitative criteria are also available: number of broken bones, breakage pattern, etc.

Pieces of flesh and bones are broken and eaten by special teeth in mammals, and salivary glands in the mouth produce enzymes able to etch the food. Most carnivorous mammals consume the bones of their prey, and are able to digest bones, in order to assimilate Ca, P, K and other essential elements. Thus, skeletal remains in their faeces are rare or very small smooth fragments. Due to the calcium contents of bones, bone-eaters as some carnivores (especially hyenids, canids) produce hard faeces which can become fossilized (named coprolites: see Esteban Nadal *et al* 2011, Ogara *et al* 2011 for scat analysis and potential tapho- and eco-logical input). Information on behavior of recent bone-accumulators, notably hyenid, has been developed and recent studies is now currently made on modern carnivore dens or lairs to evaluate the bone selection and representation, breakage, category/size of preys and tooth marks for example. (*e.g.*, Egeland et al. 2008, Prendergast et al. 2008, Fosse et al. 2011). One of the few studies dedicated to the comparison of a large range of modern and fossil predator tooth marks from dinosaurs to mammals is due to Pobiner (2008). On the other hand, tooth marks from a single predator vary according to the bone and the body size (Egeland et al. 2008) (Figure 5).

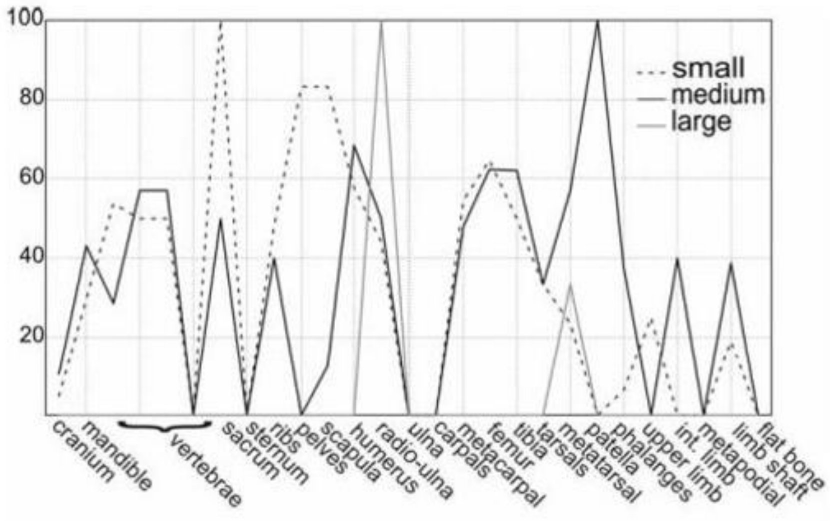

Figure 5. Tooth mark frequency by skeletal element and body size in a modern hyena den (data from Egeland et al. 2008).

Prendergast & Dominguez-Rodrigo (2008) also emphasize the differences between various sites for a single predator species, and hypothesize the rôle of young pups, less efficient in catching, killing or gnawing preys.

While predation is a main factor of accumulation, other factors contribute to create and modify the primary accumulation. We can mention the special case of a large rodent like the porcupine (genus *Hystrix*) which tends to select and accumulate dry bones in order to intensively gnaw them to control their growing incisors; most of the time bones are sculpted and morphological features totally disappeared. Herbivores (caprids, cervids, etc.) can also modify bones or antlers for calcium sources and chew the tip of long bones remodeled as 'forked' ends; this is named osteophagy. Another important alteration process is the bioturbation due to the biological activities of organisms within soils and sediments. Badgers are powerful bioturbators for burrowing and predation purposes (Johnson 2004, and see Mallye 2011 for use of badger remains in cave deposit).

Cavities are often used by secondary bone accumulators. Bioturbation is not only from large animals trampling on remains (trampling). Bioturbation can be due do small animals (worms, insects), plants (roots) acting on buried remains. In such processes, not only the topography of the soil or sediment is modified by tunnels, holes, disturbed layers..., but chemical changes are also induced. Proliferation of roots has an impact on the composition of the soil, because cells absorb water and nutrients. Roots can also initiate intrusion through mineral dissolutions (Gabet et al. 2003). Many invertebrates live in soils, physically or chemically altering structure and composition of soil itself, but also of biological remains. Earthworms are abundant and sometimes large, so that they have been well studied in modern soils (Edwards & Bohlen 1996) or archaeological sites. Small mammal bones can be transported in both horizontal and vertical directions, and then mixed with bones from different origins. Moreover, they can be broken during the transport (Armour-Chelu & Andrews 1994). Vertebrates such as rodents (marmots, prairie dogs, ground squirrels) or moles are also efficient bioturbators. In term of preservation and alteration, the activities of living organisms can affect their near environment and associated remains, and the term ichnology concerns all studies of traces (footprints, tracks, etc.) which can also cover archaeological context (see Baucon *et al* 2008 for a review).

Predation also exists in the sea, but direct observations are more difficult. However, predation yahoomarks have been described on ammonite shells (Martill 1990, Kauffman 2004, Andrew et al. 2011). Bite marks were attributed to fishes or reptiles.

4.2. Physical Processes

Mechanical and climatic actions, on dead organisms in relationship with location into ecosystem, have strong incidences on preservation state and on their representativeness within fossil assemblages.

By instances, once a pellet has been regurgitated, it is exposed to physico-chemical weathering processes on the soil. Depending on the intensity of the modifications induced by the predation stage, the post-burial alteration greatly differs. Within a regurgitation pellet, for a given bone, Terry (2004) has shown that the surface in contact with a forest soil has a higher degree of bone modification than the surface that is exposed to the air.

Water, aeolian or gravity transports, cyclic climatic actions in term of cycle (dry/wet, warm/cold, freeze...) induce important changes both in the internal structure of elements and external surface. They are demonstrated by dispersal, fragmentation, rounding and weathering of material and then loss of scientific information's about the analyzed materials. During glacial periods, the process of cryoturbation affects both sediment and organic remains: experimental gelifraction clearly shows the fragmentation, cracking until total disintegration of bones and teeth (Guadelli 2008).

Alterations related to these physical and biological processes are described in 5.2.1 (Macroscopic observations) and 6 (Various examples).

5. Methods

According to Efremov (1940), taphonomy encompasses "*Microscopical and chemical analyses of fossilized remains, conducted together with experimental work of artificial fossilization, and with observations of the destruction of the surfaces of organic remains in different surroundings*". Thus, taphonomy begins with the collect of samples on a site, but never ends! A large range of methods and techniques are used, and new analytical techniques can help to unravel some problems. Depending on the nature and abundance of the object to be studied, destructive or non destructive analyses will be used. Applications related to these techniques and methods are illustrated in part 6 (Some examples).

5.1. Sample Collect

The methods to collect sample are diverse according to the type of fossils (ex. pollen, rodents or large mammal's remains) and rocks and sediments (and then type of site: from open-air to karstic cavities, or cores). The example of excavations made on archaeological sites is interesting (Leroi-Gourhan & Brézillon 1966). A grid is set (at least 1sq-meter) and all objects of a certain size for fragments (cm) or relevant specimens in term of technical, anatomical or taxonomical elements are spatially located (x, y, z), sketched or photographed. These data are associated with the indication of orientation, slope, and all other possible observations (burnt, broken, connection with other surrounding material, oxide impregnation, carbonate encrustement …). Calculation on density of remains per weight of sediment sampled is another possibility for microfossils. Large samples are seen with naked eye. However, in terrestrial or marine sediments, abundant remains are microfossils. In this case, large bags of sediment are collected to be studied during the field work or later in the laboratory. Dry or wet sieving is done to separate, to sort and to concentrate the sedimentary particles (fossils included). The size of the mesh of the sieve will determine what you find in the sample (Bowler & Hall 1989). Then, the collect of fossils (pollens, foraminifera, rodent teeth…) is done looking under a microscope.

5.2 In the Lab

5.2.1. Macroscopic Observations

In the case of bones and teeth of vertebrates, especially mammals and ungulates for the prehistoric subsistence, several criterions are used to evaluate the impact of taphonomy factors. They are i) natural (physical, chemical) more or less controlled by climatic and pedologic formations and/or ii) biological from diverse agents, from microorganism, invertebrates (insects, mollusks...) and vertebrates (birds, rodents, carnivores…), including humans. Many studies, both from direct natural observations and experimental depicted the variety of damage occurring on bones and teeth which ultimately tend to completely destroy the fossil material. As final instances, teeth are the most mineralized parts of a skeleton - carbonate hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$) almost 96% - and they would preserve better than bones: fossil mammals assemblages made essentially by teeth, or teeth fragments, are clearly strongly taphonomically biased.

Moreover, we can also suspect combination of several factors, acting before and then after burials (with the possibility for buried materials to start diagenesis, then to be exhumed again, and start another "cycle"). As a simplified sequence (Figure 6), a prey died of natural causes (ex. age, epizootic, flooding…) or predation (meat-eaters: hunting, scavenging), and its skeletal parts are fragmented, gnawed, dispersed, transported, trampled, burned...and the remains start to be buried in a soil with roots or insects/arthropod actions, and tend to decay and become fossilized or to disappear. All these modifications have to be depicted and interpreted, and many works discuss about involved changes and processes; the study of marks are essential (traceology/tribology) and they are observed with lens or SEM. In this paper, only some examples can be quoted, focusing on vertebrate bones and archaeological context (Bonnichsen & Sorg 1989).

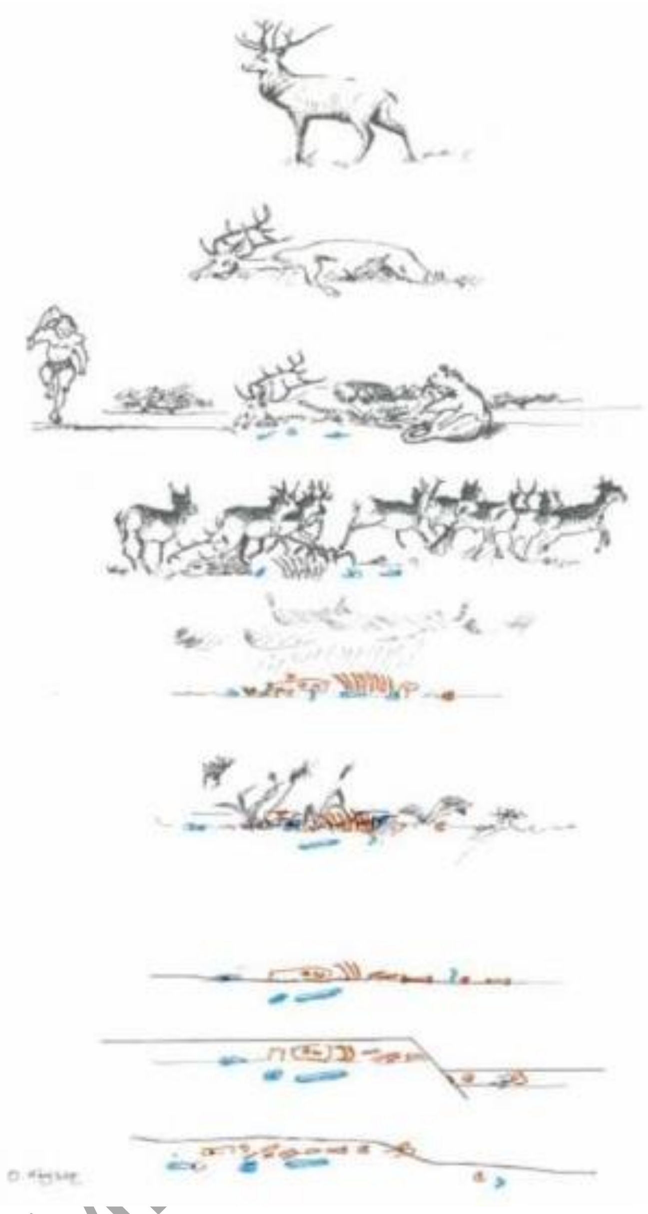

Figure 6. Simplified taphonomic sequence (by O. Keyser, modified from Shipman 1981).

Bone Weathering: It is possible to categorize the state of bone surface according to the duration of exposure under local conditions (temperature, humidity, soil chemistry), as defined by Berhrensmeyer (1978) from modern bones in equatorial setting (Amboseli, Kenya). Six stages have been described, related to time of exposure and most material is decomposed in 10 to 15 years; moreover, bones from young individuals or less than 100 kg weather more quickly than bones or large animals and adults (Figure 7). Similar analyses have been done for large mammals in a temperate environment (Andrews & Armour-Chelu 1998, Fosse et al 2004). Such studies are useful and are actually applied for forensic science (Ubelaker 1997).

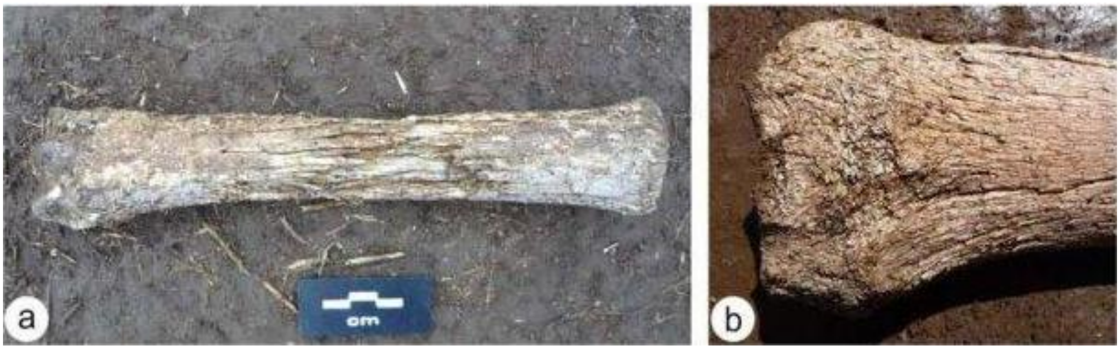

Figure 7a. Metapodial of zebra heavily weathered (Kenya, Shompole); note exfoliation of cortical bone, especially on shaft (ph. JPB); b. Proximal end of radius of giraffe heavily weathered (Kenya, Shompole), ph. JPB.

Bone transport: Water's actions on single bone or fossil assemblages are diverse and dynamic, and constitute an important "taphonomic motor" (Brugal 1994) with a large spectrum of processes. Hydrodynamic action plays as centripetal or centrifugal mechanism, dispersing or concentrating objects (Isaac 1983). In the case of water transport, anatomical elements behave differently and following the composition of assemblages, it is possible to infer the degree of perturbation/transport (Voorhies 1969, Badgley 1986a, b) (Table 1) in connection with sedimentary context.

		Cause of Mortality	
	Predator	Natural Trap	Sudden Disaster
Condition of	-	-	-
Transport	-	-	-
None	articulation present	articulation present	articulation common
	most specimens clustered	specimens clustered	specimens clustered
	high % juveniles	moderate % juveniles	moderate % juveniles
	punctures, scratches	little bone damage	little bone damage
	hydraulic sorting absent	hydraulic sorting absent	hydraulic sorting absent
By predators or	articulation variable	articulation variable	articulation variable
Scavengers to	some specimens clustered	some specimens clustered	some specimens clustered
A focal area	moderate-high % juveniles	low-moderate % juveniles	low-moderate % juveniles
	punctures, scratches	punctures, scratches	punctures, scratches
	hydraulic sorting absent	hydraulic sorting absent	hydraulic sorting absent
By currents	articulation absent	articulation absent	articulation absent
	specimens scattered	specimens scattered	specimens scattered
	moderate % juveniles	low % juveniles	low % juveniles
	polish and abrasion	polish and abrasion	polish and abrasion
	hydraulic sorting present	hydraulic sorting present	hydraulic sorting present

Table 1. Taphonomic characteristics of hypothetical fossil assemblages. Each assemblage results from one cause of mortality and one condition of transport. From Badgley 1986b.

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Bibliography

Note: studies and bibliography involving 'taphonomy' increase of spectacular manner from the last two decades and concern ecology, environment, evolutionary, anthropology, paleontology, archaeology, geology researches. To give a short and rapid example, the word 'Taphonomy' indicates e.500 000 ref./links with Yahoo, e.170 000 with Google, e.90 000 with Scirus, e.27 000 with Google scholars, e.4200 with Sciencedirect, etc. Then, here, only very restricted, biased and limited references are given.

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