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RESEARCH

Set in Stone: Human–Horse Relations as Embodied in Shaped Stone Balls

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ABSTRACT

The enigmatic presence of uniquely shaped, spherical stones attracted the attention of archaeologists at Oldowan sites in Africa as early as a century ago. Shaped stone balls (SSBs) are among the oldest implements used by humans. For nearly 2 million years, they accompanied ancient humans as a stable cultural anchor throughout the Lower Paleolithic period and beyond. These tools reflect techno-cultural processes and Lower Paleolithic human perceptions of their relationships with the non-human animal world. Nonetheless, the few techno-functional studies focussing on these items have only scraped the surface of their research potential. In this paper, I will explore evidence suggesting that SSBs embody the relations of ancient humans with a particular animal—the horse—and propose that they might have played an active role in the social and cosmological realms of Lower Paleolithic (LP) ontology. Several previous studies indicate that they were shaped through a meticulous process. Traces of use and organic residues of marrow/fat associate them with bone-breaking activities. Furthermore, a comprehensive contextual analysis points to a correlation, observed at various sites, between SSBs and large herbivores, specifically horses. This correlation supports the premise that early humans relied on SSBs to extract calories from horses and points to a possible link between the simultaneous disappearance of large horses and SSBs from the Levantine landscape at the end of the LP. The role of horses in Paleolithic diet and culture is well reflected in the archaeological record. Following recent anthropological views, I advocate that SSBs played an important role in the human–horse alignment, embodying within them the world of perceptions and relationships of ancient humans with this non-human animal who shared their habitat.

Résumé: La présence énigmatique de pierres d'une forme sphérique unique a attiré l'attention des archéologues sur les sites Oldowan en Afrique dès le siècle dernier. Les pétrosphères (SSB—Shaped Stone Ball) sont parmi les outils les plus anciens utilisés par les êtres humains. Durant presque 2 millions d'années, ils ont accompagné les êtres humains anciens en tant que point d'ancrage culturel stable tout au long de la période du Paléolithique inférieur et au-delà. Ces outils reflètent les processus techno-culturels et les perceptions humaines du Paléolithique inférieur de leurs liens avec le monde animal non-humain. Toutefois, les quelques études techno-fonctionnelles s'intéressant à ces objets n'ont fait qu'effleurer la surface de leur potentiel de recherche. J'étudierai dans cet article les éléments suggérant que les SSB incarnent les relations des êtres humains anciens avec un animal particulier—le cheval—et je proposerai qu'elles aient pu jouer un rôle actif dans les aspects sociaux et cosmologiques de l'ontologie du Paléolithique inférieur. Plusieurs études antérieures indiquent qu'elles étaient façonnées suivant un processus méticuleux. Des traces d'utilisation et des résidus organiques de moelle/graisse les associent à des activités de broyage d'os. De surcroît, une analyse contextuelle exhaustive suggère une corrélation, observée sur différents sites, entre les SSB et de grands herbivores, en particulier les chevaux. Cette corrélation vient à l'appui du postulat que les premiers êtres humains recouraient aux SSB pour extraire des calories des chevaux et indique un lien possible entre la disparition simultanée des grands chevaux et des SSB du paysage du Levantin à la fin du Paléolithique inférieur. Le rôle des chevaux dans la culture et le régime alimentaire du Paléolithique est bien représenté dans les archives archéologiques. À la suite des récentes observations anthropologiques, je postule que les SSB ont joué un rôle important dans l'alignement entre êtres humains et chevaux, incarnant en leur sein le monde des perceptions et des relations des êtres humains anciens avec cet animal non-humain qui partageait leur habitat.

Resumen: La enigmática presencia de piedras esféricas de formas únicas atrajo la atención de los arqueólogos en sitios olduvayenses en África hace ya un siglo. Las esferas de piedra moldeadas (SSB, por sus siglas en inglés) se encuentran entre los instrumentos más antiguos utilizados por los seres humanos. Durante casi 2 millones de años, acompañaron a los humanos antiguos como un ancla cultural estable durante todo el Paleolítico inferior y más allá. Estas herramientas reflejan procesos tecnoculturales y las percepciones humanas del Paleolítico inferior sobre sus relaciones con el mundo animal no humano. Sin embargo, los pocos estudios tecnofuncionales que se centran en estos elementos sólo han rozado la superficie de su potencial de investigación. En este artículo, exploraré la evidencia que sugiere que las SSB encarnan las relaciones de los humanos antiguos con un animal en particular (el caballo) y propondré que podrían haber desempeñado un papel activo en los ámbitos social y cosmológico de la ontología del Paleolítico inferior (PI). Varios estudios previos indican que fueron moldeados mediante un proceso meticuloso. Las huellas de uso y los residuos orgánicos de médula/grasa los asocian con actividades que rompen los huesos. Además, un análisis contextual exhaustivo apunta a una correlación, observada en varios sitios, entre las SSB y los grandes herbívoros, específicamente los caballos. Esta correlación apoya la premisa de que los primeros humanos dependían de las SSB para extraer calorías de los caballos y apunta a un posible vínculo entre la desaparición simultánea de los grandes caballos y las SSB del paisaje levantino al final del PI. El papel de los caballos en la dieta y la cultura del Paleolítico está bien reflejado en el registro arqueológico. Siguiendo puntos de vista antropológicos recientes, defiendo que las SSB desempeñaron un papel importante en la alineación entre humanos y caballos, encarnando en ellos el mundo de las percepciones y relaciones de los humanos antiguos con este animal no humano que compartía su hábitat.

KEY WORDS

Lower Paleolithic, Shaped stone ball, Horse, Ontology

Introduction

The enigmatic presence of uniquely shaped, spherical stones attracted the attention of archaeologists at Oldowan sites in Africa as early as a century ago. Shaped stone balls (SSBs) are among the oldest implements used by humans. For nearly 2 million years, they accompanied ancient humans as a stable cultural anchor throughout the Lower Paleolithic (LP) period and beyond (Assaf et al. submitted). Nonetheless, the few techno-functional studies focussing on these items have only scraped the surface of their research potential. Several previous studies indicate that they were shaped through a meticulous process (Assaf and Presler 2022; De Weyer 2017; Titton et al. 2020). Usewear and traces of marrow/fat residues on LP Qesem Cave (Israel) shaped stone balls indicate they were used for bone-breaking activities (Assaf et al. 2020). Furthermore, a distinct contextual correlation between SSBs and large horses was recently discovered in a specific area of Qesem Cave. A comprehensive contextual analysis points to a similar correlation between SSBs and large herbivores, particularly the horse, at several Levantine and African sites. I present evidence of this correlation, which supports the premise that early humans relied on SSBs to extract calories from their habitat-sharing allies. Moreover, I will argue for a possi-

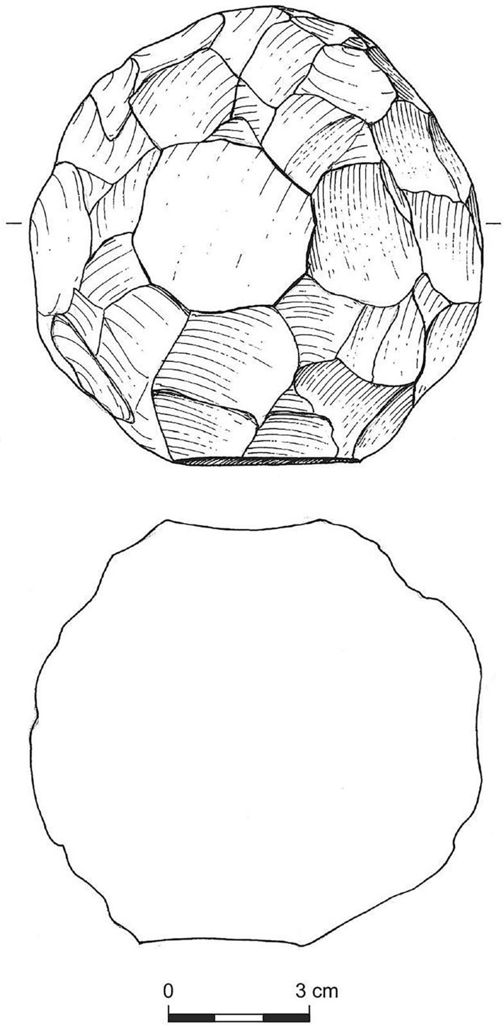

Figure 1. Shaped Stone Ball from Qesem Cave, dated to 300,000 BP (by Rodika Pinhas)

ble link between the simultaneous disappearance of large horses and SSBs from the Levantine landscape at the end of the Lower Paleolithic.

The significant role of horses (*Equus*) in the Paleolithic diet is evident from the presence of horse skeletal remains, and specifically horse teeth, at multiple LP sites (e.g. Bunn et al. 1986; Eisenman 1986; Rivals et al. 2021; Sahnouni et al. 2002; Sahnouni et al. 2013; Shipman et al. 1981). I submit that because of their unique nutritional value, horses were essential to early human adaptation in the Paleolithic: horsemeat, and especially horse marrow, has a unique nutritional profile superior to that of most other ungulates (Badiani et al. 1997; Guil-Guerrero et al. 2013; Lorenzo 2013; Outram and Rowley-Conwy 1998). SSBs, due to their unique round morphology, size, and intersecting high ridges, served as efficient tools for extracting marrow from the limbs and jaws of large-medium-sized herbivores (Assaf et al. 2023), such as horses. I argue that SSBs also may be seen as embodiments of early human social and cosmological perceptions of their relationships with herbivores. Following recent anthropological views, I offer that SSBs embody the world of perceptions and relationships of ancient humans with non-human animals and entities within them. Tools are perceived as a bridge or expression of relationships with specific non-human animals (Hendon 2017; Ingold 2000; McNiven 2018; Tanner 2021). Fat and bone marrow are essential in the diet of hunter-gatherers (Ben-Dor et al. 2021; Outram 2002; Plummer et al. 2023; Speth 1983), and it is reasonable to speculate that in ancient times tools used to extract animal fat were of significant importance (Barkai 2019; Tanner 2021). In this paper, I will suggest that SSBs embody the relations of ancient humans with a specific animal—the horse, and that they might have played an active role in the social and cosmological realms of LP ontology.

About Shaped Stone Balls

Shaped stone balls are ubiquitous at Oldowan and Acheulian sites in Africa (Cabanès et al. 2022; Diez-Martín et al. 2009; De la Torre et al. 2013; García-Vadillo et al. 2022; Jones 1994; Mora and de la Torre 2005; Sahnouni et al. 2018; Santonja et al. 2014; Willoughby 1985), Asia (Barkai and Gopher 2016; Bar-Yosef and Goren-Inbar 1993; Sharon 2010; Shemer et al. 2019; Yang et al. 2014), and Europe (Barsky et al. 2015; Titton et al. 2020), and also at Middle Stone-Age African sites (Walker 2008).

The faceted, intersecting, negative flake scars over some or their entire surface establish that SSBs were intentionally shaped (Figure 1). While these general features are common to all SSBs, they vary in size and regularity, as some are more intensively shaped, rounded, angular, or symmetrical than others. Some SSBs are pecked and/or battered to a nearly smooth surface, while others have projecting, obtuse-angled, high ridges. Over the years, several typological classifications have been proposed based on the different shaping degrees of these items and the level of skill required for their manufacture: missiles, polyhedrons, bolas, spheroids, and sub-spheroids (Kleindienst 1962; Leakey 1971; Sahnouni et al. 1997). Each of these classifications may reflect a different technological/functional process (De Weyer 2017), as some consider them as end products of a preconceived shaping process (Texier and Roche 1995). Various interpretations have been proposed for their possible function: exhausted cores (Sahnouni et al. 1997; Schick and Toth 1994), hammerstones (Jones 1994; Roussel et al. 2011; Willoughby 1985), battering tools for processing vegetal material or tendering meat (Mora and de la Torre 2005), bolas or throwing stones for capturing animals (Clark 1982; Isaac 1987; Leakey 1931), or food-pounding tools (Yustos et al. 2015).

SSBs were usually made of carefully selected homogeneous carbonate rock (Cabanes et al. 2022). This pattern of selectivity, detected at dozens of sites worldwide, was further investigated in a series of experiments in which stone ball replicas were shaped from different materials and used to break bones (Assaf and Preysler 2022). The results show that carbonate rock is preferable for the peripheral knapping of stone balls because it allows better control of the knapping process, which prevents the balls from splitting. In our view, SSBs are likely to have been desired tools rather than by-products of functional/technological activity. We suggest that the distinct spherical morphology of SSBs is a result of a complex knapping trajectory, which required careful planning and necessitated a high degree of know-how and precision. The process began with the selection of a morphologically suitable blank of good quality, followed by the creation of a flat, right-angled surface, which would have been the main challenge for the knapper; and finally, the creation of a symmetrical, spherical object (Assaf et al. 2020). What function did this distinctive morphology serve?

In the Levant, a notable assemblage of SSBs was found at the late LP site of Qesem Cave (dated to ca. 300,000 bp; see Barkai and Gopher 2016). In a previous study, we examined the techno-functional properties of this sample and revealed that ten SSBs bear traces of use and organic residues indicative of bone-breaking activities for extracting fat/marrow (Assaf et al. 2020). The study also demonstrated that these items underwent several "life cycles", indicating a very long-life history of use.

Our experiments indicated that the ridges on these tools represent multiple active working edges, sharp enough to break the bone effectively and quickly without small pieces splintering and contaminating the marrow (Assaf et al. 2020). We suggested that the different morphologies of SSBs reflect various numbers of working areas and/or wear resulting from different intensities of use. While these items were deliberately shaped in a spherical morphology, the smooth outline of the spheroids/bolas is the result of their highly intensive percussive use, leading to smoothed ridges and surfaces (see Assaf and Preysler 2022 for further details). Therefore, we advocate including all SSBs under the same 'umbrella'. Additional support for this hypothesis is the specific context in which these items were found in Qesem cave and other Paleolithic sites, as elaborated below.

Qesem Cave

Qesem Cave is a late Lower Paleolithic site inhabited between 430 and 200 ka (Falguères et al. 2022) and located twelve kilometres east of Tel Aviv and the Mediterranean coast. The habitual use of fire is noticeable throughout the stratigraphic column of the cave (Karkanaset al. 2007; Shahack-Gross et al. 2014; Stiner et al. 2011). The faunal remains are dominated by fallow deer but include other species, whose selected body parts were carried into the cave, where they were butchered, roasted, and the bones then smashed to extract the marrow (Blasco et al. 2019; Stiner et al. 2011). The stratigraphic sequence of the cave, currently 11 m of layers, consists of two distinct parts: the lower part (~6 m thick), deposited while the karstic chamber cave was closed, and the upper part (~4.5 m thick), deposited when the cave was more open (Karkanas et al. 2007). The layers were defined based on their unique sedimentological characteristics. Use wear and residue analyses indicate that the lithic items from Qesem Cave are very well preserved (Assaf et al. 2020; Venditti 2019; Zupancich et al. 2016) and were minimally affected by taphonomic, post-depositional processes. While some of the archaeological layers appear to represent palimpsests, distinct horizons that seem to reflect specific activity areas could also be identified, as indicated by spatial, technological, and functional studies (e.g. Gopher et al. 2016; Venditti 2019; Zupancich et al. 2016; Assaf et al. 2022). Activities identified at the cave included, *inter alia*, intensive hide working in specific locations under the rock shelf, intensive butchering and knapping near the central fireplace, and practicing the basic principles of knapping and tool use in the southern area (Assaf et al. 2022).

All the lithic findings are associated with the Acheulo-Yabrudian Cultural Complex industries and demonstrate a number of specific trajectories: systematic blade production (which characterize the Amudian industry; see Gopher et al. 2005), large-scale production of Quina and demi-Quina scrapers (which characterize the Yabrudian industry; see Zupancich et al. 2016), various recycling trajectories (Parush et al. 2015), and a small-scale presence of bifaces and stone balls (Agam 2021; Barkai and Gopher 2016), the focus of our interest in this paper.

Traces of use and organic residues found on the shaped stone balls show that they were used at specific locations in the cave to break bones and extract the marrow (Assaf et al. 2020). This appearance of SSBs (representing a very ancient technology) alongside the abovementioned innovative technologies is intriguing (Barkai and Gopher 2016).

As of today, 50 SSBs were found in Qesem Cave, all of them in Amudian layers in the lower stratigraphic sequence of the cave (more than 300,000 years BP; see Figure 2). Two items were found near the fireplace

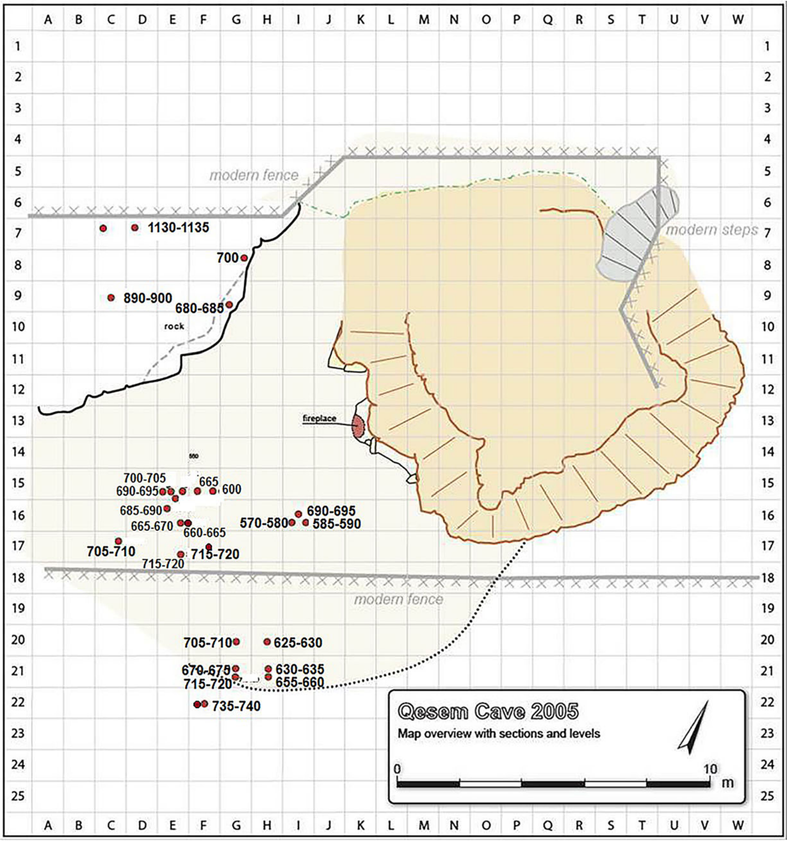

Figure 2. Location of some SSBs in Qesem Cave, including the southern parts of the cave (some items are not included in the map)

and six under the rock shelf, and several items were found in non-excavated locations within the cave, but most (n=28) were found in the southern parts of the cave. Specifically, twenty items were found in the southwest area.

The Southwest Area: SSBs and Horse Remains

The southwest area of Qesem cave originates from the upper part of the lower sequence of the cave (older than 300 ka) and yielded an Amudian (blade dominant) lithic assemblage. The area of 8.75 square metres (squares C-D-E-F 15–17) was excavated to a depth of 150 cm with a vol-

Table 1. Frequency of horse remains in the all analysed faunal assemblages of Qesem Cave (by Blasco and Rosell), prior to excavation season 2023 (provided by Blasco and Rosell for the author)

Area	Volume	Total MNI	Total NISP	*Equus* bone NISP number	NISP *Equus* bone density out of volume	N. of *Equus* individuals	% NISP *Equus* bones out of general NISP
Hearth	1.71	46	1385	71	41.52	3	5
South of hearth	2.22	39	1610	32	14.41	3	2
Rock shelf (LSBS)	1.11	25	610	9	8.11	1	1
Rock shelf (DBS)	2.3	18	552	5	2.17	1	1
Rock shelf (SCW)	4.48	20	401	3	0.67	1	1
Rock shelf (SLYBS)	2.45	13	266	4	1.63	1	2
Rock shelf (orange)	1.73	11	105	1	0.58	0	1
Rock shelf (brown)	1.81	11	134	0	0.00	0	0
Rock shelf (Yabrudian)	4.5	33	1219	4	0.89	1	0
Unit I (Yabrudian)	1.07	10	88	3	2.80	1	3
Southwest Yabrudian	1.97	20	283	11	5.58	2	4
Southwest spheroids	2.71	50	1314	61	22.51	5	5

ume of 6.125 cubic metres, consisting of soft sediments, with multiple stones indicating collapse events. Equally intriguing to the presence of 20 SSBs in this area is the discovery of 71 horse teeth (*Equus ferus*), representing at least 4 individuals in the same sequence of the cave: a unique phenomenon both in terms of frequency and due to the association with the stone balls. Table 1 illustrates the frequency of horse remains within the faunal assemblages of Qesem Cave.

While the frequency of horses in the cave in general and in the SW area is lower than that of smaller herbivores such as fallow deer (see Blasco et al. 2016), it is important to note that *Equus ferus* was much larger on average (weighing hundreds of kilos), and its marrow had, as will be explained below, unique properties. It is likely that the horse played a special role in the diet of the cave's inhabitants.

Interestingly, the horse teeth from the SW area indicated that these horses had a different diet and were mostly grazers, as opposed to the horses from other areas of the cave, such as the hearth, whose diet was based mainly on leaves (Rivals et al. 2021). As mentioned, bone marrow extraction activities using SSBs were pronounced in this area and probably aimed at horse mandibles. The SW area seems to be a distinct activity area

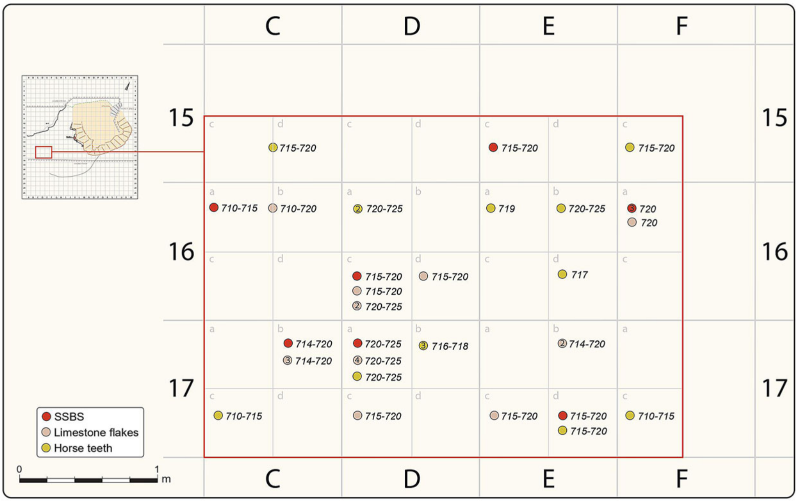

Figure 3. Distribution of the findings in the SW area: SSBs, limestone flakes and horse teeth found in the 2023 season. The number in the circle represents the number of items (a blank circle=1 item)

at a specific location of the cave that might have been used seasonally, while other areas of the cave could be used for longer durations (Rivals et al. 2021). Moreover, the horses from this area were brought from specific habitats, and this could also point to a more specific human use of this area for a dedicated purpose such as marrow extraction from horses hunted in different habitats (Rivals et al. 2021), and processed using SSBs.

Many of the SW SSBs were found in an incomplete state as a result of an old breakage rather than a post-depositional process. We associate this mainly with the production process (Assaf and Preysler 2022) and to the long "life history" of some of these items that underwent a re-shaping stage. During the excavation season of 2023, 18 limestone flakes were found in the SW area. As shaped limestone items are very scarce in Qesem in general (as opposed to flint items), we suggest that these items (or some of them) may be related to the production/re-shaping process of the balls. The map below depicts the distribution in the SW area of SSBs, limestone flakes, and horse teeth found in the 2023 season (Figures 3, 4. Flint items and other faunal remains were excluded from the map).

Another interesting point is that the modern human palm and the stone balls vary with the same pattern of proportions. Stone balls are shorter than the human palm, but display a similar range of width (Assaf et al. 2023). Attributable to their average size and morphology, the stone balls

Figure 4. The southwest area of Qesem Cave, showing 3 horse teeth (left) and a SSB (right) found during 2023 excavations

are particularly suitable for breaking bones of large-medium-sized animals such as horses. Breaking bones of megafauna would require a larger percussion tool, while breaking bones of medium-to-small sized herbivores (such as fallow deer) required less strength and precision, and perhaps a lighter, less durable implement. At the end of the LP, proboscideans were no longer present in the Levantine landscape. Medium-to-small sized herbivores were thus the focus of Levantine populations, but larger herbivores (such as *Bos, Equus* and even *Rhino*) were favoured as well, with fat being the main target (Ben-Dor et al. 2011). The findings from Qesem point to such a process (Blasco et al. 2016): there seems to be intensification in the extraction of bone marrow (as well as the development of marrow preservation techniques; see Blasco et al. 2019). This may explain the prominent presence of SSBs in Qesem Cave as tools used for marrow extraction, especially in the context of large-to-medium-sized herbivores.

The association between SSBs and horse remains at Qesem Cave raised the question of a possible similar association at other sites. The contextual analysis of this association is presented below.

SSBs and Horse Remains in the Paleolithic Record—Review of the Data

Obtaining detailed and complete data regarding the exact context of SSBs, as well as specification of *Equus* species and their context is often extremely

Table 2. African and Levantine LP sites in which SSBs were found

Site	Cultural affiliation	*Equus* species	Frequency of *Equus* bones in the assemblage	Remarks	SSBpercentage in the lithic assem blage/num ber of items/ composition	SSBs and *Equus* found in the same layer	References
Sterkfontein (South Africa)	Oldowan	Present, species not mentioned	Unknown		**6% (*n*=106)**	Yes	Kuman (1994), Willoughby (1985)
Olduvai FLK ZINJ (Tanzania)	Oldowan	Present, species not mentioned	(NISP 6% out of total NISP of faunal assemblage, **10% MNI, n=5**)	"Equids and suids are repre sented by at least 5 indi viduals in each family, while other mammalian taxa are less com mon". **Mostly teeth**	**37% of all Olduvai assemblages (*n*=596)** Quartz, quartzite lava	Yes	Bunn et al. (1986), Willoughby (1985)

Table 2. continued

Site	Cultural affiliation	*Equus* species	Frequency of *Equus* bones in the assemblage	Remarks	SSBpercentage in the lithic assem blage/num ber of items/ composition	SSBs and *Equus* found in the same layer	References
Ain Hanech (Algeria)	Oldowan	*Equus cf. mauritanicus* (large species); *Equusburchelli* (small species); *Equustabeti* (small)	11 individuals out of 24 (**46% MNI**)	"The faunal assemblage is dominated by large and medium-sized animals, **especially equids**" . Mostly teeth	**10% (n=166)** Limestone	Yes	Sahnouni et al. (1997,2002,20-13), Willoughby (1985)

Table 2. continued

Site	Cultural affiliation	*Equus* species	Frequency of *Equus* bones in the assemblage	Remarks	SSBpercentage in the lithic assemblage/number of items/composition	SSBs and *Equus* found in the same layer	References
Olduvai BED2 (Tanzania)	Developed Oldowan	Present, species not mentioned	Unknown	"…about 2900 faunal remains were also unearthed, of which Bovidae, **Equidae** and Suidae are the most abundant groups".Cut marks on horse bones	**37% of all Olduvai assemblages: (*n*=596)** Quartz, quartzite lava	Yes	Diez-Martin et al. (2009), Mora and de la Torre (2005), Willoughby (1985)

Table 2. continued

Site	Cultural affiliation	*Equus* species	Frequency of *Equus* bones in the assemblage	Remarks	SSBpercentage in the lithic assemblage/number of items/composition	SSBs and *Equus* found in the same layer	References
Olorgesailie (Kenya)	Acheulian	*Equus oldowayensis*; *Equusaff.grevi* (large species)	Unknown	…"hominids at Olorgesailie were apparently selecting giant geladas as prey in preference to the bovids, equids, and suids".	**4% (*n*=75)** Mostly basalt and lava, some quartz	**Yes**	Leakey (1948), Shipman et al. (1981), Willoughby (1985)

Table 2. continued

Site	Cultural affiliation	*Equus* species	Frequency of *Equus* bones in the assemblage	Remarks	SSBpercentage in the lithic assem blage/num ber of items/ composition	SSBs and *Equus* found in the same layer	References
Isimila (Tanzania)	Acheulian	*Equus burchelli*	Unknown		**14% (*n*=237)**	**Yes**	Cole and Kleindienst (1974), Willoughby (1985)
Hummal (Syria)	Oldowan	Present, species not mentioned	**17%** NISP out of total NISP of faunal assemblage		***n*=12**	**Yes** (layers 17–18)	Le Tensorer et al. (2011)
Latamne (Syria)	Acheulian	*Equus* sp.; *Equus.cf. altidens* (small)	Unknown	A number of teeth	Present, num- ber not mentioned (Limestone, basalt)	**Yes**	Clark (1966)

Table 2. continued

Site	Cultural affiliation	*Equus* species	Frequency of *Equus* bones in the assemblage	Remarks	SSBpercentage in the lithic assemblage/number of items/composition	SSBs and *Equus* found in the same layer	References
Ubeidiya(Israel)	Acheulian	*Equusprzewalskiigmel; Equuscaballus* (large)	**2%MNI** ($n=2$)	The hominins "… regularly focussed on horses and cervids"	**18% ($n=246$)** Limestone (94%), flint (6%)	**Yes** (layers 23–24)	Eisenmann (1986), Shea and Bar-Yosef (1999), Bar-Yosef and Goren-Inbar (1993), Gaudzinski (2004)
North Bridge Acheulian(Israel)	Acheulian	*Equus cf. africanus*	**$n=1$ NISP out of 23 identified bones**		**$n=12$,** found in situ but in a non-excavated area (limestone n=6, basalt $n=3$)	**Yes**	Sharon (2010)

Table 2. continued

Site	Cultural affiliation	*Equus* species	Frequency of *Equus* bones in the assemblage	Remarks	SSBpercentage in the lithic assemblage/number of items/composition	SSBs and *Equus* found in the same layer	References
Evron(Israel)	Early Acheulian	*Equus cf. tabeti*	Unknown	Upper molars	***n*=3(7%)** Limestone	**Yes**	Shemer et al. (2019), Tchernov et al. (1994)
Revadim Quarry(Israel)	Late Acheulian	*Equus* sp.	**MNI 2%**		***n*=4**Limestone, flint	**Unknown.** SSBs found in area D; the fauna of this area is not published	Rabinovich et al. (2012), Marder et al. (2007)
Qesem Cave (Israel)	Acheulo-Yabrudian	*Equus ferus* (large); *Equushydruntinus* (small)	**11% (MNI)**	Only teeth, mostly mandibular	***n*=30**probably limestone, 1 flint item	**Yes**, 11 spheroids found in the southwest area with 57 horse teeth	Blasco et al. (2014, 2016), Barkai and Gopher (2016)

Relevant data regarding horse remains are described challenging, as many of these sites were excavated long ago, and many details were not recorded.

Table 2 lists the African and Levantine LP sites where SSBs were found. Information regarding the presence of horses at each of these sites is also provided.

For many sites, it is impossible to closely examine the spatial distribution of the findings. However, in all the sites, SSBs and horse remains appear at the same level, except Revadim, for which relevant data are absent. In most of these sites, SSBs are made of carbonate rock, with FLK, Bed 2, and Olorgesailie being exceptions (in which quartz and basalt and lava prevails). All the sites listed in Table 2 include both small and large species of horses, comprising between 2 and 46% MNI of the total faunal assemblage (usually 11–17%). In several sites, horse teeth and mandibles notably appear (FLK, Ain Hanech, Latamne, NBA, Qesem Cave, Evron). It is important to note that all sites in the Levant at which SSBs were found do include horse remains in the same layer.

Several other African and Levantine LP sites are not discussed here because although they include horse remains, they do not include SSBs. In fact, horse remains appear in most LP sites in various frequencies, indicating that these animals formed a rather consistent part of humans' diet. In the Levant, at some early and late LP sites, large herbivores such as horses were mainly targeted. Some sites seem to be located in areas where horse/zebra/steppe ass formed the principal attraction (see Deves et al. 2014 and therein). Breakage patterns indicating marrow extraction from horse bones were observed in Gesher Benot Ya'aqov and 'Ubeidiya (Gaudzinski 2004; Rabinovich and Biton 2011). While the frequency of horses is sometimes lower than that of smaller herbivores, (as in the case of Qesem), the substantially larger average size of the horse and its unique nutritional properties probably attest to their specific place in the LP diet.

All of this changes in the Levantine Middle Paleolithic period (Table 3): At some sites, no large horses are found (e.g. Missliyah, Adlun, Shanidar; see Griggo 2004; Rabinovitch and Hovers 2004; Roe 1983; Yeshurun et al. 2007); at some sites, small equids appear but with low frequency of 0.3–0.5% or 2% of the assemblage (e.g. Amud, Hayonim; Dederiheh, Kebara; see Griggo 2004; Speth and Clark 2006; Stiner and Bar-Yosef 2005; Tchernov 2002); and at other sites unidentified horse species appear, also with low frequency (e.g. Dederiheh, Kebara). Speth and Clark (2006) report that equids are very rare at Kebara. Stiner and Bar-Yosef (2005:123) write that "members of the equidae are rare in the Wadi Meged series, but two species are represented". Several researchers have mentioned a possible reduction in horse size in the MP and a decreased frequency in the faunal assemblages. Davis mentions a reduction in horse numbers which might be related to an encroachment of forest and linked reduction of open grass-

Table 3. Horses in Levantine MP sites

Site	Species	Frequency	References
Amud	*Equus assinus*	N. of NISP=1, frequency=0.5%	Griggo (2004), Kolska Horwitz and Hongo. (2008)
Hayonim cave	Not mentioned	0.5%	Stiner and Bar-Yosef (2005), Tchernov (2002)
Kebara	*Equus* spp. (unidentified); *Equus caballus; Equus asinus; Equushydrunti*	2% NISP	Speth and Clark (2006),
Misliya	No horses	None	Yeshurun et al. (2007)
Qafzeh	*Equus caballus; Equushydrunti; Equustabeti africanus*	5%	Tchernov (2002)
Dederiyeh	*Equus* sp.*; Equus caballus; Equus africanus*	0.2–0.4% out of n. of ungulate remains	Griggo 2004
Adlun	No horses	None	Griggo (2004)
Shanidar	No horses	None	Griggo (2004)
Douara cave	*Equus* sp.	8% out of n. of ungulate remains	Griggo (2004)
Umm El Tlel	*Equus* sp.	9–70% out of n. of ungulate remains	Griggo (2004)
Nesher	*Equus caballus; Equus asinus*	NISP 7%	Zaidner et al. (2014)
Rantis	No horses		Marder et al. (2011)
Geula cave area D	*Equus* sp.	NIPS 1%	Barzilai et al. (2022)

land, and "a concomitant reduction of equids and possibly a greater degree of field butchering of gazelle" (Davis 1977:163). In another paper, he writes "In the Lower Mousterian levels of Tabun and Djebel Qafzeh, the morphologically hydruntinus-like teeth were larger than those of *hydruntinus* from post-Lower Mousterian times" (Davis 1980:311). Eisenmann (1992) mentions a mere diminution of size in the "zebra" lineage during the MP. In Tabun cave, there is a decrease in *Equus ferus* remains between the LP (layer E) and MP (layer C) layers (Garrard 1982). Exceptions to this trend do exist: in Nesher, Douara cave and Umm El Tlel horse remains were documented in relatively high numbers (7%), although the exact species is unknown. However, the overall tendency in the Levant region seems to be a decline of large horses and a diminution of the medium size equids. This tendency is further demonstrated in Table 3, which lists the main MP sites in the Levant for which relevant faunal information is provided. To the best of our knowledge, no SSBs have been found in MP sites in the Levant.

Thus, I submit that SSBs belonged to the large- and medium-sized fauna world of the LP. Over time, a reduction in animal size (a universal phenomenon in general; see Dembitzer, et al. 2022) might explain their replacement by other technologies and smaller implements (Ben-Dor and Barkai 2023).

Meanwhile, in Africa, horses continue to appear in the MSA record (at frequencies of 6–12% and higher, Table 4). At some sites, horse remains were found in association with SSBs. At Kalkbank, SSBs were found in a layer that also had "relatively high numbers of pig and equid teeth" (Mason et al. 1958; Walker 2008). At the Mousterian site of El Guettar, Tunisia, more than 60 limestone balls were found in a pile, with "a remarkable selection of animal bones and teeth (especially equid teeth)" (Aouadi-Abdeljaouad and Belhouchet 2008; Walker 2008). The association between the two certainly raises questions and might be considered, as Walker (2008:16) stated, "evidence of modern-like behaviour in a belief system involving spherical stones, water and probably specific animals".

Following functional analyses of SSBs and extensive experimental work conducted in recent years, we have suggested elsewhere that the development of SSBs by *Homo erectus* (sensu lato) in the LP was related to the growing need for dietary fat. Extracting this desirable fat from large-to-medium-sized herbivores required efficient, durable tools (Assaf et al. 2023). The horse and horse fat were an essential part of early humans' diet, and for several very good reasons.

The Nutritional Value of Horsemeat and Its Significance to Paleolithic Humans

As the human brain became larger, fat (from both plant and animal resources) played a vital role in the evolution of the human body structure, supporting many biochemical functions, assisting in providing the ingredients for the building up of cells and maintaining their structural integrity in tissues, including the brain and other internal organs (Ben-Dor et al. 2021; Roccisano et al. 2016). The need to consume animal fat is the result of the physiological ceiling on the consumption of protein and plant foods (Ben-Dor et al. 2011, 2021). Obligatory animal fat consumption turned the large prey preference of *Homo erectus* into dependence. The archaeological data support this premise, indicating that *H. erectus* and other archaic spe-

Table 4. Selected African MSA sites which include SSBs

African MSA/Mousterian sites	Equus species	Frequency in faunal assemblage	Remarks	SSBs	SSBs and horse remains in the same layer	References
Kalkbank (South Africa, MSA)	*Equus capensis; Equusburchelli*	**24%** (MNI)	"…Especially crania (there are relatively high numbers of pig and equid teeth (79%) compared to postcranial bones which are dominated by bovids (88%)"	(Made of Quartz and quartzite)	Yes	Mason et al. (1958), Walker (2008)
Florisbad (South Africa, MSA)	*Equus capensis; Equus burchelli*	**Unknown**		Yes	Yes	Kuman et al. (1999)
El Guettar (Tunisia, Mousterian)	Unknown	**41.3%**, percentage of each taxon (total identified=172)	"A remarkable selection of animal bones and teeth (especially equid teeth) were stacked up against the pile.El Guettar: Bones of equids and bovids are dominant"	More than 60	Yes	Aouadi-Abdeljaouadand Belhouchet (2008), Gruet (1955), Walker (2008)
Tsodilo (South Africa, MSA)	*Equus* spp.; *Equus capensis; Equusburchelli*	**6%** (MNI)		Yes	Unknown	Robbins et al. (2000), Walker (2008)

Information regarding horse remains is provided cies living in Africa, the Levant and Europe consumed large proboscideans (Agam and Barkai 2016, 2018; Barkai 2021; Plummer et al. 2023), but other taxa like *Bos*and *Equus* also played a significant dietary role.

Although equine meat is characterized by low fat and low cholesterol content, with a lower marrow yield than other large animals, especially at certain times of year, their heads and mandibles contain very stable and predictable fat reserves. The lower bone density of the mandibles also makes them relatively easier to break (Blasco, personal com.).These parts of the horse are thus an essential food resource (Pryor 2008) and might also explain the high frequency of mandibular horse teeth at Qesem Cave and other LP and MSA African and Levantine sites (as seen in Tables 1, 3). The chemical constitution of the marrow also differs from that of most other ungulates; it is a good source of polyunsaturated acids such as oleic and α-linolenic acids, which makes the marrow far more liquid (Badiani et al 1997; Erasmus 1986; Hilditch and Williams 1964; Mead et al. 1986). These acids occur abundantly in grass, and ruminant ungulates (unlike horses) turn them into their saturated forms during digestion (Erasmus 1986; Mead et al. 1986). The oleic and linolenic acids are considerably healthier to consume than the large quantities of saturates found in most animals' marrow. They can help, for example, to prevent coronary heart disease (Mead et al. 1986; Outram and Rowley-Conwy 1998) and could contribute to fulfilling the daily needs of omega-3 for hominins (Guil-Guerrero et al. 2013). Moreover, horse marrow oil has a stronger antioxidant activity compared to sheep, bovine, and camel and exhibits significant antimicrobial activities (Rozi et al. 2018).

The percentage of subcutaneous and body cavity fat (which can be easily trimmed off) in a horse carcass is also higher than in a bovine carcass of the same weight and overall fat content, with a lower percentage of intermuscular and intramuscular fat (Rossier and Berger 1988), giving it further dietary advantages. Moreover, despite horse meat having a higher collagen level than beef in the same muscles, sensory trials have found horsemeat to be more tender (Rossier and Berger 1988). It also has a favourable fatty acid profile, with a high content of unsaturated fatty acids relative to saturated acids (Lorenzo 2013). It contains some macro and trace elements (magnesium, phosphorus, iron, zinc, and copper) and some water-soluble vitamins (niacin and pyridoxine; see Badiani et al. 1997).

Ruminant, "polygastric" mammals hydrogenate fat during digestion, and therefore lack significant amounts of essential omega-3 fatty acids in their fat reservoirs (Noble 1978). Monogastric, "single-stomached" mammals (i.e. horses, elephants, rhinos, bears, mammoths, and woolly rhinos) accumulate fat without hydrogenating it, as they consume it. Therefore, they provide better quality nutrients for hominins, since these nutrients, omega-3 fatty acids, are essential for development, especially to nourish the brain (Simopoulos 2011).

The nutritional qualities probably explain the notable presence of horse remains in African and Levantine Paleolithic sites. Although an in-depth analysis of European sites is beyond the scope of this study, it is worth mentioning that horses are significantly present in several LP contexts where humans clearly preferred horse meat in their diet. The Schöningen site in Germany is a famous example of a horse butchery site, in which more than 50 individual horses were found (the large species *Equus mosbachensis*), represented by ribs, long bones, and mandibles, many of them bearing cut marks and impact marks (including breakage of mandibles to extract the marrow, Batler 2014; Van Kolfschoten et al. 2015). Another example is Boxgrove, UK (GTP17), where a horse butchery area was identified. These horse remains exhibited evidence of wounds from both bone breakage and projectile impact (Pope 2003). The unique nutritional value of horsemeat compared to other animals, especially in the marrow itself, might explain its notable presence in many Paleolithic sites around the world.

Discussion

Relationships such as the one between humans, SSBs, and horses are not necessarily unique, although each such relationship between human, stone, and other-than-human persons arose for its own unique reasons. Such relationships have been hypothesized to have existed throughout the Lower Paleolithic. Humans, proboscideans, and handaxes are one salient example (Barkai 2021); humans, fallow deer, and laminar items are another (Assaf 2021).

We have proposed that shaped stone balls were developed by Lower Paleolithic humans to assist with their growing need for fat and the need to extract it efficiently (Assaf et al. 2023).Used for almost 2 million years, these tools exhibit several universal, recurrent characteristics, most notably their distinctive spherical morphology. A round shape is especially suitable for intensive percussion activities such as bone breaking, as it concentrates the force and makes the implement harder to break. Furthermore, a round shape is a cross-cultural preference, even in great apes. Preference for curved over sharp-angled lines is grounded in human perceptual and cognitive mechanisms, and it may have played an adaptive role throughout human evolution (Gómez-Puerto et al. 2016; Munar et al. 2015).

The use of carbonic rock for the shaping of SSBs enabled the formation of the spherical morphology and the intersecting ridges. Selectivity in rock type was observed in several Lower and Middle Paleolithic sites (Agam

2021; Bar-Yosef and Goren-Inbar 1993; Belfer-Cohen and Goren-Inbar 1994; Braun et al. 2009; Goldman-Neuman and Hovers 2009; Stout et al. 2005; Wedage et al. 2019), and it is usually said to have a "practical" explanation. Indeed, shaping the carbonatic rock in a spherical outline makes it efficient for the extremely important task of marrow extraction.

Fat and bone marrow played a critical role in the diet of prehistoric and contemporary hunter-gatherers (Ben-Dor et al. 2021; Outram 2002; Plummer et al. 2023; Speth 1983), and their extraction and use also played a significant role in the perceptional world of these people. Among Arctic societies, every part of a hunted caribou is used: antler, fur, meat, fat, sinews, bone fat, and bone marrow. The tradition of the marrow fracturing of the bones is part of an economic strategy and a perception of "nothing is wasted" (Pasda and Odgaard 2011).

Among non-Western, non-industrial societies, tools, and specifically those used for meat processing and fat extraction often hold significant cosmological meaning (Barkai 2021; Tanner 2021). From an ontological point of view, one might say that giving shape to such a tool also empowers it. Tools are perceived as a bridge, a reflection of perceptions of meat processing and the relations with non-human animals transmitted over generations(Arthur 2018; Hendon 2017; Hollenback and Schiffer 2010; Ingold 2000). Among many non-Western, non-industrial societies every element of the natural world has an essence, a soul, including trees, animals, stones, and stone/bone tools; they are personified as and when engaging with them (Naveh and Bird-David 2014). Tools are produced and used by humans to process and consume different elements (beings): animals, stones, plants. The continuous use of these tools creates and preserves traditions that embody human relationships with these 'object-beings' that are designed to enable socio-cultural relations with the world (McNiven 2018). The materials used in daily activities are thus not seen as passive resources to be exploited for economic benefit. Stones and bones are seen as playing an active role in the spheres of social and cosmological life. The materials from which tools are made reflect important aspects of these relationships, such as respectful behaviour towards one's prey (Tanner 2021). The specific shape of a tool is also imbued with ontological meaning, as is the colour of the material from which it is made (Arthur 2018; Brumm 2010;Reimer 2018; Taçon 1991, 2008; Tanner 2021). The material, shape, and colour of a tool might also be selected in association with the specific anatomical parts that it is used to process, and not just for its functional efficiency in processing the meat of the specific animal. Among the Innu, for example, white flint is specifically selected for tool making, as it resembles the colour of caribou fat (Tanner 2021). I thus suggests that SSBs embody ontological perceptions formed and transmitted throughout the Lower Paleolithic, reflected in shape, rock type selection, spatial distribution at sites, and association with a specific animal—the horse, and a specific body element (mandible).

The deep connection between humans and horses is well reflected in the Paleolithic record from its earliest stages, a connection that extends well beyond the geographical and chronological scope of the Levant and Africa that are the primary focus of this paper. Tools (retouchers) made of horse bones were found as early as the LP period, in Boxgrove, UK (Pope et al. 2020), Schöningen GE (Van Kolfschoten et al. 2015), and in the LP-MP site of Payre FR (Daujeard et al. 2014). In Swartkrans SA, a horse mandible was used as a digging tool (Shipman 2001). Much can be said about the cosmological significance of turning an animal bone into a tool, with which an animal is dismembered, its meat processed, or its marrow extracted (Assaf and Romagnoli 2021; Barkai 2021; Hill 2011).

This deep human–horse relationship is present visually in later periods in Europe. A sharp increase in the presence of horses at archaeological sites indicates these animals were the main prey species for Aurignacian people along with reindeer (Hussain and Floss 2015). Horses were the most commonly depicted animal, painted, sculpted, modelled, and engraved at many UP sites (Pigeaud 2007). These representations reflect deep knowledge of the physiology and lifeways of the horse as a social animal. The horse head was given special focus, as were mandibles, tongue bones, and teeth. An engraved mandible was found in Kendrick's Cave UK and in Arcy-sur-Cure FR six incised horse mandibles were found. At Duruthy rockshelter FR, 23 mandibles, some of them engraved, were found in association with horse sculptures (Birouste et al. 2016). A horse skull was discovered in La Garma (Cantabria, Spain), attributed to the late Magdalenian. It had undergone special treatment with the removal of several elements including the maxillary, nasal, frontal, and parietal bones and the incisors, as well as the opening of the cerebral cavity (Arias et al. 2011). In multiple Magdalenian sites "contours découpés"—representations of a horse head 'cut' from a thin piece of the horse tongue bone (stylohyid)—were found (Buisson et al. 1996:100; Cattelain and Bellier 2014;Leroi-Gourhan 1968). Horse heads were also depicted on spear throwers (e.g. at Teufelsbrücke and Thuringia DE, Braun 2018). In Erberua FR, more than half of the animal images in the iconographic complex depict horses. Installations consisting of stones were found arranged in a circle, close to the wall decorations. Objects were identified in the centre of one of the installations, including a horse's tooth (Larribau and Prudhomme 1989).

Beyond the intimate human–horse bond reflected in these representations, they embody the attachment to specific elements of the horse: the skull, mandible, teeth, and tongue. These elements are also dominant in European UP faunal assemblages (e.g. Biśnik Cave, Vogelherd Cave and others, see Niven 2007; Van Asperen and Stefaniak 2011) probably due to the nutritional aspects mentioned above. It has been argued that processing of the horse skull, mandible, and teeth might also reflect the wishes of Paleolithic humans to connect with the interior self of the horse (Birouste et al. 2016). Among non-Western, non-industrial societies, social relationships and the responsibility to create 'trust' and 'reciprocity' often include special treatment of prey remains, especially skulls, to ensure spiritual renewal (McNiven 2018). The skulls are used as amulets for hunting or as offerings (Tanner 2021), and a significant part of the evidence for the ritual use of bones from hunted animals concerns the skulls, which house the main sensory organs of sight (eyes), hearing (ears), smell (nose), and taste (mouth). In many hunting societies, animals are seen as voluntarily presenting themselves to the hunters as prey (Hill 2011; Nadasdy 2007; Tanner 1979, 2021). Apart from the nutritional aspect, the act of beheading the horse might have been related to a shamanistic practice, with the removal of the head intended to release the animal's spirit. Horses represent ideal shamanistic totems and liminal agents on account of their ability to travel distances, necessary for journeying to the afterlife and communicating with entities in other worlds; this characteristic also makes them attractive spirit guardians (Lepp 2004). The deep meanings of Upper Paleolithic European practices certainly deserve their own research. I will say, though, that they highlight the importance that Paleolithic humans attributed to horses and especially to horse skulls and mandibles, a relationship whose roots lie in the LP, and perhaps in the unique nutritional role horses (and horse mandibles) played in the early human diet.

It is important to note that the specific nature of human–horse relations probably changed over time and in different environments, and was expressed differently in different contexts. Therefore, I do not aim to fully understand the essence of this relationship. I would like to direct the spotlight to the ancient roots of human–horse relations in the LP, and propose that some aspects of these relations were also reflected in the stone tools used to extract fat from these animals. Ancient humans aimed to extract meat and fat from large-to-medium herbivores and horses in particular in an optimal way. The stone balls, as one of the tools that made it possible, served as a stable cultural anchor throughout the LP and MSA, even when other technologies disappeared and new ones developed. This embodiment, 'set in stone', allowed the tradition of using this tool to last for such a long time.

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