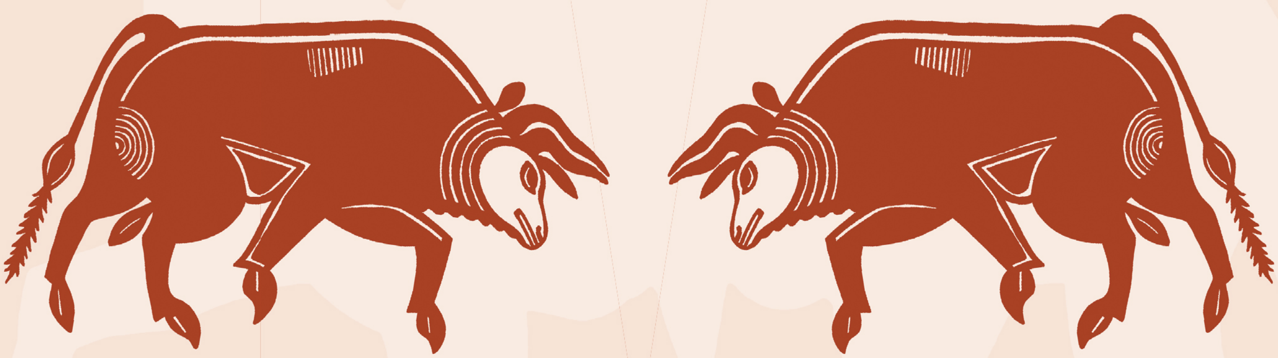
Archaeobiology 3

ARCHAEOZOOLOGY OF SOUTHWEST ASIA AND ADJACENT AREAS XIII



Proceedings of the Thirteenth International Symposium, University of Cyprus, Nicosia, Cyprus, June 7–10, 2017

edited by

Julie Daujat, Angelos Hadjikoumis, Rémi Berthon, Jwana Chahoud, Vasiliki Kassianidou, and Jean-Denis Vigne

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Group photo of the 13th ASWA[AA] meeting June 8th 2017
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Part 2: Subsistence Economies of Early and Late Complex Societies in Southwest Asia and Adjacent Areas

Part 3: Beyond Subsistence: Animals in the Symbolic World of Southwest Asia and Adjacent Areas

FOREWORD

The 13th ASWA conference was hosted by the University of Cyprus, one of the youngest of Europe's universities. In 2019, it was only thirty years since its foundation. Nevertheless, this is a thriving academic institution, which currently consists of eight faculties, twenty-two departments, and eleven research units.

In 1991, and just two years after the university's foundation, the Archaeological Research Unit (ARU) was founded by decree from the Government of the Republic of Cyprus, following the issuance of the dependent legislation by the House of Representatives. The decision to establish the ARU was based on the recommendation of the Interim Steering Committee of the University of Cyprus, which stated the following:

1. Cyprus is offered for primary research in the field of archaeology thanks to its distinctive cultural signature and history, as well as due to the fact that Cypriot archaeology and archaeological research on the island already has a distinguished tradition and international reputation;

2. The subsequent international recognition of the importance of archaeological research in Cyprus should comprise one of the first incentives for choosing the University of Cyprus as a center for postgraduate studies, and will pave the way for the exchange of students and academics between the University of Cyprus and academic institutions overseas.

The faculty members of the ARU, who are also part of the Department of History and Archaeology academic staff, have contributed immensely over the past 28 years to the achievement of the aforementioned objectives for the study and promotion of Cypriot cultural heritage through their research, their teaching, and the practical training they have been providing to students at undergraduate and postgraduate levels. The active study of other regions of the Mediterranean world have not been overlooked either, as members of the ARU academic staff have been carrying out excavations and research projects in Greece, Turkey, and France.

The members of the ARU are actively carrying out research in Pre- and Protohistoric Archaeology, Classical and Byzantine Archaeology but also Archaeometry and Environmental Archaeology, Maritime Archaeology, and Western Art. In the course of the past 28 years, the ARU has laid very stable foundations in all aforementioned specialisations of the archaeological discipline, none of which existed at academic level in Cyprus before the unit's establishment. Through their teaching at undergraduate and postgraduate levels, all members of the ARU academic staff have been contributing to the formation of a new generation of Cypriot archaeologists, equipped with all the necessary knowledge and practical experience needed to excel in this scientific field.

Over the years, the ARU has been very active in organizing international conferences and workshops. The ARU has organized over 50 international conferences, while members of the academic staff have published the proceedings of over 20 scientific meetings held at the ARU.

Thus, when Jean-Denis Vigne came to my office several years ago with the suggestion to co-organize the 13th Archaeozoology of Southwest Asia and Adjacent Areas conference I gladly accepted. The meeting in Nicosia brought together colleagues from all over the world and offered a venue where new results from the field or the laboratory could be presented and discussed. The publication of the conference proceedings enables colleagues who were unable to attend the conference to read about the latest developments in the archaeozoology of this culturally important region.

I would like to close by thanking all the members of the 13th ASWA organizing committee for all the work they have put into bringing so many scholars to Cyprus, many of them for the first time. I would also like to thank the co-editors of this volume for all the work they have put into the publication of the proceedings.

Professor Vasiliki Kassianidou
Director of the Archaeological Research Unit,
University of Cyprus
Nicosia, August 2019

EDITORS' PREFACE

Due to their location at the meeting point of the three Old World's continents—Africa, Asia, and Europe—Southwest Asia and its adjacent areas played a pivotal role in the history of humanity. They received successive waves of our species—*Homo sapiens*—out of Africa. Different processes in several areas of this large region brought about the transition to the Neolithic, and later on the urban revolution, the emergence of empires bringing with them important subsequent religious, cultural, social, and political consequences. Southwest Asia also played a major role in the interactions between East (Asia) and West (Europe) during the last two millennia. The unique importance of Southwest Asia in the history of humanity is strengthened by the, also related to its location, fact that this area is a hotspot of biodiversity, especially in mammals, which were—as everywhere in the world—tightly associated to the history of civilizations in a diversity of roles: game, providers of meat and milk, traded raw material, symbol of prestige and wealth, pets, etc.

Everywhere in the world, the biological and cultural interactions between humans and animals often remain under-evaluated in their heuristic value for understanding complex social and biological interactions and trajectories. This is why, almost half a century ago, archaeologists who were carrying out research and reflecting on such themes founded a very active nonprofit world organization named the International Council for Archaeozoology (ICAZ). This is also why the ICAZ working group "Archaeozoology of Southwest Asia and Adjacent Areas" (ASWA[AA]) was one of the first ones created within ICAZ, constituting one of the largest and most active of ICAZ's working groups.

The ASWA[AA] was formed during the 1990 ICAZ International Conference in Washington, D.C. Its purpose is to promote communication between researchers working on archaeological faunal remains from sites in western Asia and adjacent areas (e.g., Northeast Africa, Eastern Europe, Central Asia, and South Asia). It carries out its mandate mainly through the sponsoring of biennial international conferences. Since 1998, these meetings have alternated in being hosted in Europe or in Southwest Asia: Paris (1998), Amman (2000), London (2002), Ankara (2004), Lyon (2006), Al Ain (2008), Brussels (2011), Haifa (2013), Groningen (2015).

Ongoing armed conflicts and political tensions in several countries of Southwest Asia made it difficult to locate a safe and convenient place that would enable the organizing the 13th ASWA[AA] meeting in within that region. Although Cyprus is currently a member of the European Union, in (pre-)history Cyprus was embedded in the eastern Mediterranean "world." Because of its location, Cyprus was indeed at the confluence of African, Levantine, Anatolian, and Greek cultural streams and, as is common for islands, recombined them in different but always original ways all along its history. Archaeozoology recently provided one of the most convincing illustrations of the tight connection between Cyprus and Southwest Asia, demonstrating that the earliest domesticated mammals, especially cats, pigs, cattle, sheep, and goats, were introduced to the island very shortly after their first incipient domestication on the near continent, that is, during the ninth millennium BC. For all these reasons, Cyprus represented an ideal place to host the 13th ASWA[AA] conference.

Despite the illegal military occupation of part of its territory by a foreign country, the option of hosting the meeting in Cyprus was enthusiastically embraced by all members of the working group, especially because it is open to all nationalities and maintains good diplomatic relationships with a large majority of countries in Southwest Asia. These facts contributed towards the 13th ASWA[AA] meeting in Cyprus (June 7–9, 2017) becoming one of the best-attended ASWA[AA] meetings. It brought together 80 scientists coming from 25 different countries: from Southwest Asia (6 countries), Europe (14 countries), North America (2 countries), and Japan.

They presented their results in 36 oral and 32 poster presentations. They debated the long-term interactions between humans and biodiversity, about the beginning of animal domestication and husbandry, the strategies of animal exploitation from the Paleolithic to modern times, and the symbolic and funeral use of animals through time. They also greatly enjoyed the numerous social events organized, including a fantastic Cypriot mezze dinner, enhanced by a local folk-music band, and a nice excursion to the archaeological sites of Amathous, Kourion, and Khirokitia, and to the museums of Nicosia and Larnaca, which provided ample opportunities for scientific exchanges in a friendly atmosphere.

The hosting of the conference at the new campus of the University of Cyprus was another major reason to the meeting's success. This campus was a convenient and pleasant venue for such a conference, and the strong support of the University of Cyprus, as well as its valuable experience for the organization of such meetings were deeply appreciated by both the scientific organizers and the delegates. Several other partners contributed to the organization: the French archaeological mission "Neolithisation—Klimonas," which is itself strongly supported by the French School at Athens, the Cyprus Department of Antiquities, the French Institute of Cyprus, the French National Center for Scientific Research (Centre National de la Recherche Scientifique [CNRS]), and the French National Museum of Natural History (Muséum national d'Histoire naturelle [MNHN]).

The present volume brings together the texts of 18 of the 68 presentations of the meeting in Nicosia. The editorial board collected the papers and organized their review and editing. We are very grateful to Sarah Kansa (and Open Context), Justin Lev Tov, and Lockwood Press for their constant support in bringing this volume to fruition.

Julie Daujat
Angelos Hadjikoumis
Rémi Berthon, Jwana Chahoud
Vasiliki Kassianidou
Jean-Denis Vigne

1.8 | Old Dentitions and Young Post-crania

Sheep Burials in the Ptolemaic–Early Roman Animal Necropolis at Syene / Upper Egypt

Ursula R. Mutze,* Wolfgang Müller,† Mariola Hepa,* and Joris Peters‡

Abstract

Excavations at the Ptolemaic–Early Roman animal necropolis at Syene/Aswan in Upper Egypt revealed the presence of more than 300 domestic animal skeletons. Sheep predominate in this assemblage, but dogs, cats, and cattle were ritually buried as well. Animals have been deposited in toto in shallow pits without prior mummification. Ongoing archaeozoological analysis of sheep shows some interesting patterns meriting a closer look. Methodologically the discrepancy between age estimates based on eruption and/or abrasion of teeth and the individual's epiphyseal status is of particular interest. To quantify this discrepancy, we compared recordings with those obtained from a modern population of known-age sheep: the Karakul population housed in the Julius Kühn Collection in Halle an der Saale, Germany. The rate at which tooth wear takes place in the different populations is evaluated and possible causal relationships discussed. Being essential to reconstruct demographic profiles, an approach to estimate tooth-wear rate in ancient sheep populations will be presented.

Keywords

Ptolemaic–Roman Egypt, animal necropolis, sheep, aging criteria, tooth wear, mandibles, dental attrition

Introduction

The animal necropolis of Syene was excavated between 2011 and 2015 by the joint mission of the Swiss Institute of Architectural and Archaeological Research in Cairo and the Aswan Inspectorate of the Ministry of State for Antiquities (Müller 2014; Pilgrim et al. 2012, 2015; Pilgrim and Müller 2013, 2014). It is in the ancient town of Syene—modern Aswan in Upper Egypt—and is situated in the south-eastern corner of the Late Period town wall near the Temple of Isis.

Animals were buried around Building 1 (Figure 1.8.1), a structure consisting of a podium with a staircase to its north. Over time, several courtyards were added to the layout. Massive dung accumulations in these courtyards indicate that animals were not only buried but also kept in the area of the necropolis (Hepa et al. 2018). While the archaeological evidence clearly shows that there is a connection between burials and the building, the exact nature of this relationship has yet to be established. In the absence of parallels for the building in Egypt, the architectural features suggest a tentative interpretation as a small podium temple of a type known from other parts of the eastern Mediterranean in the Late Classical and Hellenistic periods (Conze and Schazmann 1911). The architectural development of the building

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Figure 1.8.1. Site plan with Building 1 and the animal burials. (Plan by W. Müller and M. Hepa, courtesy of the Swiss Institute of Architectural and Archaeological Research on Ancient Egypt in Cairo.)

and its surrounding architecture was organized into three major phases.

The necropolis was used from the first half of the second century BC until the end of the first century AD (Pilgrim et al. 2016). While the southern, eastern, and northern limits of the necropolis are defined, it continues toward the west under a modern street. The excavated area of the cemetery covers around 420 m^2. Approximately 320 animal burials have been excavated within this area. Numerous empty pits and dislocated bones scattered all over the site constitute evidence of a significantly higher number of original burials. Burials could be attributed to the architectural phases of Building 1. The number of burials increased over time and reached its peak in the second half of the first century AD, just before the area around Building 1 was reorganized into a domestic quarter of the town (Koch and Müller 2014).

Most of the animals were sheep, but some dogs, cats, and young cattle were buried as well. Animals were deposited in shallow pits without prior mummification. In the course of the necropolis's use, some changes in burial customs were observed. During the earliest phase of the necropolis, some pottery–mostly small bowls and plates—was found in or around the pits. During the later phases, no more pottery was deposited in graves, but the heads or bodies of the animals were covered with sherds from large vessels. Such a sheep burial is shown in Figure 1.8.2.

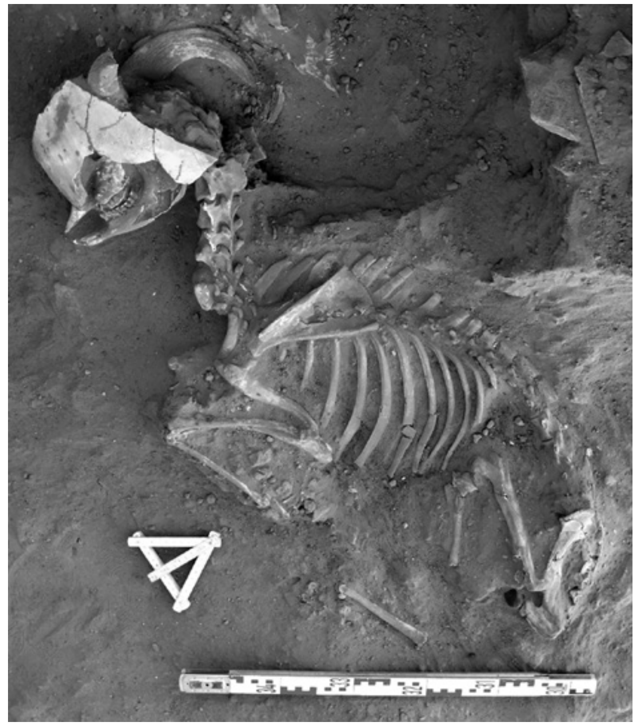

Figure 1.8.2. Sheep burial (skeleton 207, 14–2–61–3/1). The ram's head was covered with potshards. (Photograph by W. Müller and M. Hepa.)

Material and Methods

Ancient Sheep Herd Composition

From a total of 247 sheep burials, 197 had been analyzed archaeozoologically as of September 2018 and are included in this study. For slightly more than 50% of these it was possible to determine the sex (48 males and 57 females), while in 92 individuals sexing was problematic due to either their very young age or only partial preservation. Based on the greatest lengths (GL) of all long bones available per individual, we calculated the individual withers height by applying the factors proposed by Teichert (1975). Adult rams averaged 68.3 cm (N = 32, minimum = 60.8 cm; maximum = 77.3 cm) and ewes 63.9 cm in withers height (N = 44, minimum = 55.3 cm; maximum = 72.1 cm).

According to epiphyseal fusion age provided by Habermehl (1975), sheep from Syene could be classified into seven age classes (Table 1.8.1). From this we can conclude that nearly one-fifth of individuals died in their first year, while more than half of deposited sheep were older than four years of age.

Table 1.8.1. Age distribution in Syene sheep.

Age	%	N
<3 months	12.2	24
3 months–1 year	7.6	15
1–2 years	4.6	9
2–3 years	5.1	10
3–4 years	14.2	28
4–5 years	24.9	49
>5 years	31.5	62

Such an age distribution indicates natural deaths rather than selective, human-controlled kill-off. In sheep older than three years of age, a sex-related difference can be observed. Among animals aged between three to five years old, ewes outnumber rams, while in the elder group–more than five years of age—males exceed females in numbers: χ^2 (df = 1, N = 90) = 12.321; p = 0.00045. Since the epiphyses of ewes are known to fuse slightly earlier than those of rams (Davis 2000), this bias may have been even more pronounced since, compared to rams, the ages of ewes tend to be underestimated. Ewes' higher mortality, early in adulthood, might be explained by causes of death associated with reproduction, such as birthing complications, mastitis, nutritional deficiencies, or similar.

Dental versus Epiphyseal Aging

During archaeozoological examination, dental wear stages were recorded following the scoring system proposed by Payne (1973, 1987). Payne's stages can be allocated to four broad stages:

(1) Eruption
(2) Early wear stages (1A to 8A for M_1 and M_2, 1A to 10G in M_3)
(3) Long-lasting mature wear stage (9A for M_1 and M_2, 11G for M_3)
(4) Gradual wearing away of the base of the infundibula (>9A for M_1, M_2, >11G for M_3)

Epiphyseal fusion of long bones and vertebrae was documented as well. However, Syene's sheep demographic profiles produced with the two methods yielded consistently different results. Age estimates based on dentition indicated much older individuals than age estimates based on bone epiphyseal fusion. This discrepancy can be explained either by accelerated tooth wear or delayed bone epiphyseal fusion. For several reasons, the former is a more likely explanation. Popkin et al. (2012), for instance, noted a maximum delay of 12 months in the fusion of late fusing bone epiphyses due to poor nutrition. In Syene's sheep, however, we observed discrepancies of up to five years of age, which cannot be explained by delayed bone epiphyseal fusion only. There are additional arguments pointing to tooth wear as the main reason for the observed discrepancy. Understandably, food intake has a major effect on tooth wear (Healy and Ludwig 1965; Grant 1978), and nutrition in sheep in southern Egypt might not be comparable to that of Europe or Southwest Asia. Moreover, in Syene's faunal assemblage extreme tooth wear is not only restricted to sheep but has also been noted for dogs. Their upper and lower dentitions are extremely worn with extensive exposure of dentine and even antemortem tooth loss. The problem is also well known in humans. In his article on dental problems in human skeletons and mummies from the Old Kingdom, Filce Leek (1984) states that "almost every dentition from early childhood onwards" shows heavy wear of the teeth (Filce Leek 1984:125). He offers several explanations for this phenomenon, although not all of them apply to our material, like the intentional adding of sand prior to grinding cereals. He also mentions what we noted during fieldwork, namely that "anyone who has experienced eating food on a windswept desert will not be surprised that mineral particles become incorporated in their food" (Filce Leek 1984:125). Naturally, this observation also applies to animals. Grant (1982) gives combinations of molar stages in sheep and goat mandibles from nine archaeological sites in the United Kingdom. Combinations with advanced wear on M_1 are on the right-hand side and those with more advanced wear on M_3 on the left-hand side of Table 3 in that publication. The combinations found in Syene's assemblage—if indicated in the table at all—appear in the middle to right-hand side, which indicates a faster abrasion as well. A comparison with the stage combinations of M_1 and M_3 observed by Jones (2006) also showed that in Syene M_1 wear was comparably more advanced, indicating a faster abrasion.

If we accept that accelerated tooth wear among sheep from Syene is the main reason for the discrepancy observed between dental and bone epiphyseal ages, then it must be acknowledged that tooth wear depends on several parameters. Besides nutrition, which is of central importance (Healy and Ludwig 1965), an animal's sex and, in males, castration have some influence as well (Behr 1928, Davis 2000). For example, according to Davis (2000), teeth wear more slowly in ewes than in rams or wethers. However, since in Syene's assemblage the discrepancy concerns all sheep independent of their sex, this explanation seems unlikely.

This leaves us with nutrition as the primary cause for the condition observed, necessitating a closer look at how it affects tooth wear. In agricultural and archaeozoological literature, two main factors are considered responsible: ingested soil and hard-plant components like ligneous fibers and phytoliths. Healy and Ludwig (1965) observed that the quantity, rather than quality, of ingested soil was the primary factor influencing incisor wear. Deniz and Payne (1982) noted differences in wear rate between incisors and cheek teeth. More specifically, abrasion in incisors is higher because the main wear occurs during grazing activity, while cheek teeth are mostly used to comminute contents of the rumen, which might already contain a reduced portion of soil. The same authors suggested that phytoliths are the main agent of wear in cheek teeth.

In sheep mandibles excavated at Syene, incisors were missing in almost all cases and only cheek teeth could be recorded. Although Baker et al.

(1959) found phytoliths to be harder than enamel, later studies could not confirm these results. Lucas and others (2014), in contrast, conclude from their measurements that phytoliths are unlikely to wear enamel because of their insufficient hardness. They "propose the hypothesis, that phytoliths, whilst not being the actual agents of wear, are instead deployed to mimic dust and grit during the mastication of plant tissue by animals, causing them to reduce or avoid consumption and therefore providing wear protection by deception." (Lucas et al. 2014:150). By comparing different ungulate species, Damuth and Janis (2011) found a positive correlation between a grazing diet and the degree of hypsodonty, that is, high-crowned dentition. In addition, they also found higher degrees of hypsodonty in browsing ungulates that browse closer to the ground, compared to those browsing higher. Based on these observations, they conclude that dust and grit, rather than phytoliths, are likely to be the most important agents of tooth wear in ungulates and that they are mostly attached to plants close to the ground, such as grass. Sanson and others (2017) also question the role of phytoliths in tooth wear because they found profoundly different phytolith intakes in African buffalo with no observable differences in tooth wear. Since phytoliths can hardly explain the pronounced abrasion observed in dogs' teeth at the animal necropolis of Syene, dust and grit remain the most likely agents of significant wear in sheep teeth at this site. The thickness of dung layers in the courtyards associated with the necropolis, as well as the incidence of intra-articular pathologies (Mutze et al. in press; Mutze 2021) indicate that sheep were kept under crowded conditions, probably not only at night. It seems therefore likely that they were fed inside enclosures regularly. Possibly originating from some distance, the provided fodder may have contained dust and soil particles. We will return to this point later.

The unexpectedly high tooth-wear rate in the Syene sheep represents an interesting methodological challenge to work on demographic profiles. Established methods of dental aging either give relative ages (Grant 1975, 1982) or assume a specific value for the rate of tooth wear (Deniz and Payne 1979, 1982; Jones 2006; Payne 1973) to obtain absolute ages. The findings at Syene show that applying Payne's age estimates method (1973) will produce misleading results because the rate of tooth wear in Syene's sheep diverges so much from Payne's source data. The same is true for age estimates proposed by Jones (2006). Of course, when studying complete skeletons, this can be easily recognized, since epiphyseal fusion can be used for aging as well. However, archaeozoologists usually deal with isolated bone specimens from settlement refuse. In such cases, analysis of dental wear data can only produce reliable results when the tooth wear rate is correctly estimated.

It is therefore essential to develop a method allowing researchers to estimate the rate of tooth wear in mandibular tooth rows from archaeological sheep. The underlying assumption is that due to their successive eruption—a process considered to be genetically determined (Zeder 2006)—the consecutive molars (M_1–M_3) will pass through similar wear stages at different moments during the animal's life. However, the higher the intensity of tooth abrasion, the shorter the duration of each of these wear stages. To determine the rate of abrasion, an approach is needed that interrelates the degree of wear for each molar in a tooth row. To pursue this idea, we compared the intramandibular molar wear observed in sheep from Syene with those from an early twentieth century AD sheep population raised in captivity. To this purpose, we analyzed Karakul sheep skeletons housed at the Julius Kühn Collection in Halle an der Saale, Germany. The Karakul is a fat-tailed breed exploited mainly for lambskins. The breed probably originated in the region of Bukhara in present-day Uzbekistan. The flock in Halle's "Haustiergarten" was based on eighty-one Karakul sheep, imported from Bukhara between 1903 and 1928 (Frölich and Hornitschek 1954). In fact, some more rams were imported that left progeny in Halle, but these were soon passed on to other institutions. In the "Haustiergarten," Karakuls were kept in consistent conditions (Frölich 1928) and the dates of birth and death were accurately documented. Considering feeding conditions at Halle, it can be assumed that the Karakul sheep experienced moderate tooth wear. Ages determined according to Payne (1973, 1987) and Jones (2006) match the documented ages of the animals quite well, which confirms this assumption. This population is therefore perfectly suitable as reference material.

Results and Discussion

First, an attempt was made to examine intramandibular molar wear applying the indices proposed by Ducos (2000) for the first and the third lower molars.

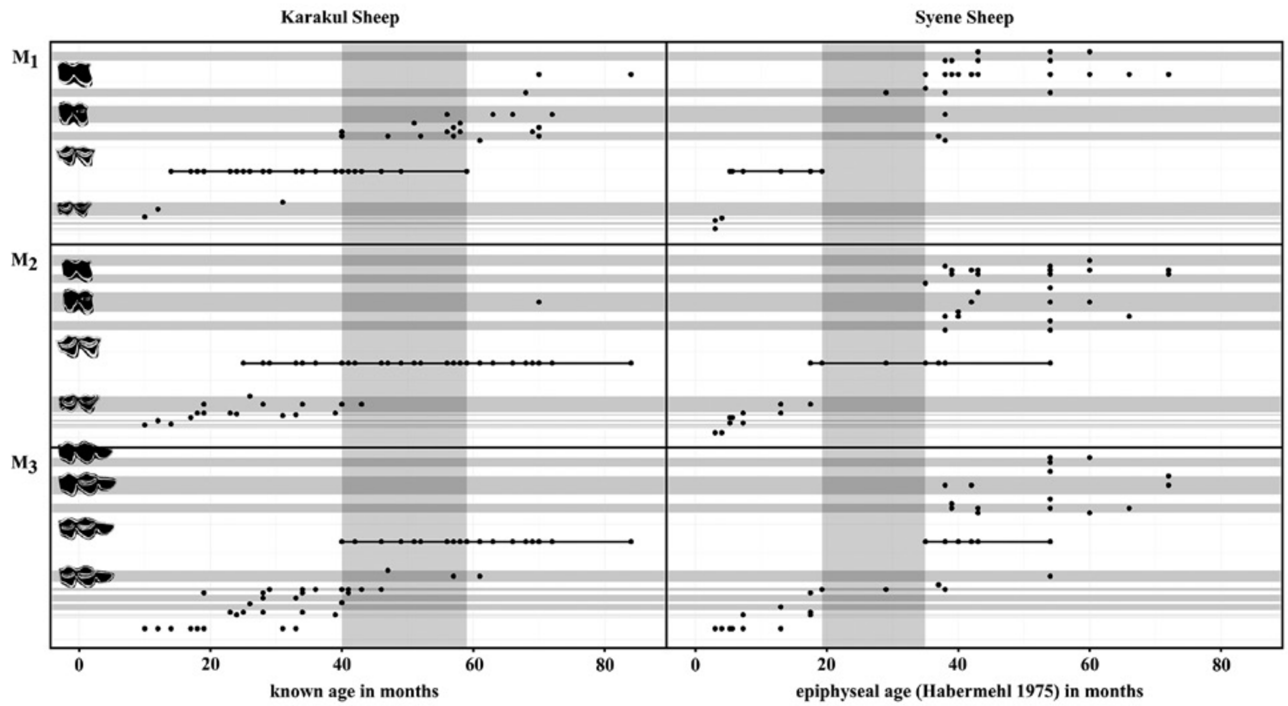

Figure 1.8.3. Wear stages of the three lower molars against age for the Karakul sheep and Syene's sheep.

This approach failed for several reasons. Firstly, the method requires animals old enough to have their M_3 fully formed. It turned out that this is only the case after the tooth has already passed several wear stages (Twiss 2008). Although this is not a problem for Syene's sheep, it becomes a problem when dealing with settlement refuse, since many sheep are slaughtered before reaching this age. Secondly, when the M_3 is measurable, the M_1 is almost worn down, even in populations with slow rates of abrasion. We, therefore, modified our approach by comparing M_1 with M_2 and M_2 with M_3. Unfortunately, the differences were small even in populations with very different tooth wear rates. Thirdly, another major obstacle when applying Ducos's method is that it requires breaking mandibles to access individual teeth. Complete mandibles are scientifically valuable specimens and their future potential should not be compromised to measure individual teeth.

For these reasons we decided to abandon that approach and shifted to quantifying patterns of intramandibular tooth abrasion with the aid of wear stages published by Payne (1973). In Figure 1.8.3, the horizontal gray and white bars symbolize the consecutive wear stages, whereby broad bars correspond to longer and narrow bars to shorter time intervals. Here, the assumption is made that the tooth structure, and particularly the relative depth of the infundibula within the crown, is similar in all sheep, regardless of breed, sex, or other differences. Since it is determined by the tooth's inner structure, the duration of each wear stage in relation to the others is also considered equal in all sheep. The graphical representation of these relationships in Figure 1.8.3 is based on an extensive study undertaken by Jones (2006). For all molars, the stages with long-lasting wear—M_1 and M_2: 9A; M_3: 11G (following the Reference Codes proposed by Payne 1987)—are highlighted by a black line. The diagram illustrating molar wear in the Karakul population shows that at an estimated age of 40 to 60 months, the long-lasting wear stages in all three molars temporally overlap—left vertical gray bar. During this phase, the occlusal surfaces of all three molars can exhibit the classic selenodont—crescent-shaped—cusp pattern typical in ruminants. Conversely, in Syene's sheep, such overlapping was absent (Figure 1.8.3). Indeed, by the time M_3 is fully functional with all three lobes in use and completed selenodont cusps in the first two lobes, M_1 had already passed the mature-wear stage 9A. This situation explains the gap between the corresponding wear stages of M_1 and M_3, indicated

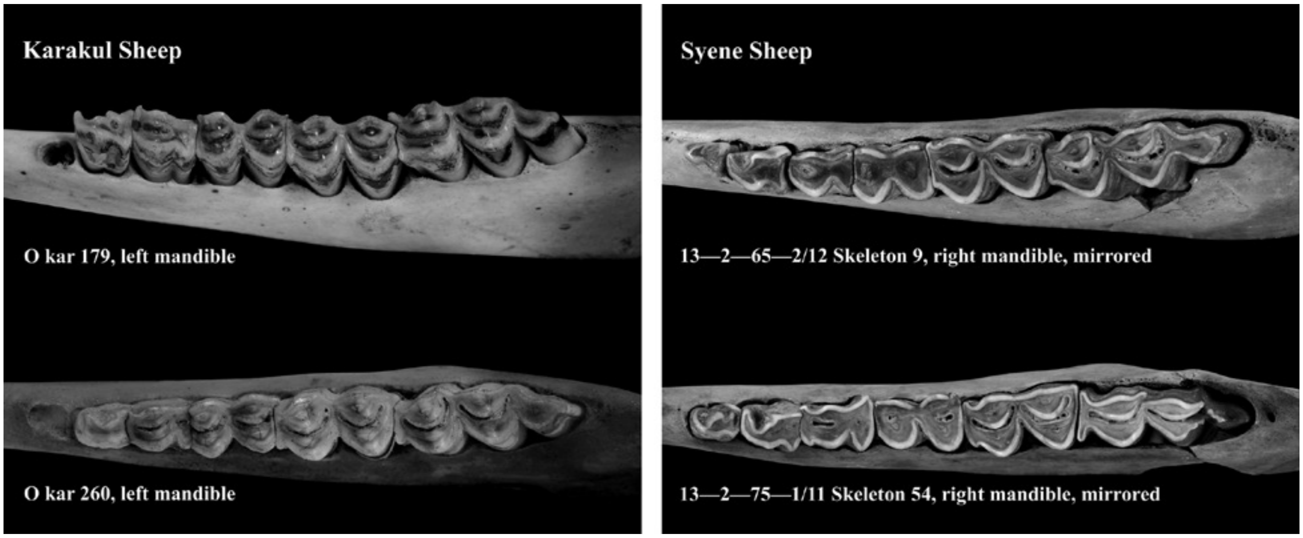

Figure 1.8.4. Example specimens from the Julius Kühn Collection in Halle on the left side and from the animal necropolis of Syene on the right side. The mandibles show the conditions illustrated in Figure 1.8.3—gray bars. (Photographs by U. Mutze.)

by the right vertical gray bar. Figure 1.8.4 presents examples of mandibles from Karakul and Syene's sheep, illustrating the differences in the rate of intramandibular molar wear.

Based on these results, we can conclude that by combining wear stages of the three molars, patterns of intramandibular molar wear can be generated allowing us to estimate the rate of molar abrasion. Thus, presence or absence of specific combinations of wear stages in an assemblage of sheep mandibles can be used for estimating the rate of tooth wear. We modeled this for two fictitious populations: one with lower rates of abrasion and one with higher rates of abrasion (Figure 1.8.5), whereby upon an animal's death (= d), the lifetime of a lower molar is the sum of the period before eruption (= e) plus the time (= w) elapsing while passing through the consecutive wear stages until the death of the animal. Although animal's sex as well as castration and nutrition may affect the timing of (pre-)molar eruption, Worley et al. (2016) could not find any significant difference between ewes, rams, and castrates or between high and low levels of nutrition. Hence, it can be reasonably assumed that the timing of tooth eruption in sheep is genetically determined within comparably narrow limits. Most authors propose an age of three months for the eruption of M_1 (Elbers 1926; Habermehl 1975; Jones 2006; for improved breeds, see Silver 1969). For M_2, eruption dates vary from nine months (Habermehl 1975; Miller and Robertson 1959) up to twelve months (Elbers 1926; Silver 1969 for improved breeds; Getty 1975). Jones (2006) recorded that M_2 was erupted in less than half of the 9-months-old sheep and more than half of the 10-months-of-age individuals, which matches well the results of the above-mentioned studies. Eruption of M_3 was found to be more variable. Early eruption occurs at the age of 18 months (Habermehl 1975), but in late maturing breeds eruption may vary between 19 and 30 months (Elbers 1926). Similar times are given by Jones (2006) with M_3 eruption spread from 18 to 27 months. Much later eruption dates are provided by Silver (1969) for sheep defined as "semi-wild hill sheep", but these derive from a source dated from 1790. Because those results have not been confirmed by later studies, these values have been omitted from further consideration. Even though variability of eruption in M_3 is higher than in M_1 and M_2, passage through the consecutive wear stages is even more variable. Compared with tooth wear, tooth eruption can therefore be considered constant.

Returning to our model, Figure 1.8.5 shows the wear conditions in a population with a lower (a) and one with a higher (b) rate of tooth wear. The timing of tooth eruption is considered the same in the two populations. However, the time intervals corresponding to the consecutive wear stages are shorter in the population with higher wear, and correspondingly the overall duration of the process (= w) is shorter. One major premise in the proposed model

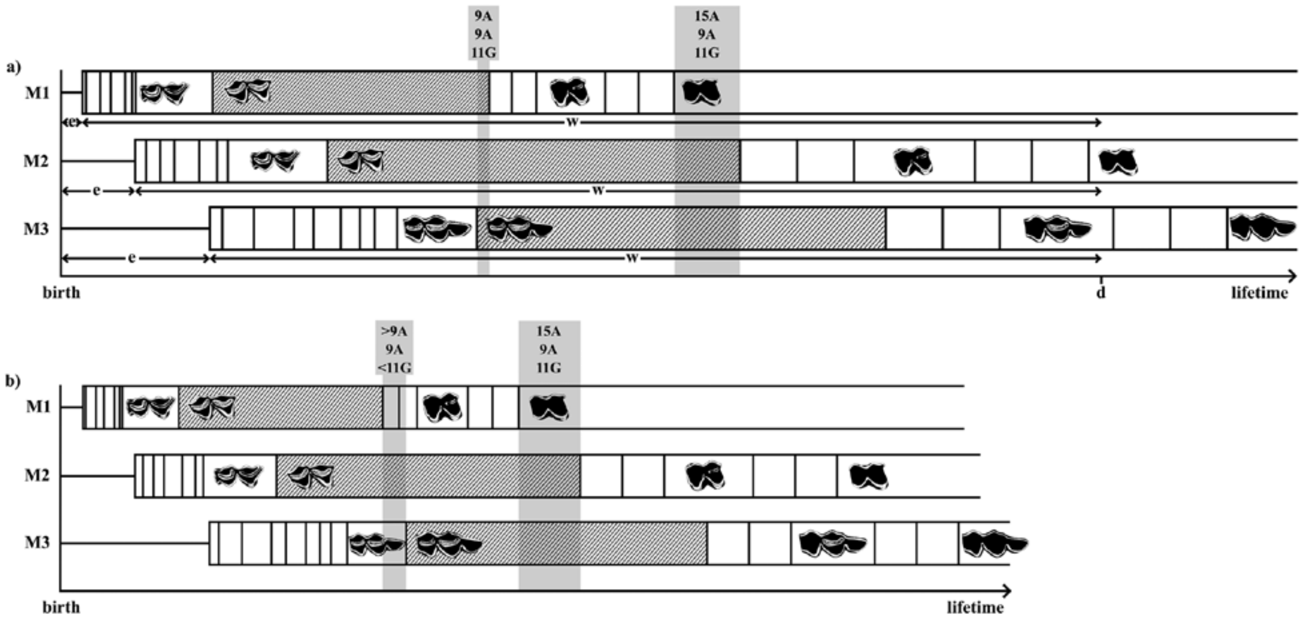

Figure 1.8.5. Model of wear conditions in a fictitious population with lower rates of wear (a) and one with higher rates of wear (b). Eruption times (= e) are the same in the two populations, but the overall lifetime of a molar in a mandible (= w) is significantly shortened in the population with a higher tooth wear rate (b).

is that, independent of the wear rate, the relative duration of each wear stage remained the same compared to either the preceding or succeeding stage(s) (cf. Jones 2006), since the tooth's inner structure primarily determines it. Moreover, we assume that abrasion affects all three molars similarly, implying that if the M_1 wear rate increases by a factor of two, the same is also true for M_2 and M_3.

Figure 1.8.5 helps to visualize and explain the differences noted between Karakul and Syene sheep (Figure 1.8.3). Any variation in tooth wear will cause wear stages to shift between the three molars. Consequently, certain combinations of wear stages will be characteristic for populations exhibiting low rates of tooth wear, such as combination "9A 9A 11G" in Figure 1.8.5a and in Karakul sheep. Other combinations will be indicative of distinctly more pronounced tooth wear as combination ">9A 9A <11G" in Figure 1.8.5b and in Syene's sheep. Other combinations can be seen in both Figures 1.8.5a and b, which means they reflect fairly wide ranges of tooth wear—like "15A 9A 11G." Thus, if in an archaeological assemblage a sufficient number of observations of comprehensive combinations is available, accommodating all observations in a single pattern can be attempted in order to estimate a population's average tooth wear rate.

In sum, analysis of intramandibular molar wear illustrates that the sheep population of Ptolemaic–Roman Syene was kept in peculiar living conditions. The latter obviously caused significantly higher rates of wear in M_1–M_3 compared to an early twentieth-century AD sheep population kept in Central Europe. This observation limits previous assertions about a general high correlation between estimated and absolute ages made for example by Greenfield and Arnold (2008). Nutrition being particularly relevant in this respect, we refer to Healy and Ludwig (1965), who consider the quantity rather than the quality of ingested soil the most relevant factor. Since we assume that at least a part of the fodder was provisioned (p. 133), it may have been contaminated with sand and dust during its transportation and, once deposited inside the enclosures, contaminated further by trampling or pulling of food. It is, therefore, possible that the unexpectedly high abrasion of cheek teeth is related to the on-site environmental conditions. With the method presented here and currently being developed further, it will be possible to determine tooth wear rate in archaeological sheep mandibles from other sites along the Nile Valley, in order to detect the extent of this phenomenon.

Conclusions and Prospects

Comparative analysis of dental profiles in early twentieth-century AD Karakul sheep and the sheep mandibles from the animal necropolis at Syene revealed differences in intramandibular molar wear. The intake of sand and dust particles during feeding is the most likely reason for the fast abrasion of dentitions in the latter population.

To develop a model for molar wear in sheep mandibles, the following premises are essential:

(1) Compared with tooth wear, the eruption times of cheek teeth vary only little and can, therefore, be considered constant.
(2) Ratios between time intervals assigned to wear stages in a molar depend on the species-specific inner structure of the tooth and are therefore considered constant as well.
(3) Accelerated or decelerated tooth wear affects all molars of a mandible to the same degree.

The resultant model (Figure 1.8.5) shows that variations in tooth wear cause a shift of wear stages in the three molars. Some combinations, such as those observed in the sample of Karakul sheep, reflect moderate wear, while others are indicative of intense wear, such as in the case of Syene's sheep.

Our goal is to produce a method that allows quantification of tooth wear rate using a computer program. This method will be based on the results and approaches presented here. A preliminary version of the program is currently being tested with different known-age populations. The use of a computer allows the calculation of all ages simultaneously by applying the determined tooth wear rate. Finally, the program will be made available as a script in the free computer language R together with documentation. Using it will not require programming knowledge.

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