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EVERY BONE CAN TELL ITS STORY. A REMARKABLE PATHOLOGICAL HORSE BONE FROM THE MIDDLE PALAEOLITHIC OF THE PFRIMM VALLEY IN PFEDDERSHEIM (RHINE-HESSE, GERMANY)

Abstract

The article presents the diagnosis and aetiology of an arthropathological horse (*Equus* sp.) radius from the Middle Palaeolithic site of Pfeddersheim (Rhine-Hesse, Germany). For the contextualisation of the results the chronological and archaeological frame of the site, the taphonomic history of the faunal assemblage and site formation are summarised. A fracture of the ulna caused a malposition of the humeroradial joint, that developed into a degenerative arthrosis with severe grooving of the articular surface of the radius, extension of the joint by new bone formation and exostosis around the epiphysis. The progression of the disease from the trauma to the final grade of arthrosis and how it affected the horse's life is portrayed. Eventually, the horse fell prey to a large carnivore. Finally, the palaeoecological significance of this very specific palaeopathological finding is discussed.

Keywords

Palaeopathology, arthropathology, osteoarthrosis, taphonomy, palaeoecology, Middle Palaeolithic

PREFACE

About 20 years ago, while desperately looking for a Master thesis topic in order to become a zooarchaeologist, the former head of MONREPOS, Prof. Dr. Gerhard Bosinski, told me that, if I want to study material from Mesolithic or Upper Palaeolithic contexts, then I would need Martin as a supervisor, and if I would prefer the Middle to Lower Palaeolithic, then I would need Elaine. So it was Elaine who escorted me through the study of Middle Palaeolithic bones from the Pfrimm valley in Rhine-Hesse (Kindler, 2001). Afterwards I could tap into her knowledge of cave bears for my PhD, and in the course of time we became colleagues in the same institute and shared responsibilities for the Taphonomical Zooarchaeology Lab in MONREPOS. What I immediately absorbed from Martin and Elaine in my first attempts at becoming a zooarchaeologist was – besides the interest of past human subsistence – their interest in the animals they study. I understood this perspective as their motivation for the detailed extraction of even the tiniest anectodical information from bones to reveal very specific stories of an animal's fate, which adds colour to our pictures of past lifeways. To quote: "every bone can tell its story", was my first and most important lesson. Now, what makes a better topic for their *Festschrift*, than my expression of gratitude for this lesson. When Elaine had a first look through the material I should study she just said "interesting material", which – for me, as a young student – provided enough motivation to hammer in the last nail in the coffin of the "hunter *vs*. scavenger debate" which had fought its last battles at the turn of the century. The result then deviated somewhat from it. Afterwards I learned that, whenever we screened faunal remains together, it was always "interesting material". But, there were different connotations of "interesting". Sometimes the whole material was worth

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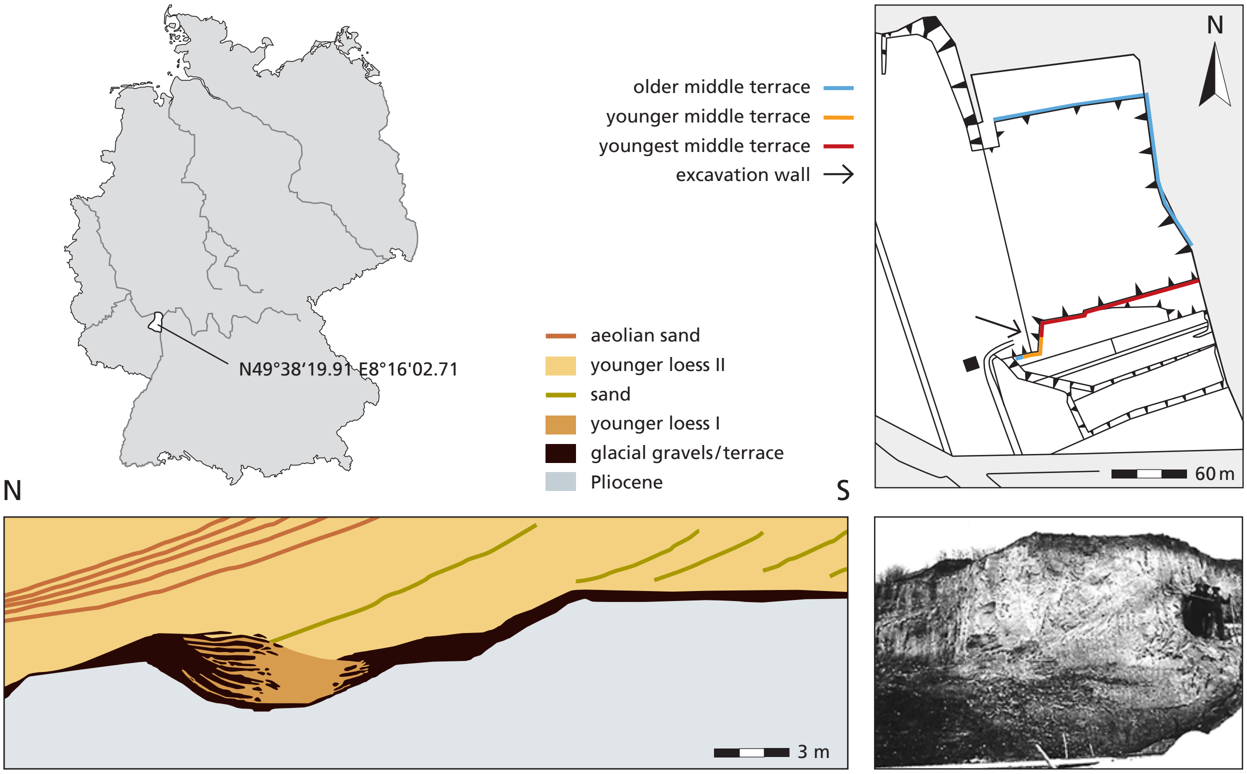

Fig. 1 Pfeddersheim. Top left: location of the Middle Palaeolithic site on the left banks of the Pfrimm in the Upper Rhine Graben (Image produced with Google maps). Top right: sketch of the sand quarry in Pfeddersheim. The arrow indicates the excavation wall (taken from Weiler, 1937). Bottom left: Profile of the excavation wall with gravel ridge and channel (redrawn from Weiler, 1937). Bottom right: historic photograph of the excavation wall with gravel ridge and channel, Eastern 1935 (from Weiler, 1937).

studying, sometimes a specific bone or some features grabbed her attention, and sometimes the material was interesting because there was nothing more to say about it besides the expectation that some bones will somehow "tell their stories". So, I browsed in my old Master thesis files in search of a bone that has a very unique story. It is a sad story of the discovery of a palaeopathological horse long bone, but a revealing story of my joyful first collaboration with Elaine: definitely interesting.

INTRODUCTION

Health and disease in past animal populations is rarely addressed in Pleistocene zooarchaeology. With the advent of animal husbandry, past societies would have had a self-interest in keeping their livestock healthy, well-nourished, and in finding ways and means to prevent and cure diseases. For hunter-gatherer societies there are almost no opportunities to counter diseases in wild game populations, apart from a general rule of "staying away from the sick". Animal palaeopathological studies in zooarchaeology therefore focus particularly on societies relying on animal husbandry (Baker and Brothwell, 1980; Davies et al., 2005; Thomas, 2012). In contrast, the knowledge obtained regarding veterinary considerations of wild game in Pleistocene forager contexts is more limited. In the taphonomic perspective we are dealing here, the fragmentation of individual bones during food processing hampers the identification of lesions. Subsequent syn- and post-depositional attrition is an additional influence on the "survival" of *pre-mortem* lesions (Bartosiewicz, 2008). From an ecological perspective, bone diseases and fractures can pose a vital threat to an animal (e. g., individuals with a limb bone trauma are vulnerable prey); however, the prevalence of skeletal injuries and healed lesions in wild mammals is rarely recorded (Taylor, 1971; Bulstrode et al., 1986; Argyros and Roth, 2016). Thus, it is hard to estimate the rate of bone lesions to be expected in zooarchaeological assemblages. In a survey of more than 250,000 prehistoric and historic bones from North America, only 0.03 % of the specimens showed pathologies, with most of them without significant effects on the individual's life (Shaffer and Baker, 1997). In late Pleistocene cave bear assemblages, somewhat higher rates of bone pathologies are observed, with many of them being age-related (Germonpré and Sablin, 2001; Withalm, 2004). From this small amount of documented bone pathologies in the fossil record a portion might be considered as atavisms, which evolutionary paths can be traced back deep in time to ancestral taxa, exemplified by the lineages of horses (Rooney, 1997). Against this background, pathological bones in Pleistocene faunal assemblages are rare, and usually unrelated to typical zooarchaeological questions concerning human and animal behaviour. On the other hand, zooarchaeologists play with enormous numbers of bones in their careers und thus easily detect "abnormal" bones, but are usually not veterinarians, not trained in aetiology, nor in pathogenesis and disease symptoms. Especially locally restricted and "superficial" bone lesions might not be detected, biasing our awareness of the impact of especially infectious diseases on past animal populations. In wildlife conservation pathogens are recognised to facilitate extinction risk at least in already threatened species (Smith et al., 2006; Smith et al., 2009; Cunningham et al., 2017), but recent data is still sparse and historical evidence missing. However, in a study of late Pleistocene Mastodon bones, half of the individuals in the sample show lesions indicative of tuberculosis (Rothschild and Laub, 2006), and DNA of the respective pathogen *Mycobacterium tuberculosis* was detected in a late Pleistocene bison (Rothschild et al., 2001), nourishing the hypothesis of a pandemic disease contributing to faunal extinction at the Pleistocene-Holocene boundary in North America.

Apart from the question of the ecological significance of pathogens, injuries and diseases affect individuals directly. The most apparent question from a palaeopathological finding on a bone concerns its negative impact on the individual's life history. In conjunction with find context and additional ecological information, palaeopathology can help to identify processes and interactions in past biocoenoses. This contribution discusses the find context and pathological investigation of an adult horse radius from the Middle Palaeolithic site of Pfeddersheim (Rhine-Hesse, Germany) (Kindler, 2001).

THE MIDDLE PALAEOLITHIC SITE OF PFEDDERSHEIM

The village of Pfeddersheim is a district of Worms in the lower course of the river Pfrimm in the eastern part of the Upper Rhine Rift in southern Rhine-Hesse. The Pfrimm is a left tributary of the Rhine, approximately 40 km long, which originates in the Buntsandstein of the Palatinate Forest, passes in its middle course the limestone plateaus of the low, rolling hills of Alzey, and running through a slightly undulating landscape in its lower course. Although more a stream than a river today, the Pfrimm built up rather thick fluvial terraces during the Pleistocene. The natural history of the Pfrimm and the Pleistocene palaeontology in southern Rhine-Hesse was intensively studied by Wilhelm Weiler (Weiler, 1931, 1935, 1937, 1938a, 1938b, 1939, 1949/1950, 1953). Later, a revised terrace stratigraphy and history of landscape development of the Pfrimm was established by Leser (1967), which is still valid today (see Peters and van Balen, 2007).

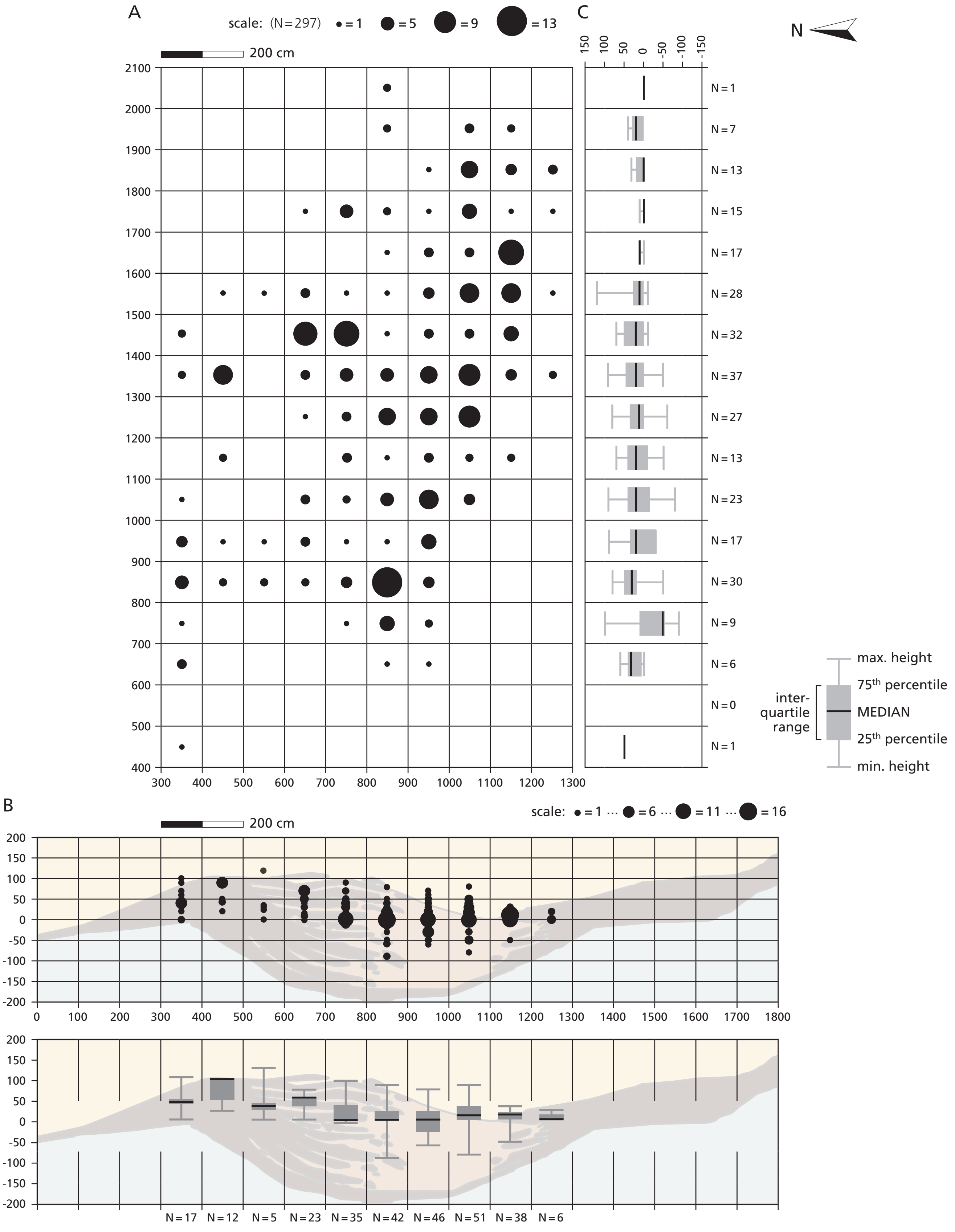

Fig. 2 Pfeddersheim. Horizontal distribution (A) (n = 297) and profile projections (B, C) (n = 276) of large mammal bones from the excavations in 1936 and 1937. In B the vertical distribution is projected on the profile of the excavation wall indicating the Pfrimm terrace and its remnants (grey) and the location of the channel (taken from Weiler, 1937 and modified by observations registered in Weiler's excavation diary).

	Pebbles with negative(s)	Cores	Flakes	artificial shatter	[n]
Porphyry	1		14	2	17
Devonian Quartzite, red	1		14		15
Devonian Quartzite, green		2	6		8
Lydite			1		1
Chalcedony			1		1
[n]	**2**	**2**	**36**	**2**	**42**

Tab. 1 Pfeddersheim. Raw material groups and lithic artefacts present in the Weiler collection in the Natural History Museum Mainz.

During his mapping of terraces in the former sand quarry of Pfeddersheim on the northern banks of the Pfrimm – the local football field is now located here – Weiler found bones and lithic artefacts on a gravel ridge and in an adjacent channel filled with reworked gravels and loess (**Fig. 1**). He excavated the site from 1935 to 1937, and originally separated a Middle (labelled "Pm") and early Upper Palaeolithic (labelled "Pa") find level. The associated herbivore bones – including mammoth, rhino, Bos/Bison, giant deer, red deer, reindeer, horse and wild ass – were interpreted as the remains of a hunted fauna (in sum 32-34 individuals were calculated); additional carnivore and small mammal bones were considered natural elements (Weiler, 1937, 1938a). The lithic material was typologically analysed by Bosinski (1967); according to this study, both find levels are Middle Palaeolithic. Leser (1967) described additional profiles nearby the site which also indicate a close temporal association of the two find horizons. According to Leser (1967), the gravel ridge is the remnant of an eroded younger middle terrace of the Pfrimm attributed to the late Riss. The reworking of the younger middle terrace can be observed over a wider area in other profiles along the Pfrimm valley and is attributed to the early Würm. The gravel ridge, the channelling and its filling should be considered as syngenetic processes, placing the finds also in an early Würm context (see also Kindler, 2001).

For my analyses of the find material I could take advantage of the excavation diaries of Wilhelm Weiler, which allow – at least for the campaigns in 1936 and 1937 – comprehensive insights into the depositional contexts and spatial distribution of the finds (Kindler, 2001). During the excavation Weiler and his team of excavators followed the west-east course of the gravel ridge and the adjacent channel, with fluctuations in the breadth of both features up to 1 m (see also Weiler, 1937). Beside observations of the progression and sedimentological features of the gravel ridge and channel, the diary includes in ideal cases three-dimensional recording of finds, partly with sketches and information on orientation and dipping. Height information of finds is relative to the upper or lower boundary of the channel. For the campaigns in 1936 and 1937, the find distribution covers an area of approximately 17 m × 10 m (**Fig. 2**). The recordings in the diary clearly suggest that the two find levels "Pa" and "Pm" indicate the embedding milieu of finds and not two stratigraphically separated find levels, with "Pa" embedded in loessic and "Pm" in gravelly material. The fluvial loess infill of the channel was interspersed with scraps of reworked terrace gravels, especially on the slope of the gravel ridge. Here, the heights of finds show an inversion of the find levels, finds attributed to "Pm" are above finds attributed to "Pa". In addition, several bones attributed to level "Pm" and "Pa" could be refitted, also invalidating the separation of these two find levels. Rather, it is to be assumed that during reworking of the terrace – with the gravel ridge as its remnant – finds were translocated from higher positions and became embedded during the filling up of the channel. This context suggests a palimpsest in a hydrodynamic milieu as important parameters in the site formation process and taphonomic history of the bone accumulation.

Species	NISP	%
Large mammals		
Canis lupus	1	0.3
Vulpes vulpes	6	1.8
Panthera leo cf. *spelaea*	1	0.3
Mammuthus primigenius	15	4.5
Equus sp.	218	65.1
Coelodonta antiquitatis	10	3.0
Megaloceros giganteus	5	1.5
Rangifer tarandus	28	8.4
Bos/Bison	51	15.2
[n]	335	100.0
Small mammals		
Lepus sp.	9	50.0
Marmott sp.	1	5.6
Dicronstonxy sp.	2	11.1
Rodentia indet.	6	33.3
[n]	18	100.0
Birds		
Aves sp.	1	100.0

Tab. 2 Pfeddersheim. Species representation in the Weiler collection in the Natural History Museum Mainz. NISP = number of identified specimens per taxon.

Lithics, fauna and taphonomic signatures

The find material from Pfeddersheim is stored in the Museum of Natural History in Mainz. A comprehensive presentation and discussion of the material can be found in Kindler (2001). The collection comprises 152 lithics, three larger blocks of fossilised wood and 354 bones and teeth; the overwhelming majority consists of larger specimens easily to identify. Comparisons with the excavation diary shows that almost all recovered small bone fragments (labelled "bone fragments" and even smaller pieces "bone splinters") are now missing. Presumably because of their lack of any taxonomic value, the "bone fragments/splinters" – half of the material originally present – were discarded soon after excavation or in the course of storage. Three lithic artefacts – a handaxe and two scrapers, which are illustrated in Bosinski (1967) – are also missing.

Of the 152 lithics present in the Weiler collection, only 42 pieces can be identified as artefacts. A total of 36 specimens represent simple flakes, two are simple cores, two pebbles with negatives and two artificial shatters. The artefacts are made of porphyry and a red and green variety of Devonian quartzite (**Tab. 1**; **Fig. 3**). Both raw materials – together with quartz – constitute the main components of the Pfrimm gravels. Two flakes are made of most likely non-local lydite and chalcedony, which may indicate connections to raw material sources outside the Pfrimm valley (Floss, 1994). The dimensions of the flakes range for most specimens between 20-40 mm. Smaller chips and debitage are missing, maybe because of the excavation technique or due to winnowing by hydrodynamic processes. In most of the cases the cores, flakes and striking platforms display larger areas covered with cortex. The cores and frequencies and distribution of dorsal negatives indicate predominantly unidirectional reduction. Thus, the small lithic ensemble represents an economic approach to obtain cutting edges rather than the realisation of distinct concepts of reduction and flake shape; but one must consider the possibility that the size of the river gravels used for lithic production may have prevented the implementation of a more sophisticated lithic technology at Pfeddersheim.

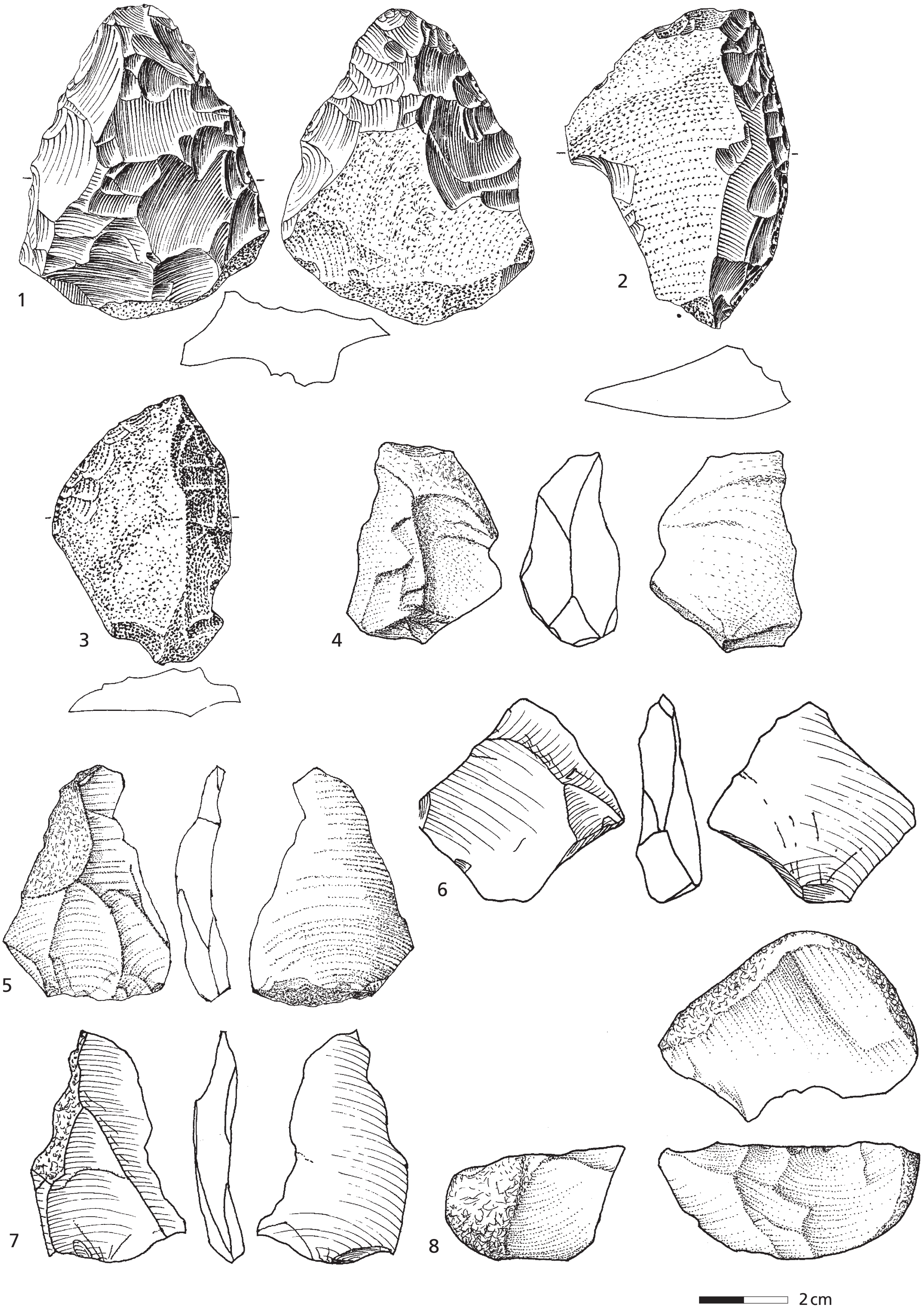

Fig. 3 Pfeddersheim. Examples for lithic artefacts from the sand quarry. **1** Biface (porphyry), **2** Scraper (porphyry), **3** Scraper (quartzite), **4** Flake (red quartzite), **5** Flake (green quartzite), **6-7** Flake (porphyry), **8** Core (green quartzite).

However, the small biface and two scrapers discussed in Bosinski (1967) may indicate modification of flakes and tool production at the site.

In addition to teeth, the 354 faunal specimens in the Weiler collection mainly consist of relatively complete long bone diaphyses and epiphyses, or larger fragments thereof. Horse dominates the species spectrum among the large mammals with a proportion of 65 %, followed by Bos/Bison (15 %) and reindeer (8 %). Additional herbivores are woolly mammoth, rhino and giant deer. Carnivores have a share of 2 % of the large mammal bones, with one bone belonging to each of wolf and lion. Fox bones are somewhat more frequent. The material of small mammals consists of several post-cranial bones from a hare, plus teeth from a marmot and a lemming. Additional teeth could not be assigned to a specific taxon. One bone belongs to an unidentified bird (**Tab. 2**). The species spectrum comprises the typical taxa of the "mammoth steppe" and indicate stadial steppic conditions during formation of the thanatocoenosis (Kahlke, 1999).

Syn- and postdepositional processes have led to both partly heavy and quite heterogeneous bone surface modifications. The faunal assemblage is "colourful": the bones display seven different colour schemes. Most bones show a grey colour, with gradients to a darker brown coloration and gradients to a lighter yellow coloration. Bone colour has a heterogeneous horizontal spatial distribution when plotted in the excavation grid; however, bones displaying a brownish gradient tend to be located higher in profile projections than the ones with a yellowish gradient. Thus, composition and changes in embedding milieu can be regarded as the most important aspect governing bone colour (Turner, 1990). In Pfeddersheim bone colour may also have an addition chronological aspect. Bones deposited in fluvial contexts are prone to become abraded and edge rounded. As a rule of thumb, the higher the hydrodynamic loading and coarser the material, the more severe the attrition of bones. Interestingly, only a minor fraction of the Pfeddersheim bones are edge rounded: this accounts for 29 bones out of 335 large mammal bones. In addition, 25 of these bones are labelled "Pa" and are associated with a more fine-grained loessic matrix. This may indicate that bones embedded in the loessic milieu were subjected to hydrodynamic processes for a longer time or for additional reworking cycles than bones embedded in a more gravelly matrix. A longer temporal succession of bones entering the thanatocoenosis and/or fluctuations in sedimentation rates can be discerned by differential rates of bone weathering (Behrensmeyer, 1978; Turner, 2000). Following the subdivision of climatic induced weathering by Behrensmeyer (1978) – from stage 0 (= fresh and unweathered) to stage 5 (= almost disintegrated *in situ*) – more than 90 % of the Pfeddersheim bones in both subsamples "Pm" and "Pa" display advanced stages of surface modification (stage 2 and 3). Only 2 bones can be attributed to stage 1, and 17 bones belong in stage 4. The bones must have stayed for a prolonged period on the ground before burial. Originally, Behrensmeyer (1978) links such patterns with natural death rates in animal populations due to starvation, dying of thirst and old age, disease and predation. The modest appearance of stage 4 and the lack of stage 5 bones indicate that climatic-induced weathering is not a significant factor for bone loss and destruction at Pfeddersheim.

Another significant taphonomic pattern of the faunal assemblage is root etching. More than 75 % of all bones display root etching; in most cases more than half of the bone surfaces are affected. Severe root etching and advanced stages of weathering in the Pfeddersheim assemblage limits the preservation of modifications of preceding biogenic and anthropogenic processes and actions. Shallow striations occur regularly on the bones, which may result from the movement of bones in gravelly to sandy sediments and/or trampling by other animals (Behrensmeyer et al., 1989). Undisputable cut-marks and hammerstone impacts are not present on the bones.

Quantitative and qualitative considerations of the identified bone specimens follow standard methods described in Lyman (1994). The biased nature of the Weiler collection is best illustrated by the minimum number of elements (MNE) present in the faunal assemblage, which largely correspond to the number of identified specimens (NISP) after refitting.

Element	NISP			MNE
	sin	indet	dex	
Cranium/Maxilla		1		1
Mandibula	1	1	2	4
teeth, mandibulary	4	4	10	18
teeth, maxillary	34	3	37	73
Vertebrae, cervical		7		3
Vertebrae, thoracic-lumbar		2		2
Costae				
Sacrum				
Pelvis	3		4	6
Scapula	2	1	4	5
Humerus	10		11	19
Radius	7		5	12
Ulna			2	2
Carpals				
Metacarpus III	6	2	3	11
Metacarpus II				
Metacarpus IV				
Phalanx 1	3		5	8
Phalanx 2		1		1
Phalanx 3		2		2
Femur	5			5
Tibia	5		3	8
Astragalus	3			3
Calcaneus	3		3	6
other tarsals				
Metatarsus III	5	1	7	12
Metatarsus II	1			1
Metatarsus IV	2		3	5
[n]	218			207

Tab. 3 Pfeddersheim. *Equus* sp., NISP (number of identified specimens per taxon) and MNE (minimum number of elements) of skeletal elements. In the case of the phalanges no differentiation was made between anterior and posterior phalanges. Ulnae were only counted when isolated from the radius.

Element	NISP			MNE
	sin	indet	dex	
Cranium/Maxilla				
Mandibula	1		1	2
teeth, mandibulary		1	1	2
teeth, maxillary	8		5	13
Vertebrae, cervical				
Vertebrae, thoracic-lumbar				
Costae				
Sacrum				
Pelvis	1		1	2
Scapula				
Humerus	1			1
Radius	5		2	2
Ulna				
Carpals	1			1
Metacarpus		4	1	4
Phalanx 1				
Phalanx 2				
Phalanx 3		1		1
Femur			1	1
Tibia	5		2	2
Astragalus				
Calcaneus	1			1
other tarsals	1		1	2
Metatarsus	4	1	1	4
[n]	51			38

Tab. 4 Pfeddersheim. Bos/Bison, NISP (number of identified specimens per taxon) and MNE (minimum number of elements) of skeletal elements. In the case of the phalanges no differentiation was made between anterior and posterior phalanges.

With 218 out of 335, horse dominate among the large mammal bones. The NISP and MNE is given in **Table 3**. Almost exclusively, teeth and appendicular bones are present. A discrepancy in the preservation of upper and lower teeth is striking. Bones of the fore leg are better represented than bones from the rear leg. Based on bone counts, a minimum number of individuals (MNI) of 10 is given by left humeri and 7 by left radii. A distal femur and radius still display the epiphyseal line, and in three metapodials the distal joints were not fused. Taking crown height and occlusal wear patterns of tooth rows and isolated teeth into account (Habermehl, 1975; Levine, 1979, 1982, 1983), an MNI of 12 for teeth can be calculated. Three individuals died as juveniles (one at an age of approximately one year, another at a maximal age of 2 years and the third between 1 ⅓ and 3 ½ years). Eight individuals are in the prime ages between 6 ½ and 11 ½ years. A senile individual is represented by a heavily worn and chewed down molar, giving a minimal age

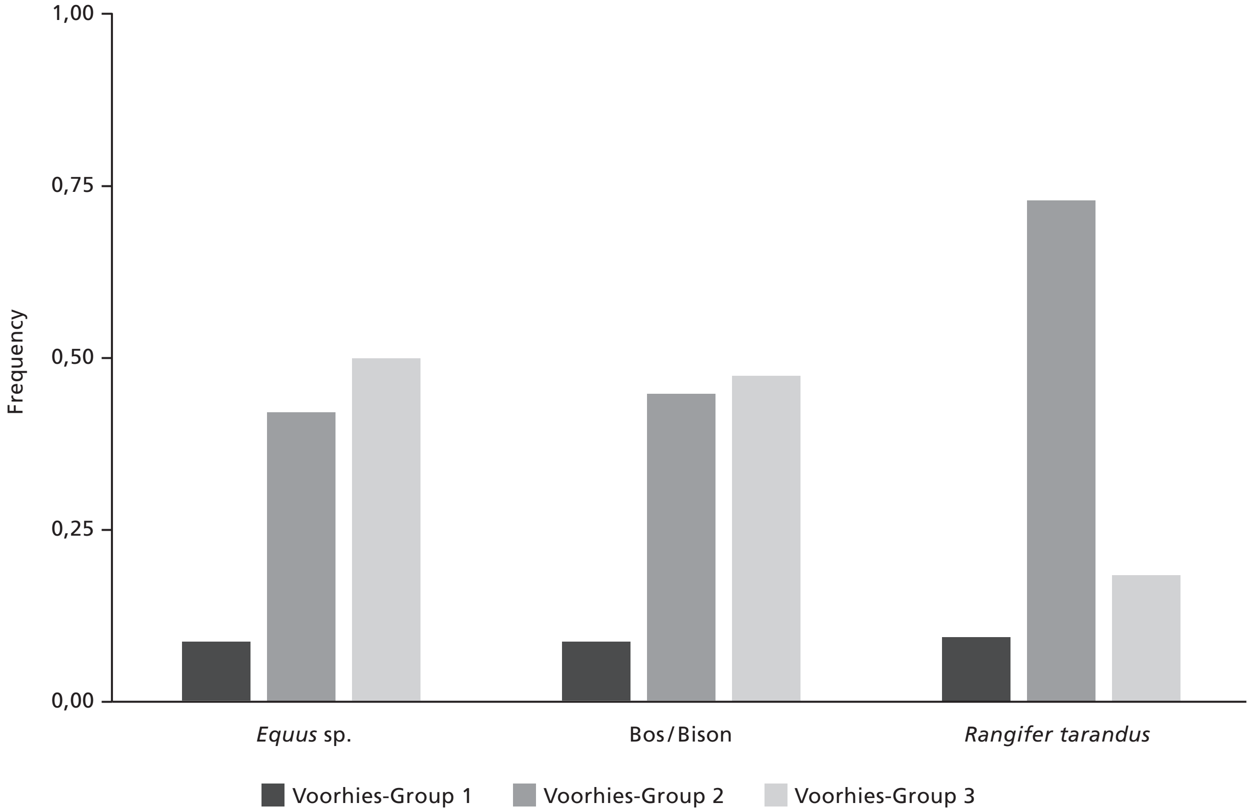

Fig. 4 Pfeddersheim. Frequencies of Voorhies-Groups (Voorhies, 1969; Behrensmeyer, 1975) based on the minimum number of identified specimens (NISP) of *Equus* sp., Bos/Bison and *Rangifer tarandus.*

of death of 15 years. Discounting the teeth, 15 % of the bones display traces of carnivore modifications, mainly at or near the proximal parts of the long bones.

Bones of large bovids (Bos/Bison) make of 15 % of the Pfeddersheim assemblage. The material lack clear diagnostic criteria to discriminate between *Bos* and *Bison*. Again, mainly teeth and appendicular bones are present (Tab. 4). Bones and teeth belong to a minimum of four prime age individuals, based on the upper molars. Seven bones show carnivore modification (20 % of all specimens, discounting teeth).

Reindeer is represented by 14 bones (2 scapula, 2 humeri, 4 radii, 1 calcaneus, 1 metatarsus and 4 metapodials), 11 antler fragments and 3 partly larger unshed antler fragments with attached skull parts. The MNI is 3, based on the antlers. Carnivore gnawing is present on both humeri and on one antler fragment.

Remains of giant deer include one antler fragment with pedicle, two isolated upper deciduous molars, a mandible fragment with two milk molars and three metatarsi. The MNI is two. No traces of carnivore modification could be observed.

The NISP for the woolly rhino is 15, and comprises fragments and larger portions of humerus, radius and tibia as well as three molars. Two teeth belong to an adult individual, a fragment of a third tooth represents an unerupted molar of a juvenile individual. The long bone remains also represent an adult and a juvenile. Hence, the MNI is two. A humerus shows carnivore gnawing near the proximal joint and a tibia fragment is gnawed on its proximal and distal break edges.

The NISP for woolly mammoth is also 15: tooth fragments, a vertebra and ribs as well as fragments of pelvis and long bones. An upper M2 and a lower dP2 belong to an adult and juvenile individual, with reconstructed ages of 26 ½ and 3 years (Laws, 1966; Haynes, 1991). An additional adult may be represented by fragmentary tooth plates from a large and worn molar, presumably a lower M3. The post-cranial bones are also be attributed to one adult and one juvenile individual. No carnivore gnawing is present on the mammoth bones. A distal humerus can be designated to *Canis lupus*, and two mandible fragments with teeth, a distal tibia and three metapodials to *Vulpes vulpes.* The cave lion is present by an Ulna, but an association with the channel infill is not secured. The bones don't wear traces of carnivore modification.

Bone loss and survival are governed by successive processes in the taphonomic chain. As pointed out in the general characteristics of the Pfeddersheim assemblage, climatic-induced weathering can be considered as a minor contributor to bone destruction at the site. A general proxy for a bone's capability for preservation and susceptibility for destruction is its bone mineral density (BMD) (Brain, 1969; Lyman, 1994). Correlations of skeletal element frequencies and their respective BMD values are generally used to describe post-depositional or *in-situ* attrition, but biostratinomic process may also lead to density dependent bone preservation. As pointed out, the Pfeddersheim faunal assemblage is a biased assemblage and only horse bones occur in frequencies high enough to enable comparison with bone mineral density data. Using values obtained by Lam et al. (1999), the relative MNI for each survived bone element portion results in

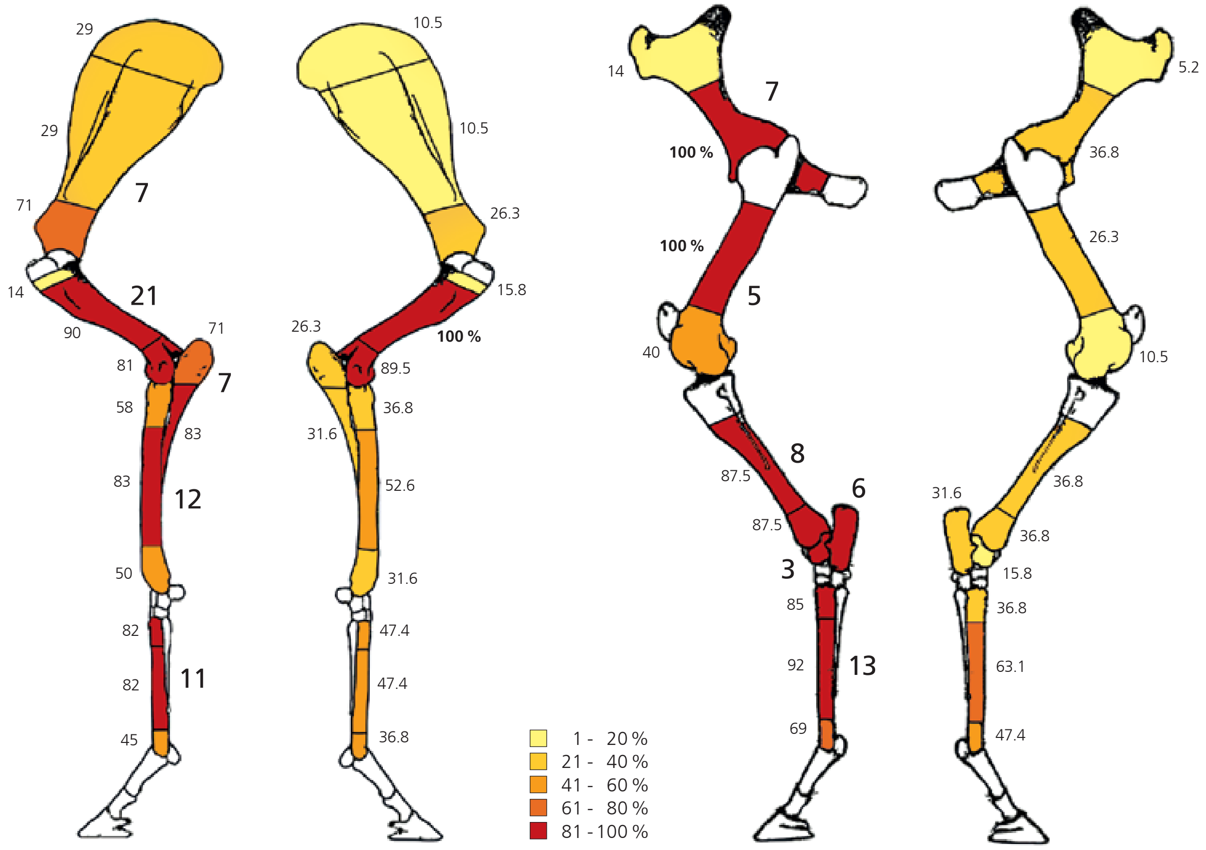

Fig. 5 Pfeddersheim. Skeletal intra-element representation of front leg (including scapula) and hind limb (including pelvis) of *Equus* sp. On the right side of the legs, the NISP for each skeletal element and the percentage of the proximal and distal parts and the diaphysis are given. The frequencies have been grouped and are shown in different colours. The left side of the legs display the proportions in relation to the most common bone area, the humerus diaphysis (= 100 %). Example: 83 % of the 12 radii are distributed in the diaphyses and 50 % in the distal epiphyses. The proportion related to the humeral diaphysis is 52.6 % for the radius diaphysis. The humeral diaphysis occurs almost twice as often as the radius diaphysis (see also Turner, 2002).

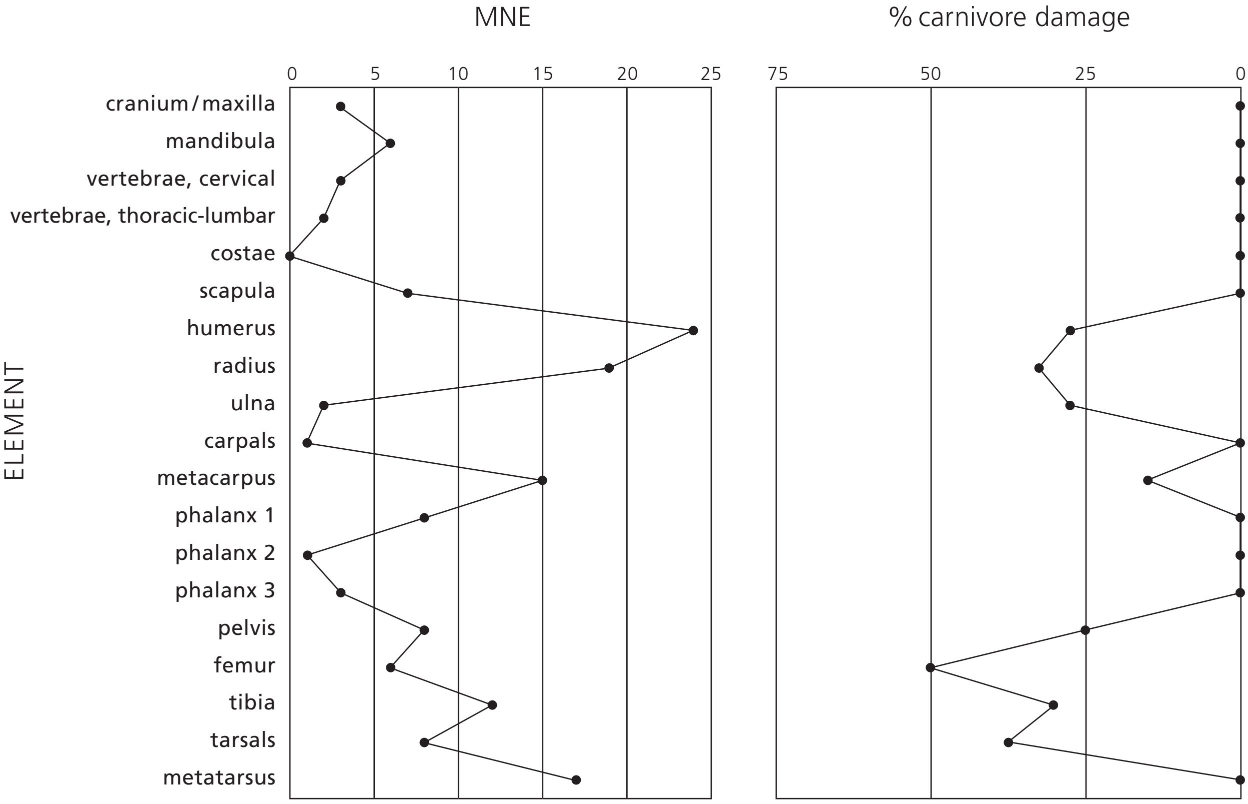

Fig. 6 Pfeddersheim. Left: Skeletal element representation of *Equus* sp., Bos/Bison, *Rangifer tarandus* and *Coelodonta antiquitatis* (MNE = 154). Right: Percentage of skeletal elements displaying carnivore damage.

a moderate relationship between both variables (R^2 = 35 %). Thus, taphonomic factors in addition to the preservation capacity of a skeletal element must be considered as important contributors influencing bone survival at Pfeddersheim. From the given sedimentary context, fluvial processes must be considered. Bone mineral content as an indicator for weight and the shape of skeletal parts are major properties influencing hydrodynamic bone transport. Sorting processes in water streams are investigated in experiments and simulated in models (Voorhies, 1969; Behrensmeyer, 1975, 1982; Hanson, 1980). In river streams with constant flow isolated bones of a skeleton can be separated in three groups (so-called Voorhies-Groups), representing different susceptibility for transport. In general, short and flat bones belong to group 1, group 2 consists mainly of the long bones, and group 3 of the cranium and mandible (Voorhies, 1969). The arrangement, frequency and/or lack of the individual groups give information of stream velocity and distance to the source assemblage of a transported fauna. All Voorhies-groups are present for the Pfeddersheim horses and the large bovids, but group 1 is only represented in low quantities. In contrast reindeer is almost exclusively represented by group 2 (**Fig. 4**), which indicates a longer distance to the source assemblage in comparison to horses and bovids (Behrensmeyer, 1975; Gaudzinski, 1992). Thus, fluvial transport can be considered as a major taphonomic process shaping bone representation at Pfeddersheim. However, initial sorting of bones may have occurred prior to fluvial transport. Carnivore damage is another major characteristic of Pfeddersheim faunal assemblage, and is present on horse, large bovid, reindeer and woolly rhino bones. 20 % of the bones of these four taxa show traces of carnivore gnawing. In general, bones of the front leg are more frequent than bones from the hind limb, as illustrated by the skeletal part representation of the horse (**Fig. 5**). The intra-element representation corresponds mostly with mineral density. 42 % of all breaks have a helical outline and must have occurred in fresh condition (Lyman, 1994). In contrast to the skeletal representation, the relative frequency of carnivore damage is higher on the hind legs (**Fig. 6**). Most carnivore gnawing is located near the epiphyses. All these features, representation of the appendicular skeleton, breakage and loss of less dense epiphyseal parts are typical for assemblages generated and accumulated by carnivores (Haynes, 1980b, 1983a, 1983b; Binford, 1981; Brain, 1981; Blumenschine, 1986; Gifford-Gonzales, 1989; Hill, 1989; Marean and Spencer, 1991; Lyman, 1994; Marean, 1998; Marean and Kim, 1998).

Predation of ungulates along the Pfrimm, consumption, collection and transport of body parts by carnivores must be regarded as the most prominent process from which the Pfeddersheim faunal assemblage originated. The remaining carcasses parts were lying on the river banks for a prolonged period of time, as advanced stages of weathering show. From here, bones were repeatedly raised by the river, translocated downstream and (re-)deposited in the channel where the bones accumulated in their final position. Thus, the taphonomic chain at Pfeddersheim can bridge a considerable time depth. Against these major taphonomic processes and actors, a human contribution to the formation of the faunal assemblage – as suggested by the presence of lithic artefacts – becomes completely obscured by succeeding processes.

THE PATHOLOGICAL HORSE BONE

A right radius with attached ulna of an adult horse show multiple arthropathological features, traumatic as well as degenerative, which caused pain, restriction of motion and potentially joint stiffness during life (**Fig. 7**). Weiler (1936, 1937) already recognized the lesions on the bones and summarised them as an *Arthritis* (sic) *deformans*.

On the proximal radius the compact bone of the medial joint plate was almost completely removed by extensive erosion by deep parallel fissures. These fissures are accompanied in some areas by exostosis, in other areas the grooving exposed the underlying trabecular bone. Along the radial tuberosity to the medial face of the joint, the complete area is covered by extensive exostosis, extending the articular surface. Co-occurrence of grooving of the articular surface and its extension by new bone formation as well as exostosis around the joint and eburnation are diagnostic criteria for osteoarthritis (Baker and Brothwell, 1980). Osteoarthritis is synonymous with *Arthrosis deformans* and in most instances is a degenerative disease. The suffix -*arthritis* suggests the joint disorders originate from an inflammation of the soft tissue and cartilage of the joint, which may also affect the bone and subsequently cause a degenerative arthrosis. An acute inflammation and its pathogen are rarely found on bone, especially in archaeological ones. Thus, the term osteoarthrosis provides a more proper and neutral label for the disorders on the horse radius (O'Connor, 2008).

Osteoarthrosis proceeds in stages in which the space between the joint becomes lost by progressive degradation and destruction of cartilage and remodelling of bone. When the subchondral bone becomes exposed, sclerosis develops and osteophytes as well as bone cysts form (Arden et al., 2018). An age-related development of osteoarthrosis seems to be common in wild horse populations (Cantley et al., 1999). However, osteoarthrosis may occur in higher frequencies in populations maladapted to the environments they are placed in (Lyras et al., 2016). In the Pfeddersheim specimen the degree and magnitude of the bone modifications correspond to a final grade of severe and prolonged progress of osteoarthrosis. Especially the extend of joint surface erosion and the depth of the attendant fissures are remarkable, when compared

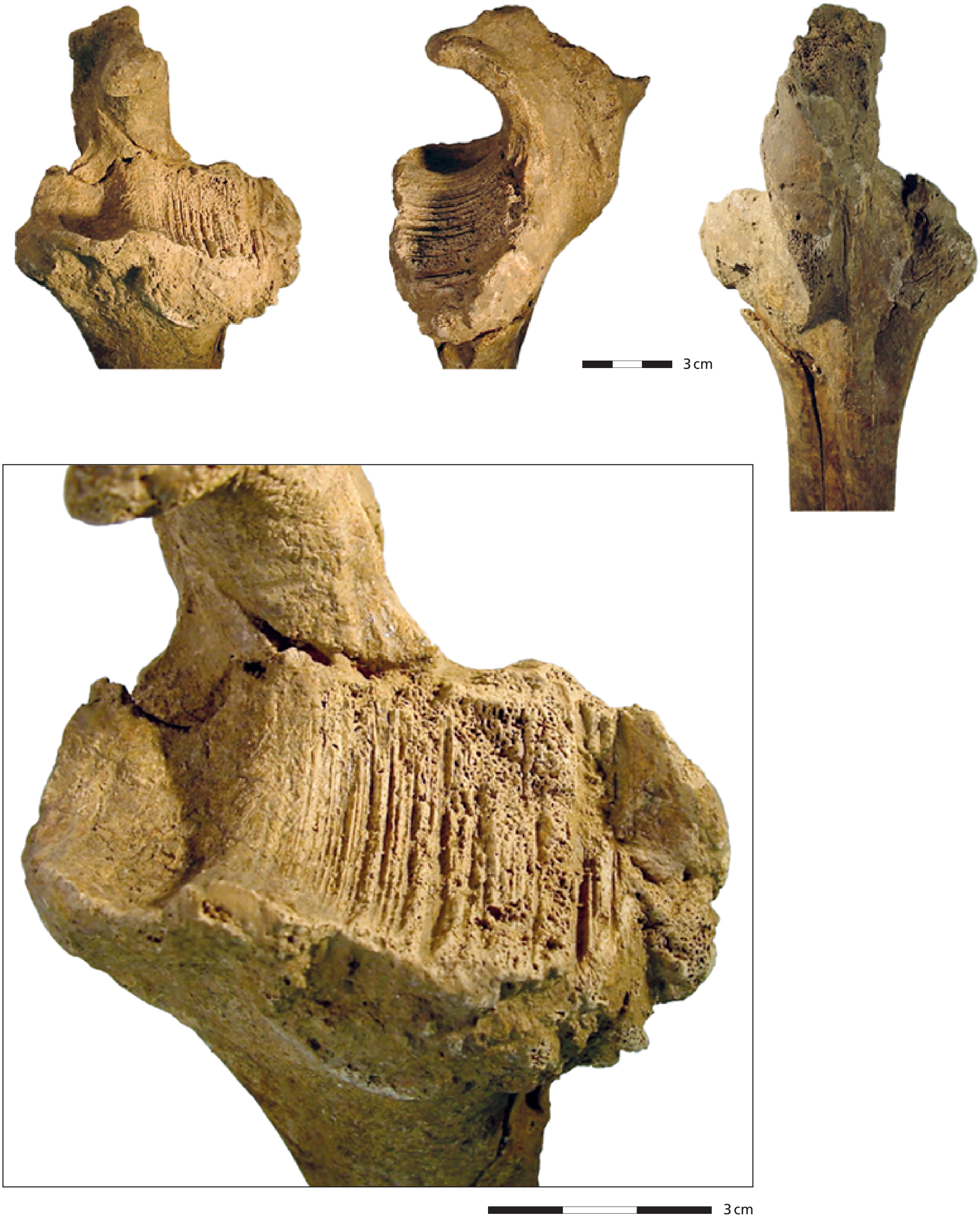

Fig. 7 Pfeddersheim. *Equus* sp., proximal epiphysis of the right Radioulnare with arthropathological features caused by trauma and subsequent degenerative osteoarthrosis/-itis. Top left: anterior aspect, the ulna shows abnormal position of the *Processus anconatus* and an ossified fissure on the trochlear notch. The radius joint displays deep anterior-posterior grooving, medial extension of the joint and exostosis along the medial periphery. Top centre, medial aspect of the joint showing grooving and exostosis of the proximal radius and on the ulna olecranon crenulated edges produced by a large carnivore. Top right, posterior aspect, showing abnormal S-shape bending of the ulna olecranon. Bottom, enlargement of the anterior aspect of the radius displaying severe osteoarthrosis.

to other zooarchaeological specimens diagnosed with osteoarthrosis (compare with figures in Baker and Brothwell, 1980; O'Connor, 2008). The cartilage between the joint must have been completely removed on the medial aspect of the joint, so that the trochlea of the humerus was in constant friction with the radius epiphysis.

The development of osteoarthrosis of the radius is not age-related but resulted from a posttraumatic malposition of the joint. The remaining distal part of the olecranon bends on the posterior face in a *S*-shape in lateral direction. The anconeal process is also displaced laterally. An ossified fissure proceeds diagonally along the trochlear notch. These features imply one or multiple fractures of the olecranon including the ulna joint. Ulna fractures are not uncommon among recent domesticated horses, with the majority of these fractures positioned similar to the ones reconstructed for the Pfeddersheim horse (Hertsch and Abdin-Bey, 1993). Young and still growing horses are often affected; many of these injuries are supposed to come from kicks during contentions of "pecking order" and fights for dominance. Apart from the overall dislocation of the ulna, no additional features of the healed fractures – such as callus formation and/or remnants of bone remodelling – are present. Thus, the trauma may have occurred early in the horse's life span. A still growing bone and less weight pressing on the joint facilitates wound closure and consolidation in young horses (Hertsch and Abdin-Bey, 1993). In any event, after healing of the trauma the joint deformity remained and developed in the course of time into a degenerative arthrosis, which must have progressively led to pain and lameness in the right front leg. In the end, the horse most likely died of predation. At least a large carnivore – presumably a wolf or hyena – has removed the missing parts of the olecranon below the apophysis and left typical crenulated edges.

DISCUSSION

Long bones with healed fractures are extremely rare in the archaeological record. For domesticated cattle and horses, it is suggested that individuals suffering such injuries were predominately and instantly slaughtered (Udrescu and van Neer, 2005). For wild game we can assume that animals suffering immobilisation of one leg due to a trauma will be vulnerable victims for carnivores and will also die quickly after occurrence of the long bone fracture. The healing process of a long bone fracture allows an estimation of time passed between the accident and the death of an animal. For instance, a diaphyses fracture with extensive callus formation is reported for a large and strong male bison from the lower Pleistocene site of Untermassfeld (Thuringia, Germany) (Kierdorf et al., 2012). Before death, this individual passed through an initial inflammatory response to the trauma: reorganisation of bone around the fracture to a phase of hard callus formation around the lesion. Hard callus formation around bone fractures peaks around two weeks after the injury (Marsell and Einhorn, 2011). The callus is remodelled in a subsequent absorption phase to restore the biomechanical properties of the bone. This phase initiates 3-4 weeks after the incidence and may take years to completion (Marsell and Einhorn, 2011). As the Untermassfeld tibia doesn't show any significant traces of remodelling, it is speculated that the bison died some weeks and up to some months after the fracture occurred, presumably by predation or – given the formation history of the Untermassfeld site – by drowning (Kierdorf et al., 2012).

The ulna fracture of the Pfeddersheim horse is completely healed. The good healing process could indicate that the fracture happened prior or during adolescence. Due to the remaining malposition of the elbow a degenerative arthrosis developed, which reached a severe stage in the adult horse. In general, the course of arthrosis progresses slowly, usually interrupted by phases of stabilisation. It takes many years to develop the symptoms expressed in the Pfeddersheim specimen (Arden et al., 2018). Because of the posttraumatic origin, the erosion of the cartilage and grooving of the joint may have been accelerated compared to more common causes and progression of arthrosis. After a period of lameness during healing of the fracture, the horse may have been free of symptoms for a certain amount of time. But with the increase of symptoms in the course of arthrosis the horse will have faced increased pain, joint stiffness and, again, lameness. Only in the terminal stage of the disease the horse most likely fell prey to a large carnivore, as the bite marks suggest.

To survive the ulna fracture and a degenerative arthrosis to the grade the Pfeddersheim horse shows in a Pleistocene steppe environment is remarkable. The common progression of degenerative arthrosis suggests that the horse suffered from lameness not only during the time of the ulna fracture and the terminal stage of the disease, but also during episodes of exacerbations in between. The horse was a vulnerable prey during these repeated phases of impaired locomotion, but it survived for a long time. The taphonomic context illustrates the substantial role carnivores played in the formation of the Pfeddersheim assemblage. However, taphonomic signatures are not congruent with past ecological conditions. Although, recent bone assemblages can image their original biocoenosis with high fidelity (Behrensmeyer and Miller, 2012; Miller et al., 2014), deriving past environmental conditions from fossil faunas has limitations and is challenging, when patterns of ecological processes are addressed (Lyman, 2017). An additional problem is a quantitative approach to estimate the scales of past ecological processes or even just a relational consideration of processes in different past environments (Kindler et al., 2020). Predation is a typical process present in all ecosystems; it is also present in most Pleistocene faunal assemblages, but the systemic interrelations of predation is only seldomly addressed (e. g., Hemmer, 2001). The long survival of the Pfeddersheim horse can be indicative for reduced predation pressure in the early Weichselian stadial steppe of the Pfrimm valley and, thus, of low population densities of carnivores.

Since Guthrie's (1990) "frozen fauna of the mammoth steppe," the Ice Age stadial steppes in the northern latitudes are often depicted as self-organising, highly productive ecosystems. An essential element of this vanished ecosystem was an enormous ungulate biomass. Calculations of ungulate biomass derived from the fossil record of the mammoth steppe (Zimov et al., 2012) can reach values equivalent to ungulate productivity in African savanna ecosystems. However, taking the external factors that limit the carrying capacity of an ecosystem into account, ungulate biomass production in the mammoth steppe of the northern latitudes must have been relatively low, especially in relation to interglacial ecosystems (Rodríguez et al., 2014; Kindler et al., 2020). When ungulate biomass production is low, the population densities of their predators (including humans) must decrease and the size of their hunting grounds must increase correspondingly. Thus, the lack of any human signature in the Pfeddersheim faunal assemblage as well as the generally sparse evidence concerning human subsistence in faunal assemblages of similar chronological or ecological context in nearby regions like the central Rhineland (Bosinski et al., 1995; Gaudzinski et al., 1995) may simply reflect the minor role human hunting played in the respective ecosystems, compared to other more prevalent processes. When Martin and Elaine studied the faunal material from the Central Rhineland (Turner, 1990, 1997, 2000; Street, 2002), the big question was the role of early humans in the formation of faunal assemblages (Gaudzinski and Turner, 1999); we now have to question the role of early humans in past ecosystems.

Against this background, palaeopathological considerations may help us understand the magnitude of ecological processes in Pleistocene environments. Otherwise and as always, when considering "loners" in the Pleistocene record, the horse was just lucky – an anecdotal and interesting pathological discovery. Just another bone that tells its story.

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