Research Article

Kamilla Pawłowska*, Lisa-Marie Shillito

An Integrated Zooarchaeological and Micromorphological Perspective on Midden Taphonomy at Late Neolithic Çatalhöyük

https://doi.org/10.1515/opar-2020-0215
received April 9, 2021; accepted December 15, 2021

Abstract: The disposal of cultural material at Çatalhöyük, Turkey (7100–5950 cal BCE) has created substantial midden deposits between buildings and within abandoned houses. These consist of a variety of materials, including environmental remains such as eggshell, mollusks, seeds, phytoliths, charcoal, fecal material, along with artefacts including pottery, figurines, beads, and lithics. Animal bone and human bone also form a significant component. Understanding the taphonomy of these deposits and their formation processes is essential in order to interpret the activities represented. Here we present a taphonomic analysis of middens from the TP Area of the site (Late Neolithic, Final Phase), in terms of natural and cultural alterations to bone, through a combination of zooarchaeological analysis, with micromorphological analysis of associated sedimentary contexts. Comparisons with studies of the earlier middens enable us to account for post-depositional processes, and the implications they have for interpreting past activities and waste management practices. Integrating sediment micromorphological analysis enables refinement of the taphonomic interpretations from the analysis of faunal remains and highlights the advantages of a multi-proxy approach.

Keywords: middens, bone taphonomy, micromorphology, formation process, Çatalhöyük

1 Introduction

One of the principle aims of zooarchaeology is to reconstruct socio-economic and ecological processes in the past. As with all artefacts and ecofacts in archaeology, a consideration of the taphonomy of faunal remains and formation processes of the deposits they comprise, is essential in order to achieve these wider aims. Taphonomy is the study of the processes by which artefacts and ecofacts accumulate on paleontological (Pawłowska, 2010, 2017; Pawłowska, Stefaniak, & Nowakowski, 2014; Stefaniak et al., 2014) and archaeological (Madgwick, 2016; Madgwick & Mulville, 2015; Russell & Twiss, 2017) sites, and the ways in which they are modified in the post-burial environment. This includes the postmortem, pre- and post-burial histories of the faunal remains (Lyman, 1987). An excellent example of this is provided by the cattle bucranium (along with forehead) abutted to a human skeleton (skull) discovered at Çatalhöyük (TP Area; level TP.R; Space 248) (Hodder, 2008; Whitehouse, Mazzucato, Hodder, & Atkinson, 2014), with evidence of postdepositional disturbance and displacement. Disturbances can be seen associated with the post-Neolithic pit, which cut a female

---

What is New in the Neolithic? – A Special Issue Dedicated to Lech Czerniak, edited by Joanna Pyzel, Katarzyna Inga Michalak & Marek Z. Barański.

*** Corresponding author: Kamilla Pawłowska,** Department of Palaeoenvironmental Research, Institute of Geology, Adam Mickiewicz University in Poznań, Krygowskiego 12, 61-680 Poznań, Poland, e-mail: koka@amu.edu.pl
Lisa-Marie Shillito: School of History, Classics and Archaeology, Newcastle University, Newcastle Upon Tyne, United Kingdom

Figure 1: Cattle bucranium in burial: (a) excavation stage, (b) with an indication of cattle bucranium, along with which a female skeleton was found, and (c) reconstruction of complete cattle bucranium (unit 11562, Space 248, TP Area, Level TP.R, Çatalhöyük East). (Photo by T. Kozłowski, modified).

skeleton, and with the displacement of the left horn core, as revealed by detailed analysis of the position of the cattle skull (Figure 1): its tip is at a different angle than would be expected by comparing with the right horn core (Pawłowska, 2020a). The displacement could have been caused by the weight of the overburden or other sources. Apart from taphonomic matters, the bucranium raises yet another important issue, thus demonstrating human–animal relationships along with a major change in burial rites (Pawłowska, 2020a).

The presence of animal bones on a site is usually the result of primary activities including butchery, food preparation, and craft activity. This systemic context is rarely observable, and the distribution patterns in the archaeological context are the result of depositional processes including refuse management practices, and post-depositional alterations such as animal activity and weathering. The deliberate placement of animal remains in relation to the architecture can also be considered. Generally, if the movement of materials is so minimal at a given site that the materials retain a centimeter-level proximity to their original points of deposition, then that site is potentially of high integrity and high resolution (*sensu* Binford, 1981). While some of these dispersal and movement processes can be inferred through zooarchaeological analysis, the presence of gnawing for example, others can be more difficult to pinpoint. A study of middens employing a single source (such as animal remains) provides a wealth of insights into everyday life, by contributing to the understanding of waste disposal and management pathways, of waste characteristics, and of any activity undertaken by humans in the area of its occurrence. Post-depositional processes, including movement, that have affected refuse in middens are also of relevance. However, integrating several studies allows better resolution of results to be obtained, giving precise answers to problematic issues, such as the most likely patterns of accumulation with an indication of variations in accumulation history, as recently demonstrated in a midden study in the UK (Madgwick, 2016). This is to do with the fact that combining taphonomic signatures from several studies allows for refinement of the interpretation.

Identification of taphonomic processes in Çatalhöyük middens may be refined through the integration of microscopic analysis of the sedimentary context within which animal bones are located. Micromorphology is semi-quantitative in that the relative abundances and relationships between materials can be observed. The frequency of bone can be estimated within the sediment and compared to the frequency of other materials, and the degree of surface weathering can be observed. Factors such as the roundness and fragmentation can be assessed, and products of bone decay can be seen, such as phosphate minerals (Adderley, Alberts, Simpson, & Wess, 2004). Furthermore, information on the sedimentary matrix and depositional characteristics can be observed in thin section, information that is lost when bones are removed during routine excavation. The integration of these methods has been suggested recently by Estevez, Villagran, Balbo, and Hardy (2014), who argue that a multi-scalar approach is essential for the corroboration of interpretative hypotheses. This approach can contribute to identification of qualitative taphonomy, by identifying microscopic surface modifications, weathering and breakage, and providing additional information on the depositional context of the bones, including processes of diagenesis and disturbance. In this article we focus on middens, by integrating data from faunal analysis with micromorphology at Neolithic Çatalhöyük, to provide a refinement of taphonomic reconstructions that can be interpreted from faunal remains. The implications of these processes for understanding wider social practices and site formation are discussed. Middens are particularly well suited to this approach, since they document daily waste disposal and a range of human and animal activity. This makes them a rich source of information about life paths in the past, although are often marginalized due to their obscure stratigraphy, which can make the patterns of deposition and accumulation very difficult to establish (Madgwick, 2016). In their complexity, however, there is the potential to inform economic studies, to produce reconstructions of past social history, to identify the taphonomic pathways of midden accumulation in terms of the speed of accumulation, to determine the scale of deposition and the degree of disturbance (Bronze Age-Iron Age; Madgwick, 2016), and to gain an insight into differential preservation (Middle Bronze Age to Roman; Méniel, 2008).

2 Archaeological Site and Middens

2.1 Çatalhöyük Site

Çatalhöyük (37°40′03″N, 32°49′42″E) is one of the largest early Neolithic archaeological sites in the Near East, covering 13 ha and standing over 18 m high. It is located in the Konya Plain of Central Anatolia at an elevation of ca. 1,000 m above sea level. Excavations at Çatalhöyük have focused on several areas of the East Mound (BACH and 4040, recently renamed "North"; GDN; TP; TPC; Istanbul; and South) (Figure 2). The stratigraphic sequence at Çatalhöyük East, and its chronology with respect to both Central Anatolian and Levantine periodization, is published elsewhere (Pawłowska, 2014; Wright, 2014, Table 1, p. 5; with further references). In this article we focus on the TP Area, the uppermost levels of the site, labeled TP.M–TP.R and dating from 6300 to 5950 cal BCE (Late (debatable) and Final Phases: Hodder, 2016, 2020; Barański et al., 2022). The excavation was led by Lech Czerniak and Arkadiusz Marciniak.

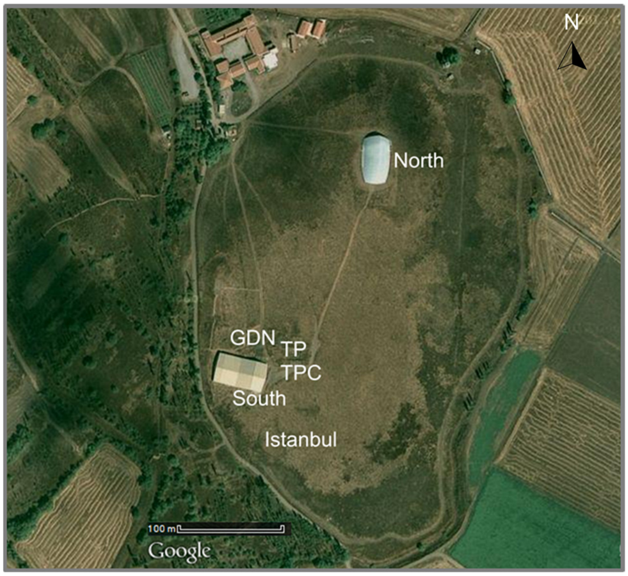

Figure 2: Map of the site with details of the excavation area. Abbreviations refer to the excavation areas. TP (Team Poznań) and South Areas are discussed here. Source: Google Earth, with modification.

2.2 Midden Taphonomy at Çatalhöyük

Çatalhöyük is characterized by a dense network of buildings, surrounded by a buildup of "midden." The term midden is used at the site for deposits primarily related to the deliberate disposal of cultural material, either outside or inside a structure (Hodder, Cessford, & Farid, 2007). The sedimentary matrix consists largely of ashes, degraded architectural materials, and decayed organic remains, with inclusions of not only animal bones but also human bone, mollusks, eggshell, figurines, beads, obsidian, clay balls, pottery, carbonized plant remains, small fragments of plaster and mudbrick, fecal material and phytoliths (Matthews, 2005; Shillito & Matthews, 2013). Middens can be viewed as a place where the rubbish were placed; however, at Çatalhöyük, in fact they represent more complex depositional history with the evidence of mixing of material from several depositional units. Many activities have taken place in middens such as firespots, human burials, recovery of building material, ritual behaviors, and a specific event (e.g., a feast) (Martin & Russell, 2005). The classification of midden deposits is complex. Although the general term "midden" is used across the site, it is recognized that middens are highly variable with a wide range of "types" (Martin & Russell, 2005). Spatially, middens are differentiated into interior middens, exterior middens, and courtyard middens. Some middens are highly stratified, while others show signs of trampling and *in situ* bonfires, suggesting a wider use for these deposits than simply for waste disposal, and "midden" spaces may change from one function to another through time (Bogaard et al., 2013; Issavi, Pawłowska, Vasić, & Veropoulidou, 2020; Shillito & Ryan, 2013). Middens are mainly studied macroscopically, which, however, provides no insight into the formation process of such finely stratified deposits (Yeomans, 2005), and what can unravel microstratigraphic approaches.

Micromorphology at Çatalhöyük has been applied to a wide range of contexts and studies, including analysis of midden formation processes (Shillito & Matthews, 2013), reconstructing use of space within buildings (Matthews, 2005), and in understanding plant taphonomy (Matthews, 2010; Shillito, 2011).

A combined analysis of zooarchaeology and micromorphology of middens from the uppermost levels in the TP Area at Çatalhöyük enables us to investigate the aspects of midden taphonomy related to the movement of material as part of their formation processes. The micromorphology and bone sampling approaches were devised in tandem to answer specific questions concerning the process of midden formation. It is also possible to evaluate the bone attrition process prior to considering subsistence issues in late Neolithic Çatalhöyük in studies of the bone assemblage. Understanding the formation processes of middens and the taphonomy of assemblages of materials within them is an important step in our ability to reconstruct human activity. The "microtaphonomic" approach to faunal remains has not been considered previously at Çatalhöyük, but various micromorphological case studies are known from other sites and contexts. Brönnimann et al. (2020a) have shown that a micromorphological approach to archaeological contexts (Iron Age; Switzerland) offers the possibility of defining microfacies types, the mapping of which reveals a differentiated use of space. Other outcomes indicate that middens probably served as material depots and that waste was not simply seen as rubbish, but was stored as a resource (Brönnimann et al., 2020b). In turn, Shahack-Gross (2017) has provided an overview of the evidence of fenced areas, where domestic animals (mostly cattle, sheep, and goats) are corralled, using micromorphological studies.

3 Materials and Methods

3.1 Bone Assemblage Sampling Strategy

To date, more than one million specimens have been recorded from various excavation areas at Çatalhöyük. One of these is TP Area, where the final season of exploration was held in 2008. Following the establishment of the final stratigraphic sequence in 2013 for Neolithic deposits and specifying of the types of deposits, it is now possible to conduct contextual analysis of the animal bones discovered. Various interpretative categories for units with animal bones have been established (such as floor, midden, fill, animal bone in cluster, and broadly contructional). The analyzed animal bones come from middens and represent almost all of the TP stratigraphic levels (labeled TP.M–TP.R). The middens of one level (TP.P) did not provide any fully recorded units and so this level does not figure in the results. However, since the units from this level were scanned in order to select samples for radiocarbon dating, meaning that articulation was recorded, these data are dealt with.

The assemblage consists of 14,815 specimens, recovered by dry sieve (4 mm mesh) and flotation (>4 mm). The results are presented as the number of identified specimens (all identified specimens assigned to genus, species, or size class, for which taphonomic data were recorded). This assemblage includes all the animal bones studied from TP middens up to 2008, which constitutes ca. 15% of all items recovered from this excavation area.

The bone remains are presented within a contextual framework of levels and spaces (the latter when there were sufficient samples), to analyze variation spatially and over time.

Taxonomy, anatomy, age, sex structures, metrical data, articulation (anatomical order), worked bone, and taphonomic characteristics were examined and recorded for each specimen using the unified recording system in the centralized Çatalhöyük Microsoft Access database (Russell & Martin, 2005). In this article, only the faunal assemblage composition and the results for the taphonomic aspects related to movement, displacement, and disturbance within the middens are presented.

Data on the abundance of taxa in the assemblage are shown using the number of identified specimens (NISP) and diagnostic zones (DZ). The frequencies of the species are given by DZ (*sensu* Bogucki, 1982, Watson, 1979). The density of the middens was calculated by weight for the TP levels, and more specifically for each context (space). The final result was expressed in grams of bone per liter of soil. For this purpose, for each unit that provided some animal bone, the total soil volume (calculated as the sum of soils for dry sieve and flotation samples) was taken into account.

The nature and quantity of all surface modifications originating from trampling (Fiorillo, 1989), carnivore and rodent gnawing, digestion (Fisher, 1995; Lyman, 1994), subaerial weathering (Behrensmeyer, 1978; Lyman & Fox, 1989), abrasion (Shipman & Rose, 1988), and root etching (Binford, 1981; Lyman, 1994) were studied. NISP were used to express the bone surface modification data. The degree of post-burial fragmentation was detected using the completeness index (CI) and the percentage of whole elements (% Whole) (Darwent & Lyman, 2002). The CI was derived by estimating the study specimen for the fraction of the original compact bone that is present, summing the values, and dividing that by the total number of specimens ascribed to the bone and taxon (Marean, 1991). In checking the CI, carpals and tarsals (excluding calcaneus samples) were taken into account. Since the inclusion of specimens with modifications tends to skew measures of fragmentation (Darwent & Lyman, 2002), all digested, burnt, and heavy gnawed specimens were omitted. Because of the relative lack of heavy weathered samples, additional selections were not necessary here.

The ratio of proximal and distal parts of the humeri and tibias served as an indicator of density-mediated attrition; the proximal parts of these bones are structurally weaker than the distal parts, and have low structural density; they are therefore expected to be lost when attrition process occurs.

3.2 Thin Section Micromorphology

Samples for micromorphology were collected from midden unit 8932 (Space 414, level TP.Q). An overlapping sequence of three large blocks were collected, forming a continuous section 60 cm in depth. The undisturbed blocks were impregnated with epoxy resin and hardened in 24 h at 70°C. Large format slides 15 cm × 7 cm were prepared from the blocks using Brot thin sectioning equipment. Slides were examined using a Leica DM750P at a range of magnifications and measurements were recorded using Leica v4.4. software. Deposits were classified according to the standard criteria (Bullock, Fedoroff, Jongerius, Stoops, & Tursina, 1985). For the purposes of this study, a particular focus was on bone inclusions. These have previously been identified to occur at <5% frequency within midden sub-units in the TP Area. The slides were divided into 5 cm intervals, and total counts of bone fragments were recorded for size categories of <0.1 to >2.0 mm. Other micromorphological characteristics for bone fragments were noted, such as morphology and weathering.

4 Results

4.1 Zooarchaeological Analysis

The TP middens are characterized by high levels of caprine bone (81.7% DZ), followed by cattle (13.4% DZ), equid (1.8% DZ), wild boar (1.4% DZ), and carnivore (1.4% DZ) (Figure 3; for detailed count data, see Pawłowska, in press). Sheep outnumbered goats (8.3:1). Human bones make up 2.7% NISP and 0.1% DZ of the total assemblage, and are especially frequently observed in level TP.R (Space 416).

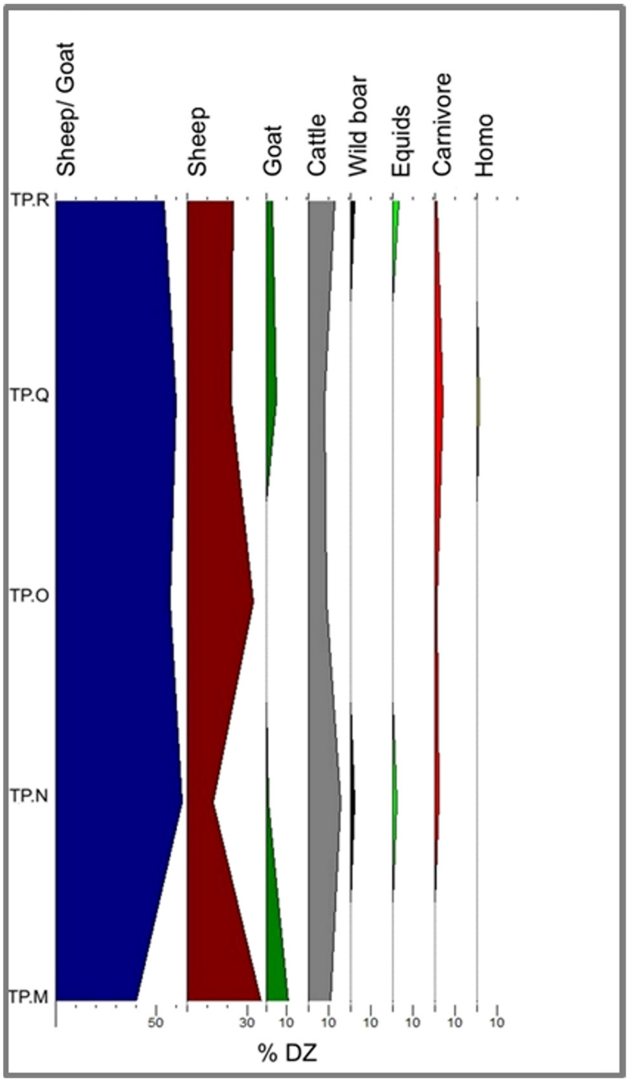

Figure 3: Çatalhöyük East, TP sequence. Proportions of the major taxa by TP levels using diagnostic zones (DZ).

The midden density data follows a decreasing trend through the TP sequence (Figure 4). The densest midden is on the TP.N level (6.0 g/L), in contrast to the less dense midden on the TP.Q level (1.3 g/L). This is also clearly visible in regard to the spaces (Figure 4).

Fifty-one specimen were found in articulation. Articulated elements occur on each TP level and in the majority of spaces (Figure 5). The exceptions are Spaces 318 (TP.N), 437 (TP.Q), and 416 (TP.R), where no

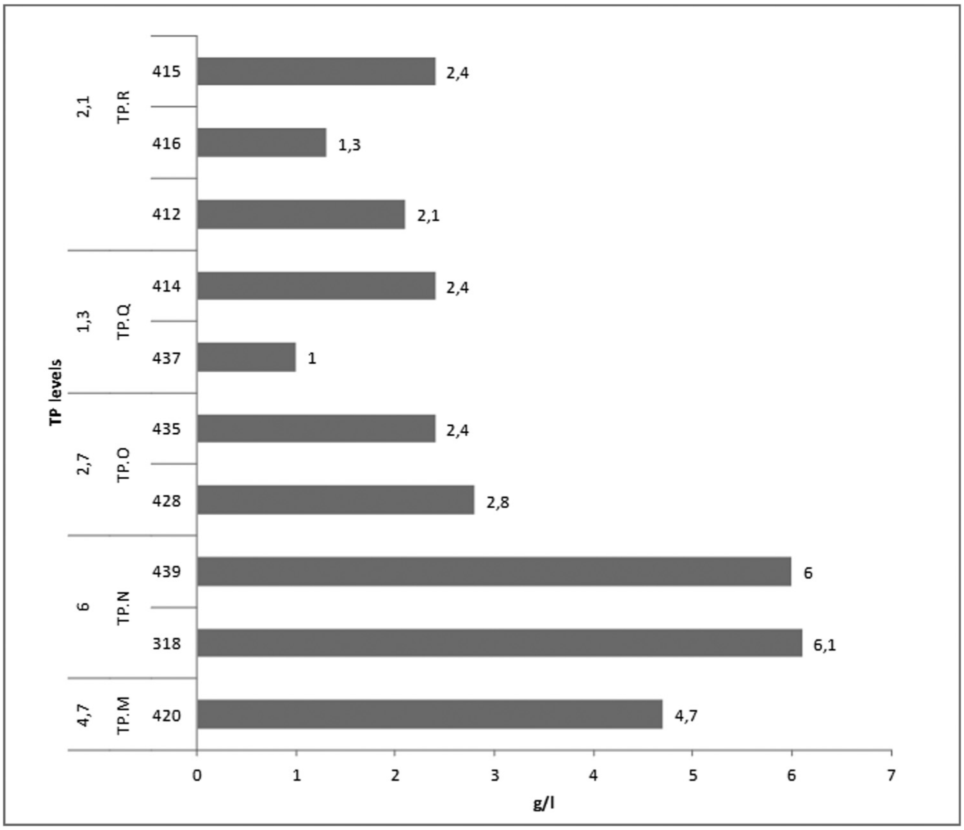

Figure 4: Çatalhöyük East, TP middens. Bar chart showing midden density through TP levels and the spaces within them.

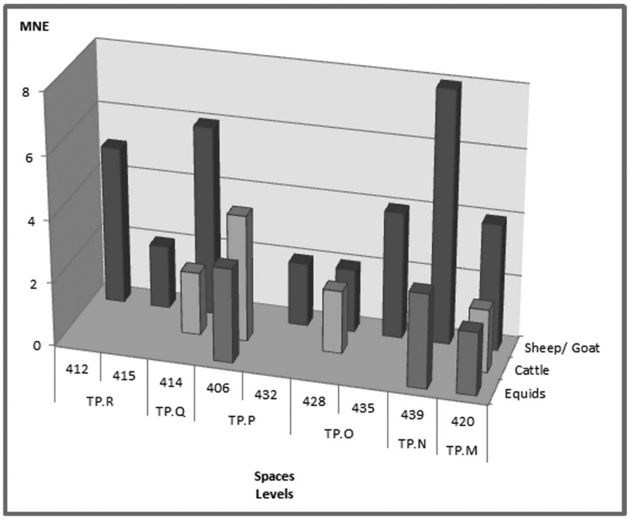

Figure 5: Çatalhöyük East, TP middens. Bar chart showing the frequency of articulated bones of sheep/goat, cattle, and equids through TP levels and the spaces within them MNE: minimum number of elements.

articulated bones were noted. The articulated bones come mainly from caprines (*n* = 33), followed by cattle (*n* = 10), and equid (*n* = 8). Forelimb and hindlimb elements have been identified: these are mostly phalanges (*n* = 11), tarsals (*n* = 10), and carpals (*n* = 9) (Pawłowska, 2014).

One hundred and one bone fragments in the TP assemblage (0.7%; with old breaks only) displayed fine, shallow, and variable oriented striations on the surface, which were considered to be effects of trampling. Trampled bones are found in all spaces except for Spaces 439, 435, and 414 and on all TP levels (Table 1). Although a slightly larger percent of trampled bones were present on the TP.R level (where they mostly come from Space 412; 2.8%; *n* = 80), their incidence generally does not exceed 0.5% which is within levels. Over 85% of them fall into the sheep-size category, followed by cow-size (ca. 12%).

Gnawing marks are recorded on 2.9% of midden specimens from the TP assemblage (Table 1). Both carnivore (2.9%) and rodent (0.05%) marks are noted, with the predominance of the former. Rodent marks, in the form of paired, broad, shallow, and flat-bottomed grooves, are only recorded within assemblages attributed to the TP.M and TP.R levels. The frequency of carnivore marks does not exceed 10% within any of the TP levels (Figure 6). About 5% are digested bone (Table 1). The size of the digested pieces does not exceed 4 cm over the whole sequence (with 2 cm length pieces predominating). A comparison of the frequencies of the gnawed and digested bones within the levels shows a predominance of gnawed specimens on the oldest level (TP.M), a balanced proportion of the two on the two consecutive levels (TP.N and TP.O), and finally, almost twice as many digested bones as gnawed on the youngest levels (TP. Q and TP.R) (Figure 6). In order to examine the effects of the material recovery methods on the distributions, the specimens from flotation (which usually provides mostly small specimens, frequently digested) were excluded from the compilation. Only in one case did the incidence of the digested bone significantly

Table 1: Taphonomic characteristics and density-mediated attrition for TP assemblage, by levels

	TP.M	TP.N	TP.O	TP.Q	TP.R	Total
Total NISP	533	6,432	2,714	1,970	3,166	14,815
% Trampling (*n* = 101)	0.4	0.03	0.1	0.4	2.8	0.7
% Carnivore gnaw	9.1	0.7	4.8	2.0	5.2	2.9
% Rodent gnaw	0.28				0.19	0.05
% Total gnaw	9.4	0.7	4.8	2.0	5.4	2.9
% Total gnaw (dry sieve only)/NISP	9.3/49	0.7/43	4.8/129	1.9/30	5.4/168	2.9/419
% Digested	3.8	1.2	4.7	10.4	10.9	5.2
% Digested (dry sieve only)/NISP	3.6/19	1.0/66	4.3/114	9.3/146	10.2/318	4.6/663
% Abrasion	<0.1					
Total completeness index (CI%) (*n* = 78)	100.0	97.0	80.3	90.0	94.5	96.3
Caprine CI% (*n* = 51)	100.0	100.0	97.5	100.0	100.0	99.5
Cattle CI% (*n* = 15)	100.0	87.5	100.0	50.0	100.0	91.7
Astragalus CI%						
Caprine (*n* = 16)	100.0	100.0	95.0			98.4
Cattle (*n* = 2)		62.5				
Central + fourth tarsal CI%						
Caprine (*n* = 4)		100.0			100.0	100.0
% Whole (*n* = 144)	92.3	72.5	78.6	60.0	75.0	76.5
Caprine (*n* = 83)	100.0	63.5	92.3	66.7	81.3	78.3
Cattle (*n* = 36)	75.0	87.5	100.0	40.0	80.0	77.8
Prox./Dist. Humerus	0/1	1/10	1/3	0/1	2/6	4/21
Caprine		1/7	0/2	0/1	1/6	2/16
Cattle	0/1	0/3				0/4
Prox./Dist. Tibia	1/1	4/7	2/5	0/2	1/7	8/22
Caprine	1/1	2/4	2/3	0/2	1/7	6/17
Cattle		2/3				2/3
% Root marks	<0.1					

Abbreviations: prox.: proximal; dist.: distal; NISP: number of identified specimens (for dry sieve and floatation).

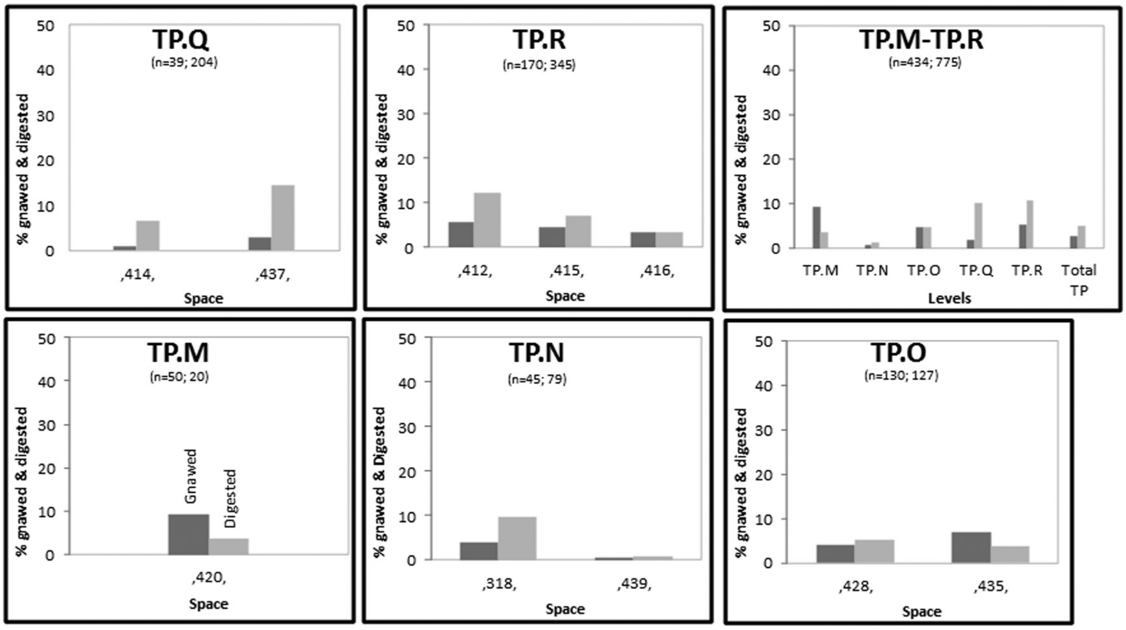

Figure 6: Çatalhöyük East, TP middens. Frequencies of the gnawed and digested bones within the spaces in each level in the TP sequence.

decrease, from 6.7 to 2.6%; this was observed in Space 414, but does not significantly alter the value for the level (TP.Q; Table 1).

The animal bones in the TP assemblages range from weathering stage 0 (unweathered) to stage 3 (moderately weathered). There were no specimens with weathering stage 4 or 5 (heavily and very heavily weathered). Many bones (ca. 60%) exhibited stage 2 (slightly weathered) than any other stage. The weathering profile differs between levels TP.M–TP.O and levels TP.Q–TP.R, shifting about one weathering stage from 2 to 1 (very slightly weathered) (Figure 7). Unfortunately, the significance of this shift cannot be statistically ascertained due to the lack of data from the missing level (TP.P). Some variation exists across

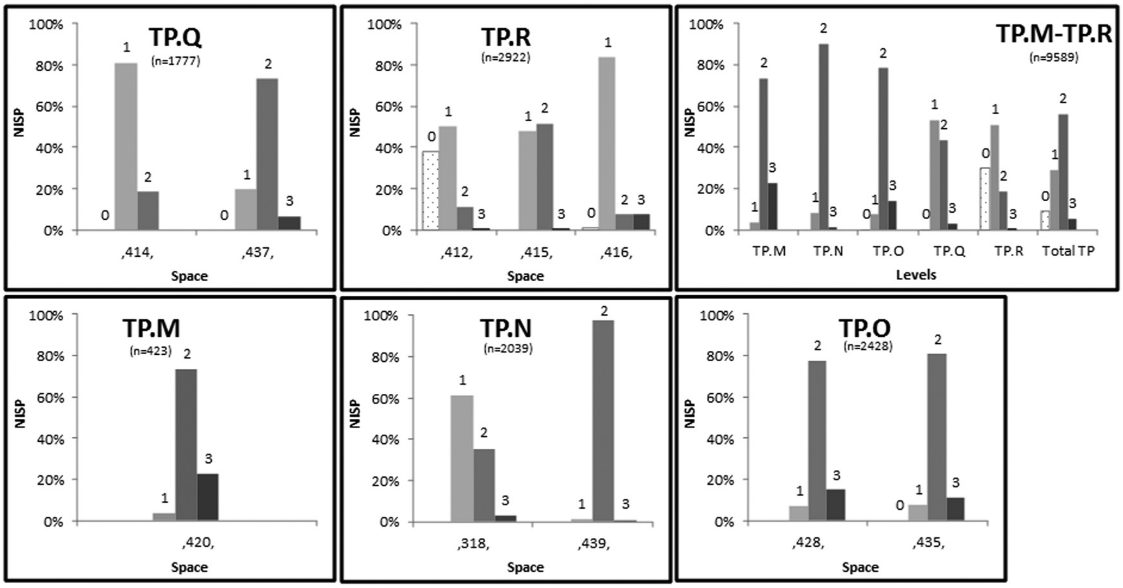

Figure 7: Çatalhöyük East, TP middens. Weathering profile of animal bones within the spaces in each level in the TP sequence. Abbreviations: 0–3 weathering stages; 0: unweathered; 1: very slightly weathered; 2: slightly weathered; and 3: moderately weathered.

spaces, with the broadest range of weathering stages being in Space 416. The percentage of bones that are abraded and percentage of specimens that display root etching is insignificant, being less than 0.1% (Table 1).

A prominent feature of TP middens is the presence of gypsum on bone surfaces and as infillings in cracks in the bones.

The value of the CI (%) for the carpals and tarsals in the TP assemblage shows that they are, on average, 96.3% complete skeletal elements (Table 1). Since astragalus and central and fourth tarsals would likely provide the most reliable indication of post-burial fragmentation (Marean, 1991), these were checked separately. Despite the small sample, their CI is high. The proportion of these specimens that are parts of an entire skeletal element (% Whole Index) was 76.5% for both caprines and cattle (Table 1). Both humerus and tibia are represented more frequently by distal parts in the assemblage (Table 1). This is true separately for both caprines and cattle. There is no balanced representation of both the parts at any level.

4.2 Micromorphological Analysis

The three slides analyzed from the TP Area have previously been shown to appear largely homogenized, with a massive structure and little fine stratification, especially when compared with the deeply buried deposits in earlier parts of the site (Shillito & Matthews, 2013). The inclusions in these deposits are similar to elsewhere, including microcharcoal, phytoliths, bone fragments, and architectural debris. A more detailed focus on the bone inclusions within the deposits shows these inclusions to be poorly orientated. Occasional

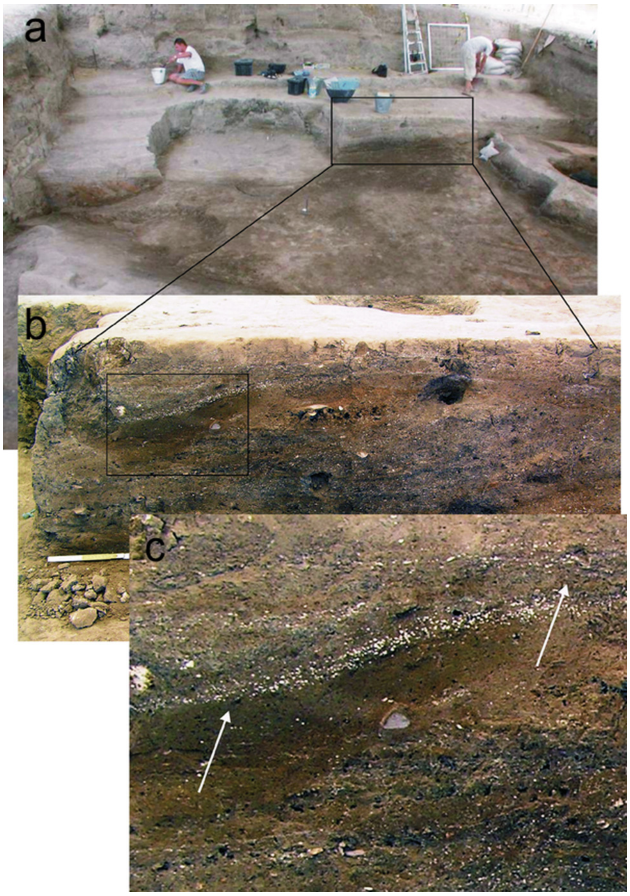

Figure 8: TP Area midden photos showing: (a) excavation area, (b) midden section studied, and (c) bands of gypsum nodules and lack of extensive fine stratification.

fine banding of material such as animal dung within the homogenous groundmass suggest that fine layering may have once been present. The presence of highly articulated reed phytoliths embedded within the groundmass also suggests that these were deposited as whole plants which have later been subjected to a degree of bioturbation. Large quantities of gypsum are present in these deposits (Figure 8), seen in thin section in a range of crystal forms including lenticular crystals and microcrystalline forms. Moreover, localized microfaunal burrowing and some plant root activities were noted. The depositional histories of the deposits, and therefore the faunal remains within, may be inferred through the sediment characteristics and associated assemblages.

Micromorphological analysis of the selected midden units has shown varying percentages of bone within sub-units. Much of this was present in abundances of less than 5% (Shillito & Matthews, 2013). Further observation of these inclusions, and their micro-context, can provide information on the preservation processes of the bones.

A total of 214 bone fragments were observed, ranging in size from less than 0.5 mm to 4 cm in length (Figure 9). The majority of bone inclusions are embedded and unorientated with a sub-rounded to sub-angular morphology. The majority of fragments are present as discrete isolated fragments embedded within the sedimentary matrix, and in some cases as clusters of fragments from single bones that have degraded *in situ*. This process can be seen in sub-unit 8932s9, where a larger bone fragment has been subjected to chemical weathering *in situ* (Figure 10b). The bone shows a loss of internal structure, with extremities showing dissolution and fragmentation. Further physical disturbance may then disperse these microscopic fragments throughout the sediment. Individual fragments display a "cracked" surface texture (Figure 10c and d). Occasional coprolites are present, some containing digested bone fragments (Figure 10a).

There are features which give insight into the deposits' history (Figure 10e). Occasional fine bands of rounded and burned aggregates are associated with the sweeping of hearth areas. Furthermore, laminated bands of animal dung indicate trampling. Compared to the earlier middens, there is very little fine stratification of the deposits, and previous analysis comparing these deposits with earlier middens in the South and North Areas has suggested that this is the result of post-depositional reworking and transformation of the deposits (Shillito & Matthews, 2013).

5 Discussion

Taphonomic analysis represents a useful supplement to stratigraphy in providing greater information on the processes affecting material and agents responsible for deposit formation, even if samples are

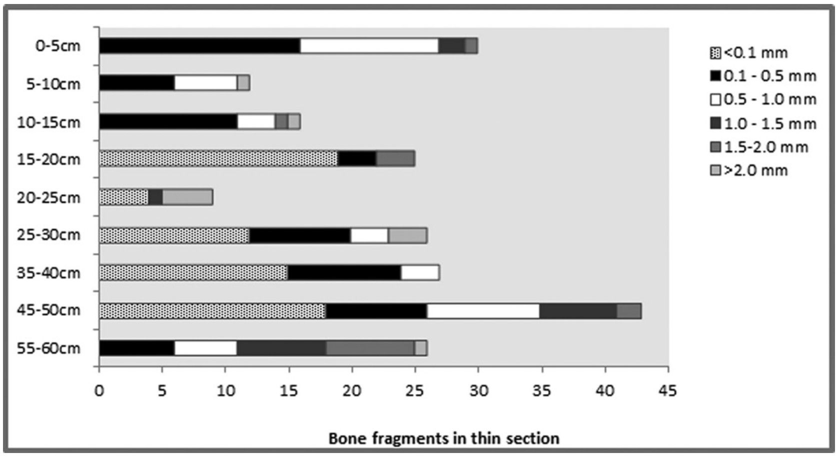

Figure 9: Summary of size distribution of bone fragments in thin sections (unit 8932, TP Area, Level TP.Q, Çatalhöyük East).

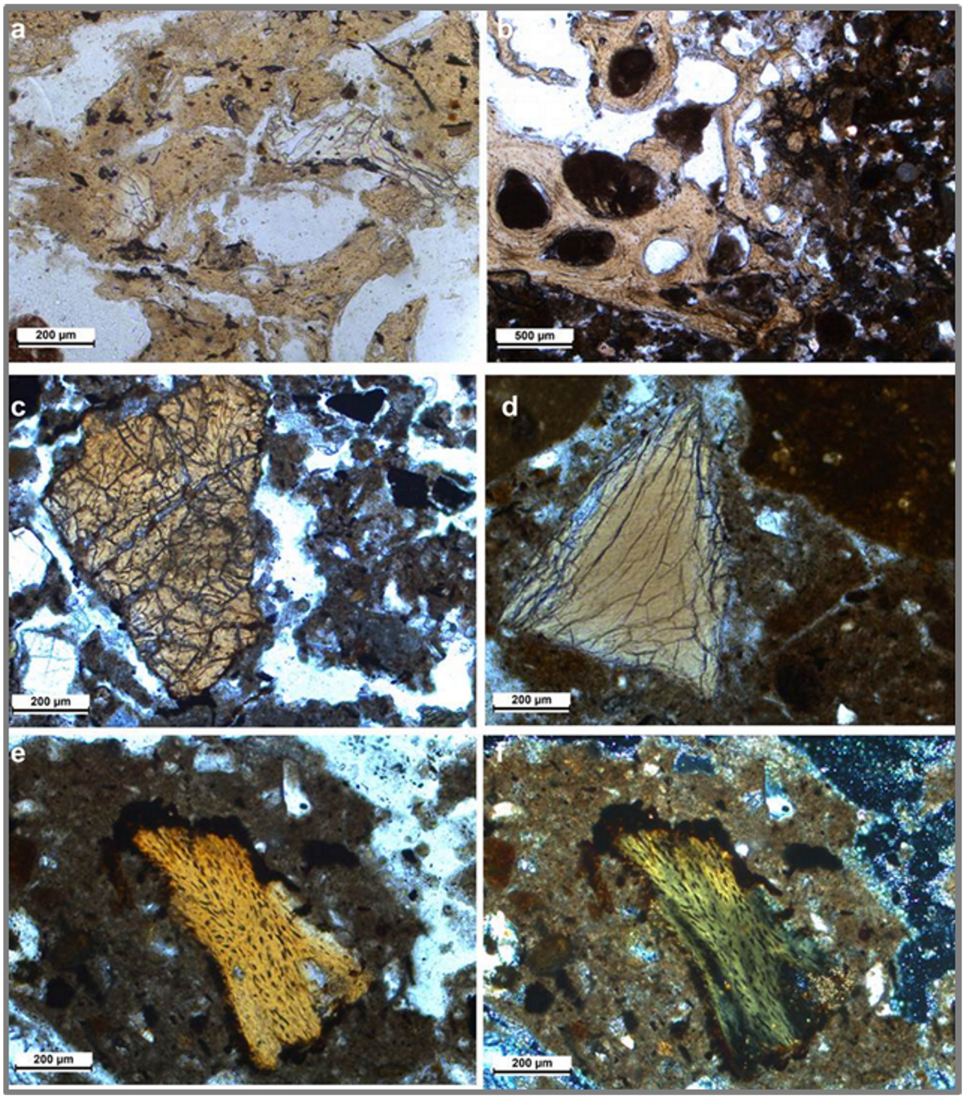

Figure 10: Micrographs from unit 8932 showing: (a) digested bone fragments within omnivore coprolite, (b) 4 cm fragment of bone showing loss of internal structure, weathering, and fragmentation at extremities, (c) and (d) highly weathered microscopic bone fragments, (e) bone fragment embedded within redeposited “mortar” fragment in PPL (plane-polarized light) and (f) XPL (cross-polarized light).

prohibitively small for statistical analysis (Madgwick & Mulville, 2015). Taphonomic analysis of faunal material, here integrated with micromorphology observations, enables us to reconstruct the depositional history of middens. The middens from the TP Area at Çatalhöyük can be considered in the light of three factors: their composition, the natural and cultural factors that played a part in their formation, and the activities related to them. Human and animal activities, as well as natural factors, are considered in terms of their effect on movement or replacement of the bones in space.

5.1 Faunal Assemblage Composition

The composition of the species forming part of the Çatalhöyük TP Late Neolithic assemblage, which is dominated by caprine and followed by cattle, is consistent with the general pattern of the Çatalhöyük subsistence strategy, in regards to the South.P-T levels. The dominance of sheep over goats (8:1), and caprines as such over other species, is typical of the Central Anatolian Neolithic from the earliest Neolithic onwards (Arbuckle, 2008). The distinct proportion of human bones in the assemblage (2.7% NISP; 0.1% DZ), seen especially in the TP.R level, can be explained as the result of burial disturbances, since TP burials are primarily disturbed loose, followed by primarily disturbed, tertiary, and secondary (Whitehouse et al., 2014, Figure 6.13).

Although most animal bones were loosely dispersed in the middens, some were found in anatomical order, suggestive of minimal disturbance. This implies some degree of coherence of these deposits, which were attributed to each TP level and to most spaces. This is especially true for caprine elements, which in fact can be correlated with their significant contribution to the subsistence level and thus to waste disposal. None of the associated bone groups seem to be deliberately placed in the middens, given the anatomical parts they represent (mostly butchery waste) and their detailed contexts. However, the social significance of faunal remains is well evidenced in other TP contexts at the site, as recently shown (Pawłowska, 2020a,b; Pawłowska & Barański, 2020; Pawłowska & Marciszak, 2018). At the microscale, "*in situ*" fragmentation can be seen whereby bone fragments undergo gradual dissolution, fragmentation into smaller pieces, and eventual reworking and distribution throughout the sediment.

Midden densities are not uniform in the sequence, and show significant variation in the distribution of bone between the TP levels. The gradual decrease in the density of bone in the middens over time is most likely related to a decrease in population in the Late Neolithic or to changes in disposal waste or in refuse management practice (Pawłowska, 2020a,b); they could also be caused by the sample size. Examining the density of other cultural materials, such as obsidian and pottery in TP middens, should help investigate this issue.

5.2 Taphonomic Processes and their Implications for Interpretation

5.2.1 Trampling

Trampling creates marks on bones, the fracturing of bones, the spatial displacement of bones, and may also abrade bones (Lyman, 1994).

The creation of a large number of closely spaced fine and shallow striations is characteristic of trampling (Madgwick, 2014 with further references). The considerable range of variability in the direction of the TP samples most likely results from friction with sedimentary particles since, according to Madgwick (2014), the direct contact of hooves with bones during trampling does not alter their surface, as they are softer than bone. The present study shows that trampled bones occurred in most TP spaces and on all levels. The effect of trampling, apart from the marks it leaves, is obvious in the reduction of element sizes, at about 0.5–3 cm. The trampled bones could have come from any place where there was movement of humans and animals, including floors. The predominance of the sheep-size category among the trampled elements may be due to the clearance of waste from building floors where sheep-related activity was the only activity performed *in situ* in the TP Area along with caprine dominance at the subsistence level. Evidence of floor deposits, associated with the sweeping of floors in buildings to remove domestic refuse (Matthews, 2005), is often found in middens in Çatalhöyük. However, in the activity areas not habitually cleaned, items can accumulate as primary refuse (Schiffer, 1983 with further references). Although what can be recognized as trampled bones makes up only a small proportion of the total TP sample (0.7%), we should be aware, as Schiffer (1983 with further references) emphasized, that artifact size also affects loss probability, especially for those small items that have a high replacement cost in activity and refuse areas. In any case, their proportion may suggest that trampling had little impact on the overall fragmentation of the TP assemblages.

Animal trampling is likely within penning areas. Currently there is no evidence of penning areas in the TP Area, though it is likely that they were present. At Çatalhöyük, generally, penning areas have been recognized both within and close to the site, for at least some periods of the year (Matthews, 2005; Russell &

Martin, 2005). The former has been found within middens in Spaces 199 and 198 on Levels XII–XI and in courtyard deposits from Level VIII, on the basis of micromorphological evidence of compacted herbivore dung (Matthews, 2005). Later "courtyard" deposits in Levels IV and V also show evidence of trampled animal dung, though some of these may relate to the collection and burning of trampled animal dung (Shillito & Ryan, 2013).

During animal trampling, bones can undergo horizontal and vertical displacement, and the effect of trampling depends on the substrate. In loose substrates, this activity usually tends to sort pieces by size, selectively burying compact bones, as has been shown by Behrensmeyer and Dechant Boaz (1980) in determining the effects of natural taphonomic processes on modern bone samples from Amboseli Park, Kenya. The experimental examination of animal trampling effects on artifact movement shows that short-period animal trampling causes equal amounts of horizontal displacement in dry and saturated substrates, and significantly greater vertical displacement in saturated substrates (Eren et al., 2010).

5.2.2 Gnawing and Digestion

Gnawing and digestion can result from larger carnivores, rodents, and omnivores. These processes cause surface modification, and can also move bones from their original depositional loci (Kent, 1981; Lyman, 1994; Marean & Bertino, 1994). In the case of the TP assemblages, this seems to have had a minor effect.

Evidence of carnivore activity occurs in the form of gnawing and digestion marks (Figure 11) usually visible in the assemblage as punctures, pits, scores, and furrows (Binford, 1981), and the presence of coprolite (Figure 12). Although these marks are present, indicating that dogs have access to the middens, the damage and destruction of the assemblage is infrequent at less than 5%. There are a number of possible explanations for this. One factor may be that there were only a small number of dogs present; alternatively or additionally, it may be the case that the refuse was not attractive to carnivores. According to Blumenschine (1988), the incidence of carnivore-gnawed bone pieces is low in assemblages in which the marrow had been removed and the bones broken prior to carnivore action. Thus, only those which retain the greatest food value are subjected to carnivore actions. Generally, this can be seen to be true for the fragmentation of TP assemblages (Pawłowska, 2014). The identification of digested bone contained within human coprolites (identified unequivocally through analysis of sterol and bile acid profiles) in the TP Area indicates one depositional pathway for digested bone (Shillito et al., 2011), and also provides support for the hypothesis that bone marrow was consumed by humans.

Figure 11: Digested bones (from midden deposit, unit 12277, Space 437, TP Area, Level TP.Q, Çatalhöyük East). (Photo by K. Pawłowska).

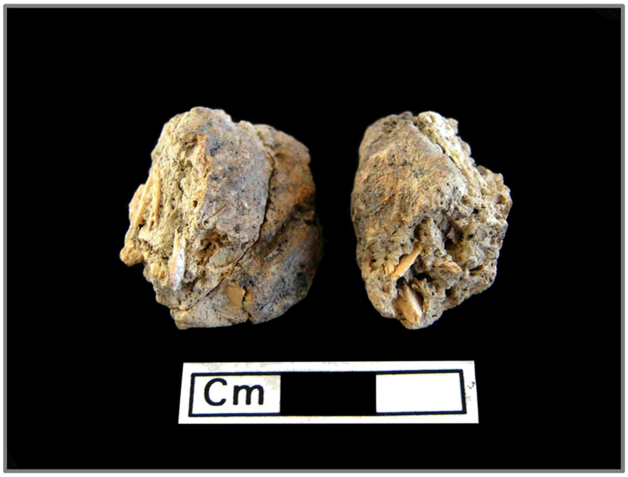

Figure 12: Animal coprolite (from midden deposit, unit 17670, Space 420, TP Area, Level TP.M, Çatalhöyük East). (Photo by K. Pawłowska).

Generally discarded bones need to be exposed for a period of time rather than rapidly buried in order for carnivores to gain access. This is true for many of the pre-XII level midden deposits which have been worked over extensively by dogs, in contrast to many of the Level V middens that show particularly rapid burial and excellent preservation, while the TP Area middens are more slowly accumulated and slightly degraded (Russell, Twiss, Pawłowska, & Henton, 2006).

The size of the digested pieces in the TP samples (2 cm-long pieces predominating over the whole sequence) is within the size range that could be swallowed by dogs. Our results show that the proportions of gnawed and digested bones change in the most recent levels (TP.Q and TP.R) in favor of digested bones. The high frequency of digested bones, resulting from the decay of feces, in the TP.Q and TP.R levels suggests that carnivores were present on the site for longer than would be needed to simply search the waste, or else that they were more abundant. It may also imply greater occupation on the surfaces of the recent levels by humans and carnivores, as is well correlated with the greater number of open spaces at Çatalhöyük at this time. Alternatively, it may indicate a practice of collection and gathering of feces in one place by inhabitants, as it has been noted by Russell and Twiss (2017) on earlier levels of the site.

Although some samples showed evidence of rodent gnawing, indicative of rodent presence and some subaerial exposure of samples, this occurred infrequently. It seems that the extraction of calcium and other minerals from bone by rodents (Klippel & Synstelien, 2007 with further references) occurred only at the times proper to TP.M and TP.R levels, leaving modifications in the form of paired, broad, shallow, and flat-bottomed grooves.

The effects of pigs on bone attrition, well recognized by Greenfield (1988), has been excluded in this case, due to the low proportion of pig elements – mostly isolated teeth (Figure 13) – and because of the lack of long shovel-type teeth marks, which, according to Greenfield, are the major characteristics allowing pig-chewed bones to be distinguished from dog-chewed bones.

5.2.3 Weathering

Weathering as it applies to bone assemblages is defined by Behrensmeyer (1978) as the process by which the original microscopic organic and inorganic components of a bone are separated from each other and destroyed by physical and chemical agents operating on the bone *in situ*, either on the surface or within the soil zone. Since the pattern of the variation in the weathering stages of bones can be attributed to variation in exposure duration and depositional microenvironment (Lyman & Fox, 1989), the lack of weathering stages 4 or 5 in the TP assemblages most likely results from them not being exposed sufficiently long to reach these stages. Consequently, our results show that animal bones from TP middens display

Figure 13: Isolated pig tooth (from burial chamber, unit 15821, Space 327, TP Area, Level TP.O, Çatalhöyük East). (Photo by K. Pawłowska).

weathering stages 1–3. Madgwick and Mulville (2012) in the context of a midden in the UK found that very few heavily weathered remains are archaeologically recovered in an identifiable state. This implies a second possible explanation for the absence of stage 4 or 5 weathering in the TP assemblages, related to the complete destruction of the remains or their reduction to unidentifiable fragments. Ultimately, their dust or fine particle fraction reached a matrix state in the context of middens, which were very often reworked. Furthermore, we found a shift of about one weathering stage between TP subphases (M–O versus Q–R), suggesting a longer accumulation history in the first three occupational levels or, conversely, the assemblage from the most recent levels (TP.Q and TP.R) represents a relatively shorter exposure duration. The broadest range of weathering stages found in Space 416, as shown in our results, along with the lack of articulated bones, indicates the complex depositional history of the assemblages, which is in their secondary or even tertiary context.

Weathering rates are also a function of environmental conditions, including climate. The contemporary climate of Turkey is semiarid continental (Köppen classification), with cold moist winters (−25°C) and hot dry summers (35°C), with average temperatures at about 0 and 22°C, respectively (De Meester, 1970). As Lyman and Fox (1989) suspect that the magnitude of seasonal changes in weather and durations of season are critical, and that the moisture content, temperature, and nature and texture of the sediment on which a bone lies may also be important in bone weathering. The climate at the time corresponding to the upper levels at Çatalhöyük can be inferred from the significant impact of chemical processes on bones in the form of large quantities of gypsum. The presence of gypsum, which macroscopically occurs as nodules, as infillings in bone cracks, and on bone surfaces, and which in micromorphological analysis is seen as lenticular crystals and microcrystalline forms, clearly indicates arid environmental conditions during the Late Neolithic, favorable for gypsum formation. This is consistent with the earlier results of Asouti (2009) and Asouti and Austin (2005) which took into account the climate data for the Holocene in Anatolia to conclude that the climate in Neolithic Çatalhöyük may have been drier than today. It is thus possible that animal bones in the uppermost levels (TP Area) were subjected to different environmental conditions than those in the lower levels in the sequence, and thus to different post-depositional processes (Wolfhagen et al., 2020). This could explain the differences between the TP middens and those earlier deposits in terms of the extent to which they are preserved and chemical processes, indicating temporal trends. This is partly due to the fact that the formation of gypsum may also be responsible for the preservation of bones, since the physical weathering processes caused by gypsum crystal formation have been suggested to cause fragmentation of bone (Clark & Ligouis, 2010; Turner-Walker & Jans, 2008). In conclusion, our data suggest that at the time attributable on TP levels, especially after TP.P, arid period appeared. These results were later corroborated using isotope evidence. The conclusion was that TP levels in some parts of the sequence (TP.P level) correspond with the 8.2ka BP event, the most prominent climatic event (Roffet-Salque et al., 2018), though this was later questioned by Wainwright and Ayala (2019), ultimately leading to the conclusion that the local climate was dominated then (as now) by high degrees of interannual variability (Ayala et al., 2020).

Cycles of wetting and drying are also indicated by the presence of silty coatings within bone void spaces. It is difficult to assess the timeframe over which these processes are occurring, though it could be tentatively argued that the post-depositional processes of large quantity of salt crystallization and wetting/drying as inferred from micromorphology, compared with a relatively low weathering stage of the bone, have occurred more recently in the site history, and have not yet had sufficient time to impact larger bone deposits.

5.2.4 Density Mediates Attrition

Weathering and carnivore gnawing, as well as human activity (such as grease processing and marrow extraction), are among the examples of numerous taphonomic agents that are a source of density-mediated bias: the density of particular bones affects their survivorship (i.a. Lyman, 1984; Munro & Bar-Oz, 2004). Artiodactyl carpals and tarsals with rather low nutritional values and relatively high structural density are best for detecting post-burial fragmentation, since they would seldom be broken by hominids in order to extract the minimal amounts of grease they contain (Darwent & Lyman, 2002). These small compact bones have high values of CI in the TP assemblage, both for caprines and cattle, thus indicating that no significant density-mediated attrition or fragmentation occurred with respect to astragali. This is later corroborated by the value of the second index of degree of fragmentation (% Whole) of more than 75%. However, the density-mediated attritional pattern is visible by comparing the frequencies of the proximal and distal parts of both humeri and tibias for caprines and cattle. The less dense proximal parts occur less frequently than distal parts in the TP assemblage (Table 1). Aside from the fact of the sample size, it seems that, in all TP levels, some effect of density-mediated destruction appears.

5.2.5 Plant Root Activity and Abrasion

Considerable alterations on bone surface could result from the solution of bone surface in some situations where dense roots covered the bone (Pei, 1938; Binford, 1981). The most common evidence of plant activity on the bones is the dendritic etching of bone surfaces. The low frequency (less than 0.1%) of such marks in TP samples indicates that any damage in the form of splitting and fragmentation (Behrensmeyer, 1978) due to plant root growth was minimal. Also, structural damage of specimens by root marking (which increases bone porosity) has not been noted in any case. The only changes seen concern dendritic patterns of shallow grooving, which is interpreted by Behrensmeyer (1978) as the result of dissolution by acids associated with the growth and decay of roots in direct contact with bone surfaces. This is supported by micromorphological observations which indicate localized root growth. Generally, root growth from modern plants is minimal, though occurs at a greater frequency than in the earlier, more deeply buried deposits at Çatalhöyük.

Abrasion is the modification of original bone morphology by the application of frictional forces to bone surface or edges (Lyman, 1994; Olsen & Shipman, 1988; Shipman & Rose, 1988). Abraded bones, which can result from many natural and cultural factors, are rarely noted in TP middens (less than 0.1%).

5.2.6 Forms of Activity in Middens

Midden deposits at Çatalhöyük were places where specific kinds of human activity took place. They include fire-spots, the construction of foundation trenches, the placing of animal parts, and others.

There is evidence in TP Area of foundation trenches made prior to the construction of a new structure, and which are associated not only with the placement of animal elements as a foundation deposit but also with certain movements of animal bone assemblages (Barański, García-Suárez, Klimowicz, Love, & Pawłowska, 2015). Further evidence of the effects on midden structure is provided by the feasting remains located in a pocket in a midden (TP.R level, Space 412). Finally, the midden at Çatalhöyük was also extracted for mortar, and bone fragments have been observed incorporated into such materials (Hodder, 2007; Matthews, 2005).

All these activities, regardless of type, are linked with spatial changes in assemblages, which may be described as movement or displacement, depending on the degree of infringement of the initial deposition.

5.2.7 Erosion

Factors such as the mound slope furnish evidence of the occurrence of many cultural and natural formation processes, which may affect the specific deposits within it (Schiffer, 1983). At Çatalhöyük, there are arguments suggesting both lower and higher degrees of erosion of the level site. The latter may be associated with later levels of activity on the tops of the northern and southern eminences of the East Mound, as suggested by Hodder (2007). Since the TP Area is situated on the top of the southern eminences of the East Mound, some degree of erosion and postdepositional movement cannot be excluded. On the other hand, the Late Neolithic and post-Neolithic architectural structure, as well as the midden deposits, have been preserved in the TP Area. The degree of potential loss of the archaeological record through postdepositional downslope movement is difficult to assess due to the lack of research.

5.2.8 Animal Burrowing

The tunnels of the Asia Minor ground squirrel or Anatolian souslik (*Spermophilus xanthoprymnus*; Bennett, 1835) are well recognized at Çatalhöyük (Figure 14). The actions of the burrowing animals are the main reworking process to affect both architectural structures and deposits (e.g., middens and infills) within the site. Regular burrows, whether used for nesting, hibernation, or feeding, vary in depth, with feeding

Figure 14: Çatalhöyük East. Example of actions of burrowing animals. (Photo by K. Pawłowska).

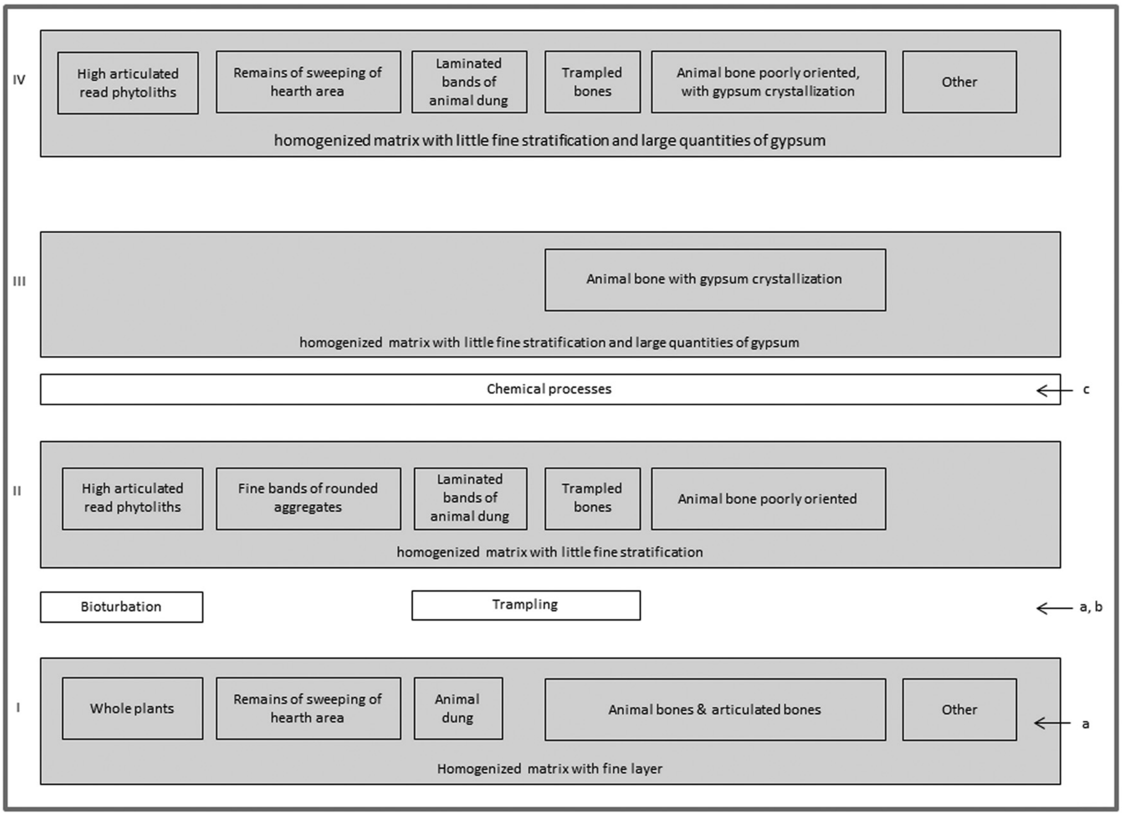

Figure 15: Reconstruction of possible midden formation process (Çatalhöyük East, TP Area, Level TP.Q). Explanation: I–IV successive stages; taphonomic processes occur between them. Stage I: discarded ecofacts and artefacts; Stage II: observed characteristics; Stage III: the impact of chemical processes; Stage IV: characteristics of excavated midden; (a–c) impact on the assemblage: (a) human activity; (b) animal activity; and (c) environmental condition including climate. The "Other" category includes charcoal, microcharcoal, human bones, pottery, and architectural debris.

burrow reaching up to 4 m (De Meester, 1970). When the burrows of fossorial mammals are back-filled with soil, krotovinas are created. These are tubes of material of a different character from their surroundings (Paton, Humphreys, & Mitchell, 1995). Burrowing animals can push artifacts from lower layers up to the surface, in this way placing older artifacts into a younger stratigraphic context (Kelly & Thomas, 2012). In other cases, size-sorted artifacts are noted in burrows, causing artificial concentration of small materials to appear near to the surface, with larger materials deeper (Bocek, 1986; Wood & Johnson, 1978). In the case of Çatalhöyük, these burrows are observed in the field, but there are no data on the scale of this phenomenon. Krotovinas are distinctive in thin section, creating voids which are infilled with homogenized fine material.

Faunal burrowing is distinctive at the microscale. No mammal burrowing was evident in the TP samples selected, though it should be noted that micromorphology sampling deliberately avoids areas with these larger disturbances. Reworking from insects and smaller fauna is apparent in some areas. By assumption, earthworms and insects also contribute to soil disturbance (Stein, 1983). The disruptive effect of earthworms is also recognized in archaeological deposits, where it reworks the matrix of the site, disturbing material of less than 2 mm in size. For example, earthworms may alter the botanical assemblage by selectively removing small plant remains, such as seeds (Stein, 1983), or moving material between depositional contexts. Features suggestive of insect and other microfaunal burrowing are seen in thin section.

Rainwash is also observed at the microscale, particularly in conjunction with burrows, which provide channels for the movement of water. Size-sorted, water-laid particles accumulate within these burrows.

6 Conclusion

This work has presented taphonomic processes related to movement, displacement, and disturbance occurring within middens from the upper levels at Çatalhöyük. The range of observed taphonomic processes include evidence of trampling, animal activity, weathering processes and abrasion, bioturbation, and some aspects of human activity (Figure 15). Erosion and the impact of chemical processes were also considered. The potential of using wide-ranging multiscalar taphonomic proxies was later emphasized by their integration with other research, here represented by micromorphology. Zooarchaeological taphonomy and soil micromorphology complement each other, because while zooarchaeology relies on macro-observations, micromorphology provides insights into microstructure and microorientation. The combination of these two levels of perspective on middens allows the refinement of depositional inferences in terms of the degree and nature of deposition with demonstration of the effects of factors that modify the assemblage. This type of approach to the study of TP middens has proved to be helpful for reconstructing particular past events, and is thus a good resource for understanding human lifeways.

The study of middens and the integration of lines of evidence for reconstructing the taphonomic trajectories of faunal assemblages and archaeological deposits in the study in which they were found allowed us to determine the extent to which the TP middens had undergone reworking, to make inferences regarding the climate, to determine the population size during the Final phase of occupation, and to estimate the impact of inhabitants on waste management. At Çatalhöyük, various middens have their own taphonomic history, and in the case of TP Area, at least some of the middens are represented by a complex depositional history and are from depositional palimpsests. This results in the presence of articulating groups of discarded waste indicative of the lack of disturbance, and with simultaneous evidence of some degree of midden reworking revealed in micromorphology. Multiple lines of evidence indicate that the middens in upper levels (TP Area) differ from those in lower levels in terms of the state of preservation of the bones and their layout within middens, as seen through intrasite comparisons. It seems that the former was subjected to distinctive natural and cultural forces that leave this taphonomic signature. The shift between levels and, simultaneously, areas at Çatalhöyük in the dominant processes of midden creation may be the result of contextual differences in this taphonomic setting, specific human activities, and various physical and environmental conditions.

These results suggest that waste, and thus production, was gradually limited from TP.O onwards, as shown by the gradual but significant decline in faunal densities in the middens, which has been linked (Pawłowska, 2020b) to a decreased population at Çatalhöyük.

Despite the fact that the influence of natural factors and attritional processes in TP Area has been noted – but seems to have had no significant impact on the assemblage – a more detailed characterization of the formation processes of TP middens through specific studies concerning other aspects of human activity, such as butchering, bone processing, and consumption within specific contexts, provides a strong foundation for future work. Expanding to these taphonomic aspects will contribute to our ability to understand refuse management practices. Also, future studies should focus on identifying the modes of consumption and agricultural production that are associated with this small (as predicted in this article) community of the Late Neolithic at Çatalhöyük.

Finally, this study has shown that zooarchaeology and micromorphology are complementary, and that their integration is a useful tool in taphonomic research into bone assemblages. This study could be replicated in different contexts, such as deposits in wells, especially in transitions between use and disuse, and other sites where waste was accumulated by humans.

Acknowledgments: We would like to thank Ian Hodder for the opportunity to participate in the Çatalhöyük Research Project, as part of which this research has been carried out. We express our gratitude to the members of this project, especially those on Team Poznań, for creating multi-aspectual knowledge during the project that could be used here for a broader synthesis. Special thanks go to the Neolithic expert Lech Czerniak for his research approach and sharing of Neolithic knowledge. This article was presented at the 12th International Conference of the International Council for Archaeozoology (ICAZ) in Argentina.

Author contributions: All authors have accepted responsibility for the entire content of this manuscript and approved its submission. KP prepared the manuscript with contributions from L-MS.

Conflict of interest: Authors state no conflict of interest.

Data availability statement: The datasets analyzed during the current study are available from the authors upon reasonable request.

References

Adderley, W. P., Alberts, I. L., Simpson, I. A., & Wess, T. J. (2004). Calcium–iron–phosphate features in archaeological sediments: Characterization through microfocus synchrotron X-ray scattering analyses. *Journal of Archaeological Science*, *31*, 1215–1224. doi: 10.1016/j.jas.2002.03.001.

Arbuckle, B. S. (2008). Caprine exploitation at Erbaba Höyük: A pottery Neolithic village in central Anatolia. *MOM Éditions*, *49*(1), 345–365. https://www.persee.fr/doc/mom_1955-4982_2008_act_49_1_2714

Asouti, E. (2009). The relationship between Early Holocene climate change and Neolithic settlement in Central Anatolia, Turkey: Current issues and prospects for future research. *Documenta Praehistorica*, *36*(2009), 1–5. doi: 10.4312/dp.36.1.

Asouti, E., & Austin, P. (2005). Reconstructing woodland vegetation and its exploitation by past societies, based on the analysis and interpretation of archaeological wood charcoal macro-remains. *Environmental Archaeology*, *10*, 1–18. doi: 10.1179/env.2005.10.1.1.

Ayala, G., Wainwright, J., Lloyd, J. M., Walker, J. R., Hodara Nelson, R., Leng, M., … Charles, M. (2020). Disentangling the Palaeoenvironmental Reconstructions of Çatalhöyük. In I. Hodder (Ed.), *Humans and environments of Çatalhöyük: Reports from the 2009–2017 seasons* (pp. 31–46). Los Angeles: Cotsen Institute of Archaeology Press.

Barański, M. Z., García-Suárez, A., Klimowicz, A., Love, S., & Pawłowska, K. (2015). The architecture of Neolithic Çatalhöyük as a process. Complexity in apparent simplicity. In I. Hodder & A. Marciniak (Eds.), *Assembling Çatalhöyük. Themes in contemporary archaeology* (Vol. 1, pp. 111–126). Leeds: Maney Publishing.

Barański, M. Z., Bayliss, A., Czerniak, L., García-Suárez, A., Love, S., Nowak, A., Pawłowska, K., Tibbetts, B., Tsoraki, C., Doyle, S., Gamble, M., Goslar, T., Guerre, L., Killackey, K., Quinlan, J., Saj, M., Sobott, R., Southon, J., Stroud, E., Tarkan, D., Wolfhagen, J. (2022). The Gdańsk (GDN) Area Excavations and Building Archaeology Research Project. In Hodder, I. (Ed.), *Çatalhöyük Excavations: The 2009–2017 Seasons*. British Institute at Ankara.

Behrensmeyer, A. K. (1978). Taphonomic and ecologic information from bone weathering. *Paleobiology*, *4*(2), 150–162. doi: 10.1017/S0094837300005820.

Behrensmeyer, A. K., & Dechant Boaz, D. E. (1980). The recent bones of Amboseli Park, Kenya, in relation to East African paleoecology. In A. K. Behrensmeyer & A. P. Hill (Eds.), *Fossils in the making: Vertebrate taphonomy and paleoecology* (pp. 72–92). Chicago and London: The University of Chicago Press.

Binford, L. R. (1981). *Bones: Ancient men and modern myths*. New York: Academic Press.

Blumenschine, R. J. (1988). An experimental model of the timing of hominid and carnivore influence on archaeological bone assemblages. *Journal of Archaeological Science*, *15*(5), 483–502. doi: 10.1016/0305-4403(88)90078-7.

Bocek, B. (1986). Rodent ecology and burrowing behavior: Predicted effects on archaeological site formation. *American Antiquity*, *51*(3), 589–603. doi: 10.2307/281754.

Bogaard, A., Charles, M., Livarda, A., Ergun, M., Filipović, D., & Jones, G. (2013). The Archaeobotany of Mid-later Occupation Levels at Neolithic Çatalhöyük. In I. Hodder (Ed.), *Humans and Landscapes of Çatalhöyük: Reports from the 2000–2008 Seasons* (pp. 93–128). Los Angeles: Cotsen Institute of Archaeology Press.

Bogucki, P. I. (1982). Early Neolithic subsistence and settlement in the Polish Lowlands. *British Archaeological Reports*, *150*, 176.

Brönnimann, D., Röder, B., Spichtig, N., Rissanen, H., Lassau, G., & Rentzel, P. (2020a). The Hidden Midden: Geoarchaeological investigation of sedimentation processes, waste disposal practices, and resource management at the La Tène settlement of Basel-Gasfabrik (Switzerland). *Geoarchaeology*, *35*(4), 522–544. doi: 10.1002/gea.21787.

Brönnimann, D., Wimmer, J., Müller-Kissing, M., Stopp, B., Rissanen, H., & Spichtig, N. (2020b). One man's trash is another man's treasure. Interdisciplinary examination of taphonomic aspects of ceramic sherds, animal bones and sediments from the La Tène period settlement at Basel-Gasfabrik. *PloS One*, *15*(7), e0236272. doi: 10.1371/journal.pone.0236272.

Bullock, P., Fedoroff, N., Jongerius, A., Stoops, G., & Tursina, T. (1985). *Handbook for soil thin section description*. Albrighton, Waine: Soil Survey Institute.

Clark, J. L., & Ligouis, B. (2010). Burned bone in the Howieson's Poort and post-Howieson's Poort Middle Stone Age deposits at Sibudu (South Africa): Behavioral and taphonomic implications. *Journal of Archaeological Science*, *37*, 2650–2661. doi: 10.1016/j.jas.2010.06.001.

Darwent, C. M., & Lyman, R. L. (2002). Detecting the postburial fragmentation of carpals, tarsals, and phalanges. In W. D. Haglund & M. H. Sorg (Eds.), *Advances in forensic taphonomy: Method, theory, and archaeological perspectives* (pp. 355–378). Boca Raton: CRC Press.

De Meester, T. (1970). Soils of the Great Konya Basin, Turkey. *Agricultural Research Reports*, *740*, 290. https://library.wur.nl/WebQuery/wurpubs/fulltext/304248

Eren, M. I., Durant, A., Neudorf, C., Haslam, M., Shipton, C., Bora, J., … Petraglia, M. (2010). Experimental examination of animal trampling effects on artifact movement in dry and water saturated substrates: A test case from South India. *Journal of Archaeological Science*, *37*(12), 3010–3021. doi: 10.1016/j.jas.2010.06.024.

Estevez, J., Villagran, X. S., Balbo, A. L., & Hardy, K. (2014). Microtaphonomy in archaeological sites: The use of soil micromorphology to better understand bone taphonomy in archaeological contexts. *Quaternary International*, *330*, 3–9. doi: 10.1016/j.quaint.2013.08.007.

Fiorillo, A. R. (1989). An experimental study of trampling: Implications for the fossil record. In R. Bonnichsen & M. H. Sorg (Eds.), *Bone modification* (pp. 61–71). Orono: University of Maine Center for the Study of the First Americans.

Fisher Jr, J. W. (1995). Bone surface modifications in zooarchaeology. *Journal of Archaeological Method and Theory*, *2*(1), 7–68. https://link.springer.com/content/pdf/10.1007/BF02228434.pdf

Greenfield, H. J. (1988). Special studies: Bone consumption by pigs in a contemporary Serbian village: Implications for the interpretation of prehistoric faunal assemblages. *Journal of Field Archaeology*, *15*(4), 473–479. doi: 10.1179/jfa.1988.15.4.473.

Hodder, I., Cessford, C., & Farid, S. (2007). Introduction to methods and approach. In I. Hodder (Ed.), *Excavating Çatalhöyük: South, North and KOPAL area reports from the 1995–99 seasons* (pp. 3–25). Cambridge: McDonald Institute for Archaeological Research/British Institute of Archaeology at Ankara.

Hodder, I. (2007). Summary of results. In I. Hodder (Ed.), *Excavating Çatalhöyük: South, North and KOPAL Area reports from the 1995–99 seasons* (pp. 25–37). Cambridge: McDonald Institute for Archaeological Research/British Institute of Archaeology at Ankara.

Hodder, I. (2008). Hitting the jackpot at Çatalhöyük. *Çatalhöyük 2008 Archive Report, Çatalhöyük Research Project*, 1–5.

Hodder, I. (2016). *Studies in human-thing entanglement*. Open access book distributed in accordance with the terms of the Creative Commons Attribution (CC BY 4.0) license.

Hodder, I. (2020). Twenty-five years of research at Çatalhöyük. *Near Eastern Archaeology*, *83*(2), 72–79. doi: 10.1086/708448.

Issavi, J., Pawłowska, K., Vasić, M., & Veropoulidou, R. (2020). Common ground: reevaluating open spaces at Çatalhöyük. *Near Eastern Archaeology*, *83*(2), 110–119. doi: 10.1086/709178.

Kelly, R. L., & Thomas, D. H. (2012). *Archaeology*. Australia, Brazil, Mexico, Singapore, United Kingdom, United States: Cengage Learning.

Kent, S. (1981). The dog: An archaeologist's best friend or worst enemy. The spatial distribution of Faunal remains. *Journal of Field Archaeology*, *8*(3), 367–372.

Klippel, W. E., & Synstelien, J. A. (2007). Rodents as taphonomic agents: Bone gnawing by brown rats and gray squirrels. *Journal of Forensic Sciences*, *52*(4), 765–773. doi: 10.1111/j.1556-4029.2007.00467.x.

Lyman, R. L. (1984). Bone density and differential survivorship of fossil classes. *Journal of Anthropological Archaeology*, *3*(4), 259–299. doi: 10.1016/0278-4165(84)90004-7.

Lyman, R. L. (1987). Zooarchaeology and taphonomy: A general consideration. *Journal of Ethnobiology*, *7*(1), 93–117. https://ethnobiology.org/sites/default/files/pdfs/JoE/7-1/Lyman1987.pdf

Lyman, R. L. (1994). *Vertebrate taphonomy*. Cambridge: Cambridge University Press.

Lyman, R. L., & Fox, G. L. (1989). A critical evaluation of bone weathering as an indication of bone assemblage formation. *Journal of Archaeological Science*, *16*(3), 293–317. doi: 10.1016/0305-4403(89)90007-1.

Madgwick, R. (2014). What makes bones shiny? Investigating trampling as a cause of bone abrasion. *Archaeological and Anthropological Sciences, 6*(2), 163–173. doi: 10.1007/s12520-013-0165-0.

Madgwick, R. (2016). New light on feasting and deposition: Exploring accumulation history through taphonomic analysis at later prehistoric middens in Britain. *Archaeological and Anthropological Sciences*, *8*(2), 329–341. doi: 10.1007/s12520-015-0271-2.

Madgwick, R., & Mulville, J. (2012). Investigating variation in the prevalence of weathering in faunal assemblages in the UK: A multivariate statistical approach. *International Journal of Osteoarchaeology*, *22*(5), 509–522. doi: 10.1002/oa.1274.

Madgwick, R., & Mulville, J. (2015). Reconstructing depositional histories through bone taphonomy: Extending the potential of faunal data. *Journal of Archaeological Science*, *53*, 255–263. doi: 10.1016/j.jas.2014.10.015.

Marean, C. W. (1991). Measuring the post-depositional destruction of bone in archaeological assemblages. *Journal of Archaeological Science*, *18*(6), 677–694. doi: 10.1016/0305-4403(91)90029-O.

Marean, C. W., & Bertino, L. (1994). Intrasite spatial analysis of bone: Subtracting the effect of secondary carnivore consumers. *American Antiquity*, *59*(4), 748–768. doi: 10.2307/282346.

Martin, L., & Russell, N. (2005). Trashing Rubbish. In I. Hodder (Ed.), *Towards reflexive method in archaeology: The example at Çatalhöyük* (pp. 27–69). Cambridge: McDonald Institute for Archaeological Research/British Institute of Archaeology at Ankara.

Matthews, W. (2005). Micromorphological and microstratigraphic traces of uses and concepts of space. In I. Hodder (Ed.), *Inhabiting Çatalhöyük: Reports from the 1995–99 seasons* (pp. 355–398). Cambridge: McDonald Institute for Archaeological Research/British Institute of Archaeology at Ankara.

Matthews, W. (2010). Geoarchaeology and taphonomy of plant remains in early urban environments in the Ancient Near East. *Quaternary International*, *214*(1–2), 98–113. doi: 10.1016/j.quaint.2009.10.019.

Méniel, P. (2008). Plotting animal bones and differential preservation in the shell midden at Mez Notariou, Ouessant (Middle Bronze Age to Roman) [Cartographie des restes osseux et conservation différentielle dans l'amas coquillier d'Ouessant «Mez Notariou» (du Bronze moyen à la période romaine)]. *Annales de Paléontologie*, *94*(4), 267–285. doi: 10.1016/j.annpal.2008.09.006.

Munro, N. D., & Bar-Oz, G. (2004). Debating issues of equifinality in ungulate skeletal part studies. *Journal of Taphonomy*, *2*(1), 1–13.

Olsen, S. L., & Shipman, P. (1988). Surface modification on bone: Trampling versus butchery. *Journal of Archaeological Science*, *15*(5), 535–553. doi: 10.1016/0305-4403(88)90081-7.

Paton, T. R., Humphreys, G. S., & Mitchell, P. B. (1995). *Soils: A new global view*. London, New York: CRC Press.

Pawłowska, K. (2010). The usefulness of a taphonomic approach for studies of Pleistocene mammals. *Geologos*, *16*(3), 183–189. doi: 10.2478/v10118-009-0012-z.

Pawłowska, K. (2014). The smells of Neolithic Çatalhöyük, Turkey: Time and space of human activity. *Journal of Anthropological Archaeology*, *36*(2014), 1–11. doi: 10.1016/j.jaa.2014.07.001.

Pawłowska, K. (2017). Large mammals affected by hominins: Paleogeography of butchering for the European Early and Middle Pleistocene. *Quaternary International*, *438*, 104–115. https://doi.org/10.1016/j.quaint.2017.03.043

Pawłowska, K., Stefaniak, K., & Nowakowski, D. (2014). Healed antler fracture in a giant deer (Megaloceros giganteus) from the Pleistocene of Poland. *Palaeontologia Electronica*, *17*(1;23A), 9. doi: 10.26879/448.

Pawłowska, K. (2020a). Time of change: Cattle in the social practices of Late Neolithic Çatalhöyük. *Archaeological and Anthropological Sciences*, *12*(39), 1–18. doi: 10.1007/s12520-019-00961-x/

Pawłowska, K. (2020b). Towards the end of the Çatalhöyük East settlement: A faunal approach. *Near Eastern Archaeology*, *83*(3), 146–154. doi: 10.1086/709999.

Pawłowska, K., & Barański, M. Z. (2020). Conceptualization of the Neolithic world in incised equid phalanges: Anthropomorphic figurine from Çatalhöyük (GDN Area). *Archaeological and Anthropological Sciences*, *12*, 18. doi: 10.1007/s12520-019-01006-z.

Pawłowska, K., & Marciszak, A. (2018). Small carnivores from a Late Neolithic burial chamber at Çatalhöyük, Turkey: Pelts, rituals, and rodents. *Archaeological and Anthropological Sciences*, *10*, 1225–1243. doi: 10.1007/s12520-017-0526-1.

Pawłowska, K. (in press). Animals at Late Neolithic Çatalhöyük: Subsistence, food processing and depositional practices. In L. Czerniak & A. Marciniak (Eds.), *Late Neolithic at Çatalhöyük East: Excavations of upper levels in the Team Poznan Area*. Los Angeles, CA: Cotsen Institute of Archaeology Press.

Pei, W.C. (1938). Le role des animaux des causes naturelles dans le cassure des os. Palaeontologica Sinica, New Series D. 7, Whole Series 118. 4to., 60 pp. Peking.

Roffet-Salque, M., Marciniak, A., Valdes, P. J., Pawłowska, K., Pyzel, J., Czerniak, L., … Evershed, R. P. (2018). Evidence for the impact of the 8.2 kyr BP climate event on Near Eastern early farmers. *Proceedings of the National Academy of Sciences of the United States of America*, *115*(35), 8705–8709. doi: 10.1073/pnas.1803607115.

Russell, N., & Martin, L. (2005). The Çatalhöyük Mammal Remains. In I. Hodder (Ed.), *Inhabiting Çatalhöyük: Reports from the 1995–99 seasons* (pp. 33–98). Cambridge: McDonald Institute for Archaeological Research/British Institute of Archaeology at Ankara.

Russell, N., & Twiss, K. C. (2017). Digesting the data: Dogs as taphonomic agents at Neolithic Çatalhöyük, Turkey. In M. Mashkour & M. Beech (Eds.), *Archaeozoology of the Near East IX: Proceedings of the Ninth International Symposium on the Archaeozoology of Southwestern Asia and Adjacent Areas* (pp. 59–75). Oxford: Oxbow.

Russell, N., Twiss, K., Pawłowska, K., & Henton, L. (2006). Animal bones. Catalhöyük 2006 archive report: Cultural and environmental materials report. *Çatalhöyük Research Project*, 141–153.

Shahack-Gross, R. (2017). Animal gathering enclosures. In C. Nicosia & G. Stoops (Eds.), *Archaeological soil and sediment micromorphology* (pp. 265–280). Oxford: John Wiley & Sons.

Schiffer, M. B. (1983). Toward the identification of formation processes. *American Antiquity*, *48*(4), 675–706. doi: 10.2307/279771.

Shillito, L-M. (2011). Simultaneous thin section and phytolith observations of finely stratified deposits from Neolithic Çatalhöyük, Turkey: Implications for paleoeconomy and Early Holocene paleoenvironment. *Journal of Quaternary Science*, *26*(6), 576–588. doi: 10.1002/jqs.1470.

Shillito, L-M., Bull, I. D., Matthews, W., Almond, M. J., Williams, J., & Evershed, R. P. (2011). Biomolecular and micromorphological analysis of suspected faecal deposits at Neolithic Çatalhöyük, Turkey. *Journal of Archaeological Science*, *38*, 1869–1877. doi: 10.1016/j.jas.2011.03.031.

Shillito, L-M., & Matthews, W. (2013). Geoarchaeological investigations of Midden-Formation Processes in the Early to Late Ceramic Neolithic Levels at Çatalhöyük, Turkey ca. 8550–8370 cal BP. *Geoarchaeology: An International Journal*, *28*, 25–49. doi: 10.1002/gea.21427.

Shillito, L-M., & Ryan, P. (2013). Surfaces and streets: Phytoliths, micromorphology and changing use of space at Neolithic Çatalhöyük (Turkey). *Antiquity*, *87*(337), 684–700. doi: 10.1017/S0003598X00049395.

Shipman, P., & Rose, J. J. (1988). Bone tools: An experimental approach. In S. L. Olsen (Ed.), *Scanning electron microscopy in archaeology* (pp. 303–335). Oxford: British Archaeological Reports.

Stefaniak, K., Pawłowska, K., Ratajczak, U., Robličková, M., Gumiński, W., & Wojtal, P. (2014). Middle and Late Pleistocene elks (Cervalces Scott, 1855 and Alces Gray, 1821) from Poland: palaeoenvironmental and palaeogeographic implications. *Annales Societatis Geologorum Poloniae*, *84*(4), 341–362.

Stein, J. K. (1983). Earthworm activity: A source of potential disturbance of archaeological sediments. *American Antiquity*, *48*(2), 277–289. doi: 10.2307/280451.

Turner-Walker, G., & Jans, M. (2008). Reconstructing taphonomic histories using histological analysis. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *266*, 227–235. doi: 10.1016/j.palaeo.2008.03.024.

Wainwright, J., & Ayala, G. (2019). Teleconnections and environmental determinism: Was there really a climate-driven collapse at Late Neolithic Çatalhöyük?. *Proceedings of the National Academy of Sciences*, *116*(9), 3343–3344. doi: 10.1073/pnas.1818336116.

Watson, J. P. N. (1979). The estimation of the relative frequencies of mammalian species: Khirokitia 1972. *Journal of Archaeological Science*, *6*, 127–137. doi: 10.1016/0305-4403(79)90058-X.

Whitehouse, H., Mazzucato, C., Hodder, I., & Atkinson, Q. D. (2014). Modes of religiosity and the evolution of social complexity at Çatalhöyük. In I. Hodder (Ed.), *Religion at work in a Neolithic Society. Vital matters* (pp. 134–158). New York: Cambridge University Press.

Wolfhagen, J., Veropoulidou, R., Ayala, G., Filipović, D., Kabukcu, K., Lancelotti, C., … Wainwright, J. (2020). The Seasonality of Wetland and Riparian Taskscapes at Çatalhöyük. *Near Eastern Archaeology*, *83*(2), 98–109. doi: 10.1086/708446.

Wood, W. R., & Johnson, D. L. (1978). A survey of disturbance processes in archaeological site formation. In M. B. Schiffer (Ed.), *Advances in archaeological method and theory* (pp. 315–381). New York, San Francisco, London: Academic Press.

Wright, K. I. K. (2014). Domestication and inequality? Households, corporate groups and food processing tools at Neolithic Çatalhöyük. *Journal of Anthropological Archaeology*, *33*, 1–33. doi: 10.1016/j.jaa.2013.09.007.

Yeomans, L. (2005). Discard and disposal practices at Çatalhöyük: A study through the characterization of the faunal remains. In I. Hodder (Ed.), *Inhabiting Çatalhöyük: Reports from the 1995–99 seasons* (pp. 573–85). Cambridge: McDonald Institute for Archaeological Research/British Institute of Archaeology at Ankara.