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Édité par Aline AVERBOUH & Marjan MASHKOUR

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Red deer (*Cervus elaphus* Linnaeus, 1758) antler exploitation strategies and technical skills among Neolithic and Transitional Chalcolithic communities of the Iranian Plateau

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ABSTRACT
On the Iranian Plateau, prehistoric societies have utilized red deer antler to manufacture tools since at least the Middle Paleolithic. Following a period of intensive use during the Upper Paleolithic, the exploitation of antler material generally declined in the Neolithic, coinciding with the emergence of domestic practices and the increased availability of osseous materials derived from domesticated animals. Nonetheless, antler remained a significant component of material culture, providing key insights into the evolving relationship between early agropastoral communities, wild fauna, and their broader environment throughout the Neolithic period. However, antler productions remain insufficiently studied, both from morpho-typological and techno-functional perspectives on the Iranian Plateau, a region of strategic importance for understanding the processes underpinning the emergence and diffusion of domestication. As part of the EXAMS project, we undertook the first comprehensive inventory of antler tools associated with Neolithic/Transitional Chalcolithic communities in Iran. This paper outlines the preliminary results of this research, along with initial data from the techno-functional analysis of assemblages recovered from three key Neolithic sites: Tepe Abdul Hosein, Tepe Sang-e Chakhmaq, and Tepe Zagheh.

KEY WORDS
Worked hard animal material,
Red deer antler productions,
osseous technology.

RÉSUMÉ
*Stratégies d'exploitation des bois de cerf (*Cervus elaphus *Linnaeus, 1758) et compétences techniques des communautés du Néolithique et du début du Chalcolithique du Plateau iranien.*
Sur le Plateau iranien, le bois de cervidé a été une matière première utilisée par les sociétés préhistoriques au Paléolithique moyen. À la suite d'une période d'exploitation plus intense au cours du paléolithique supérieur, elle décline au cours du Néolithique, coïncidant avec l'émergence des pratiques domestiques

et la disponibilité accrue des matières osseuses issues d'animaux domestiqués. Néanmoins, les bois de cervidés sont restés un élément important de la culture matérielle, fournissant des informations clés sur l'évolution des relations entre les premières communautés agropastorales, la faune sauvage et leur environnement au cours de la période néolithique. Or la production de bois de cervidés reste insuffisamment étudiée, tant du point de vue morpho-typologique que techno-fonctionnel sur le Plateau iranien, région d'importance stratégique pour comprendre les processus qui ont sous-tendu l'émergence et la diffusion de la domestication. Dans le cadre du projet EXAMS, nous avons entrepris le premier inventaire complet des outils en bois de cerf associés aux communautés néolithiques/chalcolithiques de transition en Iran. Cet article présente les résultats préliminaires de cette recherche, ainsi que les premières données issues de l'analyse techno-fonctionnelle des assemblages récupérés sur trois sites néolithiques clés : Tepe Abdul Hosein, Tepe Sang-e Chakhmaq et Tepe Zagheh.

MOTS CLÉS
Matières dures animales travaillées, productions en bois de cerf, technologie osseuse.

INTRODUCTION

This study aims to characterize human-animal relationships by focusing specifically on red deer (*Cervus elaphus* Linnaeus, 1758) and the role of antler as a raw material within the craft production systems of Neolithic and early Chalcolithic pastoral communities in Iran. During the Middle and Upper Palaeolithic red deer was exploited in many sites of the Iranian Plateau (Mashkour & Davoudi 2024). Its significant decline during the Neolithic may be due in large part to the development of domestic economies and the increased availability of bone materials from domesticated species along with regional environmental changes.

In this article, we focus on the study of deer antler as a raw material that has been worked and transformed into objects, an approach that remains underdeveloped in Southwest Asia. To address this gap, we conducted a detailed technological analysis of antler remains from three Neolithic sites –Tepe Abdul Hosein, Tepe Sang-e Chakhmaq, and Tepe Zagheh– spanning a chronological range from the Pre-Pottery Neolithic to the Final Neolithic/Early Chalcolithic (Fig. 1). It is also worthy to note that the two first sites are regularly debated for their role in the origins and spread of domestication in the Zagros and in the North East of Iran and Central Asia (Harris 2010; Roustaei & Mashkour 2016).

In the Iranian Plateau, Neolithic sites are found in the highland as in the lowlands, along the Zagros and the Alborz Mountain regions (Mashkour & Davoudi 2024). The role of wild herbivores namely, wild goat (*Capra aegagrus* Erxleben, 1777) and sheep (*Ovis aries* Linnaeus, 1758), gazelles, equids and cervids is important in the subsistence economy and cultural practices of these communities (Zeder 2008; Zeder & Hesse 2000).

The exploitation of wild fauna on the Iranian Plateau during the Neolithic period reflects the adaptive strategies employed by human groups in response to the progressive transformation of their economic systems (Mashkour & Yaghmayi 1998). While the domestication of animal species played a central role in shaping these societies, the continued practice of hunting cervids, wild caprines, and suids reveals a complementarity between wild and domestic resources. These hunting activities, possibly also seasonal, not only contributed to dietary diversification but also enabled the procurement of raw materials essential for craft production and tool manufacture.

Based on a synthesis of palynological and geochemical records in the Zagros, a notable climatic amelioration, compared to the Last Glacial Maximum (LGM) with cold and arid climatic conditions, occurred at *c.* 14 500 cal BP, characterized by a slight increase in temperature and precipitation, although arid conditions generally persisted (Van Zeist & Bottema 1977; Djamali *et al.* 2008; Wasylikova *et al.* 2008). Forests began expanding marginally during the Late Glacial Interstadial, temporarily regressed during the Younger Dryas, and underwent renewed expansion in the Early Holocene. From *c.* 9000 BC onward, a mosaic of deciduous pistachio-almond scrub and open steppe characterized the landscape, culminating in the widespread development of oak woodlands by the Middle Holocene (*c.* 4500 BC), likely driven by a reorganization of precipitation seasonality (Djamali *et al.* 2010; Safaierad *et al.* 2023).

In contrast, the central Alborz mountains present a different vegetational trajectory, as indicated by the sole long pollen record for the region spanning the last 20 000 years (Ramezani *et al.* 2023). Forest expansion during the Late glacial Interstadial was more pronounced in this region than in the Zagros, while the Early Holocene witnessed an immediate spread of oak forests in contrast to the delayed expansion in the Zagros. This discrepancy is attributed to the proximity of the Alborz to the Hyrcanian forest refugium, facilitating more rapid recolonization. Consequently, forested landscapes have characterized the Alborz highlands since the onset of the Holocene.

According to the current available data presented above, local climatic fluctuations documented throughout the Neolithic in the Zagros and the Alborz regions and the central regions of the Iranian Plateau, likely influenced species distribution and the configuration of ecological niches (Mashkour 2002: fig. 10). The transition toward more arid environmental conditions may have compelled human groups to reorient their strategies for acquiring faunal resources, thereby promoting an increased reliance on domestic animals and a gradual

Fig. 1. — Location of the studied sites.

decline in hunting practices. However, hunting was never entirely abandoned; cervids and other wild taxa continued to be exploited and sought after for economic and symbolic reasons (Mashkour *et al.* 2021).

The use of hard animal materials in Neolithic craft industries attest to both technical expertise and a nuanced management of available resources (Manca *et al.* 2021, 2022). While osseous materials belonging to cervids (bone and antler) and other wild herbivores were employed in the manufacture of tools, ornaments, and symbolic objects, their use declined progressively over time, in favor of bones sourced from domesticated species. This shift appears to reflect the growing accessibility of such materials and a broader rationalization of craft practices. Nevertheless, antler exploitation persisted in certain contexts, particularly for objects requiring specific mechanical properties – such as hide-working implements or agricultural tools.

Several questions remain regarding the economic and technical dynamics of these Neolithic/transitional Chalcolithic communities:

– What proportion of labor was allocated to agricultural activities in comparison to hunting and the procurement of animal raw materials?

– To what extent did seasonality affect the collection of shed antlers and their incorporation into production cycles?

– How did technical procedures for transforming animal materials persist or evolve over the course of the Neolithic and the following period?

These questions, which will be addressed in the discussion and concluding remarks, offer valuable insights into the interactions between Neolithic societies, their environments, and the strategies they employed to adapt to changing ecological and economic conditions.

ARCHAEOLOGICAL AND ENVIRONMENTAL CONTEXTS

Tepe Abdul Hosein: an archaeological site in the Zagros mountains

Situated at an altitude of 1860 meters, Tepe Abdul Hosein, is a small artificial mound (Tepe) measuring approximately 50 meters in diameter and rising to a height of six meters, located in the Luristan province in the heart of the Zagros Mountain range.

The sited is sheltered on the north, south, and east by the ridges of the Kuh-i-Garrin range, while the western side remains open. The site lies within the fertile valley of Ab-i-Qishlaq, an area known for the extensive cultivation of wheat. Numerous perennial streams traverse the valley and, during the spring, swell into torrents that require bridges for passage. Although J. Pullar did not visit the site during winter, she noted that it is likely cut-off during that season due to significant snowfall in the surrounding hills, even if the site itself is not directly snow-covered. In the modern times local tribal communities wintered in camps in the proximity of the site, while villagers maintain a permanent presence throughout the year.

Excavations were conducted at Tepe Abdul Hosein in 1978 under the direction of J. Pullar (1990). Ten test trenches measuring either 4×4 meters or 4×2 meters were opened, although only three were excavated to the natural substrate – two partially (7-H and 10-G), and one completely (9-G).

Radiometric dates obtained by J. Pullar (1990), despite their large standard deviations, as well as more recent radiocarbon analyses conducted on faunal samples by Y. Nishiaki (2023), indicate two distinct phases of occupation separated by a marked hiatus. The initial aceramic phase (Early Pre-Pottery Neolithic [EPPN]) has been dated between 7200 and 7000 BCE, while the later aceramic phase (Late Pre-Pottery Neolithic [LPPN]) spans from 7000 to 6500 BCE. (Pullar 1981, 1990; Broushaki *et al.* 2016; Daly *et al.* 2018, 2021). A subsequent ceramic phase, corresponding to the Early Chalcolithic (EC), has been dated to the 5th millennium BCE.

Tepe Sang-e Chakhmaq: a key Neolithic site in Northeastern Iran

Tepe Sang-e Chakhmaq, in the Semnan province, is located at the outskirt of the modern city of Shahrud city at an elevation of 1400 meters. Nestled within a rugged network of high peaks, the site is located near north-south mountain passes accessible only by foot – some of which lead to the Caspian Sea. This setting is particularly favorable due to the presence of numerous springs emerging from the edge of an alluvial fan and constituted a critical resource for the early farming communities that settled on the southeastern slopes of the Alborz Mountains in northern Iran. In the early 1970s, a Japanese archaeological mission led by Seichii Masuda carried out excavations on several trenches across the eastern and western mounds of the site (Masuda 1974, 1994; Masuda *et al.* 2013). More recent investigations, including test pits by Kourosh Roustaei, have helped to refine the stratigraphic and chronological framework of the material culture of the site (Roustaei *et al.* 2015).

The western mound corresponds to a Pre-Pottery Neolithic occupation, dated from the late 8th to the early 7th millennium cal. BCE. In contrast, the eastern mound contains ceramic levels dated from the late 7th to the mid-6th millennium cal. BCE (Nakamura 2014; Roustaei *et al.* 2015).

Tepe Sang-e Chakhmaq is a key Neolithic site providing the earliest evidence of agriculture and animal husbandry in northeastern Iran, as well as of the diffusion of the Neolithic way of life into Central Asia (Harris 2010; Roustaei *et al.* 2015).

Tepe Zagheh: a major Late Neolithic/transitional Chalcolithic site on the Qazvin Plain

The Qazvin Plain is a vast basin measuring about 120 km from east to west and 80 km from north to south. It can be divided into two distinct zones: the mountainous northern section, which includes the areas of Alamut, Roudbar, and part of Kouhpaye, and the alluvial plain. This northern region is framed by the Alborz Mountains extending from the northwest. The valleys descending from the Alborz are steep and arid, with snowmelt from the southern slopes draining into the Shahrud River, which eventually feeds into the Sefid Rud to the northwest.

The climate of the Qazvin region is continental, marked by harsh winters and hot summers, with significant variation between the mountainous areas and the plain. Today, agricultural and pastoral activities are still practiced in several areas of the region.

Tepe Zagheh is a low, nearly circular mound, with its highest point rising barely 50 cm above the surrounding plain and extends at approximately 15 000 m². Excavations revealed two types of ceramic production: the older, locally produced Tepe Zagheh ware, and the Cheshmeh Ali ware from the west. The site was initially excavated under the direction of Ezat Negahban between 1970 and 1972 (Negahban 1977, 1979) and subsequently investigated by S. Malek Shahmirzadi from 1972 to 1973 as part of his doctoral research (Malek Shahmirzadi 1977, 1990). The site was reinvestigated during several other excavations campaigns (Mollah Salehi *et al.* 2006; Fazeli Nashli *et al.* 2009).

Tepe Zagheh is dated to the late Neolithic/transitional Chalcolithic, spanning from the end of the 6th to the beginning of the 5th millennium BCE (Mashkour *et al.* 1999; Mashkour 2001; Fazeli Nashli *et al.* 2009). The discussed worked antlers here belong to the earliest excavations pre-dating the Iranian Islamic Revolution on 1979.

General remarks on these excavations

As exposed above, the material recovered from the three sites may have been affected by intrinsic differences in the circumstances of excavations. First all, these excavations were carried out more than fifty years ago, and some data may have been lost either in the documentation process or in the long-term conservation of the faunal remains. Secondly, the duration and extent of the excavations varied considerably. Tepe Abdul Hosein was investigated during a single campaign, in which only ten 4×4 meter squares (trenches) were opened. By contrast, Tepe Sang-e Chakhmaq was excavated over three sea-

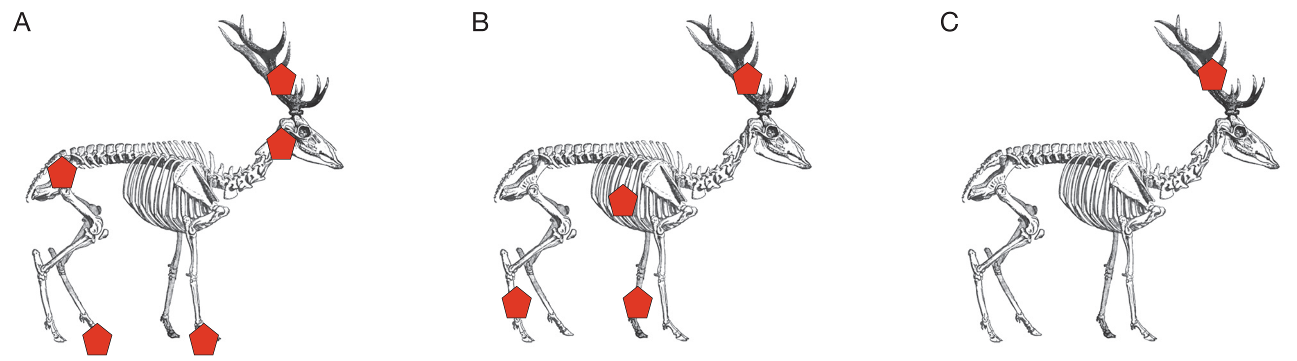

Fig. 2. — Representation of red deer (*Cervus elaphus* Linnaeus, 1758) body parts remains found in: **A**, Tepe Abdul Hosein; **B**, Tepe Sang-e Chakhmaq; **C,** Tepe Zagheh.

sons, during which extensive areas were exposed. Finally, Tepe Zagheh, one of the three sites of the Qazvin Plain, was used as a training ground for archaeology students from the University of Tehran. Excavations there, conducted between 1970 and 1973, included a large central trench together with several test trenches, covering an area of more than 40 m². Among the three sites, the best-preserved and most thoroughly documented material comes from Tepe Abdul Hosein, followed by Tepe Sang-e Chakhmaq. In contrast, the material from Tepe Zagheh has suffered from significant conservation issues, as discussed by Mashkour (2001). Consequently, the representativeness of the antler remains may not accurately reflect their original presence and distribution within these sites.

FAUNAL ASSEMBLAGES AND THE ROLE OF RED DEER IN THE ECONOMIES OF NEOLITHIC AND TRANSITIONAL CHALCOLITHIC COMMUNITIES ON THE IRANIAN PLATEAU

Tepe Abdul Hosein

The faunal spectrum at Tepe Abdul Hosein, recently analyzed by the second author and her team (Mashkour *et al.* 2021: 49-58), provides clear evidence of both domestic and wild animal exploitation. Goat remains from the second occupation phase of the site exhibit twisted horns and reduced body size – morphological traits characteristic of early domesticated forms (Daly *et al.* 2021). The detailed archaeozoological study of this site is currently in progress and will be published in the near future.

Red deer is only represented by 0,6% of the vertebrate remains while the bulk of the assemblage belongs to wild and domestic goat and sheep. A s a result over twenty remains were identified, consisting primarily of antler fragments. However, other parts of the post-cranial skeleton are also present, such as vertebrae, phalanx, and the coccyx (Fig. 2A).

Tepe Sang-e Chakhmaq

More than 1800 faunal remains were recovered from the trench on the western mound (Mashkour *et al.* 2014). However, bone preservation is generally poor across both mounds due to extensive fragmentation. The assemblage is dominated by small ruminants – primarily domesticated caprines followed by gazelles (*Gazella* cf. *subgutturosa* (Güldenstädt, 1780)) (Mashkour *et al.* 2014). Red deer although represented only by 2.2% of the vertebrate remains, counts among the hunted wild taxa at the site and seems to have been more frequently targeted in the later phase that is represented particularly in the eastern mound (Fig. 2B). The faunal remains of Tepe Sang-e Chakhmaq show the very large catchment and exploitation of various ecological niches around the site that extends from the foothills and forested areas to the edge of the central desert.

Tepe Zagheh

With regard to the faunal assemblage that counts for more than 13 000 remains, caprines are by far the most represented taxa, accounting for over 75% of the identified bones. Among these, almost all belong to domesticated caprines. Only approximately 3% of the faunal remains derive from wild species. The second most frequently attested herbivore is the gazelle. Red deer, represented by 0.1% of the in Tepe Zagheh, refers only to antlers and no other skeletal part could be identified (Fig. 2C).

The antler industry[1]

The analysis of red deer exploitation at Tepe Abdul Hosein, Tepe Sang-e Chakhmaq, and Tepe Zagheh offers valuable insight into Neolithic and Transitional Chalcolithic osseous production on the Iranian Plateau. Considering the presence of *Cervus elaphus* remains at all three sites, most of the material relates to antler-working (n = 34), while only a few pieces reflect the use of post-cranial elements (n = 6), primarily long bones.

The corpus of antler remains – three from the Early Pre-Pottery Neolithic and nine from the Late Pre-Pottery Neolithic levels at Tepe Abdul Hosein; fifteen from the East Mound and three from the West Mound at Tepe Sang-e Chakhmaq; and four from the Late Neolithic/Transitional Chalcolithic levels at Tepe Zagheh – is modest in size but nonetheless informative regarding the osseous technologies practiced by the communities of the Iranian Plateau.

1. For the technological terminology used in the text, see Averbouh 2016.

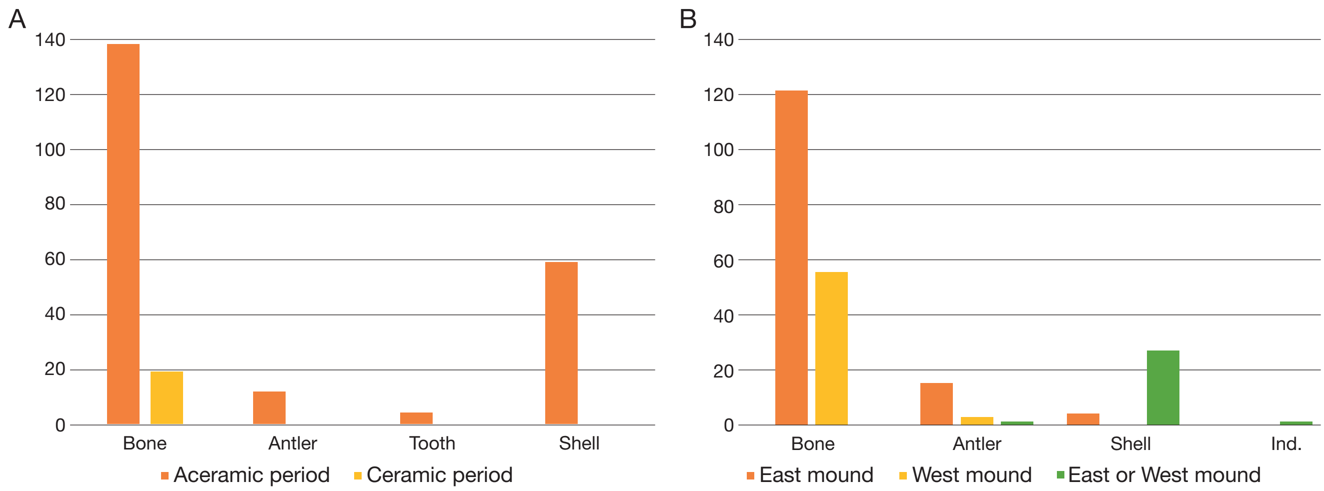

Fig. 3. — **A**, Type of hard animal material exploited in the site of Tepe Abdul Hosein; **B**, type of hard animal material exploited in the site of Tepe Sang-e Chakhmaq. Abbreviation: **Ind.**, unidentified remains.

Table 1. — Bone and antler pieces from *Cervus elaphus* Linnaeus, 1758 in the studied sites: Tepe Abdul Hosein, Tepe Sang-e Chakhmaq and Tepe Zagheh. Abbreviations: **EPPN**, Early Pre-Pottery Neolithic; **LPPN**, Late Pre-Pottery Neolithic.

Site	Taxa/size	Anatomical part	Number of pieces found	
			EPPN	**LPPN**
Tepe Abdul Hossein	*Cervus elaphus*	antler	3	9
	Cervus cf.	metatarsal	–	1
		metapodial	1	–
	Large mammal / little *Bos* or *Cervus* size	rib	1	–
		long bone	–	1
		Subtotal	**5**	**11**
			East mound	**West mound**
Tepe Sang-e Chakhmaq	*Cervus elaphus*	antler	14	3
		metapodial	1	–
	Capreolus or *Cervus* size	antler	1	–
	Large mammal / Gazelle or *Cervus* size	radius	–	1
		Subtotal	**16**	**4**
Tepe Zagheh	*Cervus elaphus*	antler	4	
		Total	**40**	

Tepe Abdul Hosein

The antler assemblage at Tepe Abdul Hosein is quantitatively limited (nr. 12), representing only about 2% of the transformed osseous material, including all products derived from bone and antler industry (Fig. 3A). In contrast to the more intensively exploited osseous remains, the use of postcranial elements of red deer –mainly metapodials– for tool production remains minimal (Table 1). Likewise, antler remains are infrequent and poorly represented, suggesting that red deer antler was not a primary raw material in the lithic and osseous industries of the site.

The antler assemblage is dominated by wastes and potential wastes (nr. 10) overwhelmingly composed of fragmentary elements, including antler tine tips (distal fragments; nr. 2), portions of tines (nr. 4) and beams (nr. 3) and burr (nr. 1) (Fig. 4A-E). Of these, four pieces can be attributed to debitage wastes based on the presence of technical marks (all located on tine portions), whereas the remaining elements were classified as potential wastes: tine tips, beam fragments, and the burr, which lack clear technical traces but display fracture surfaces consistent with fresh-state fracturing and compatible in size and morphology with an antler-working operational sequence (i.e. *chaîne opératoire*). The only identified tool is a probable burnisher fragment (Fig. 4F), recovered from a context dating to the earliest aceramic Neolithic. Shaped from a rod-like blank with parallel sides, its surfaces are poorly preserved, limiting further technological or functional observations.

A single antler burr (or base) was recovered, although its exact stratigraphic attribution remains uncertain (Fig. 4C). With regard to acquisition practices, this specimen indicates the collection of shed antlers rather than removal from a carcass, as suggested by the morphology and preservation of the burr. Although determining the animal's age is not possible, the predominance of medium-sized anatomical elements in the assemblage points to a practical selection strategy.

The technical traces identified correspond to four debitage wastes that exhibit clear evidence of intentional removal by direct percussion with a sharp lithic tool. The removal scars are all located at the base of the tines, forming more

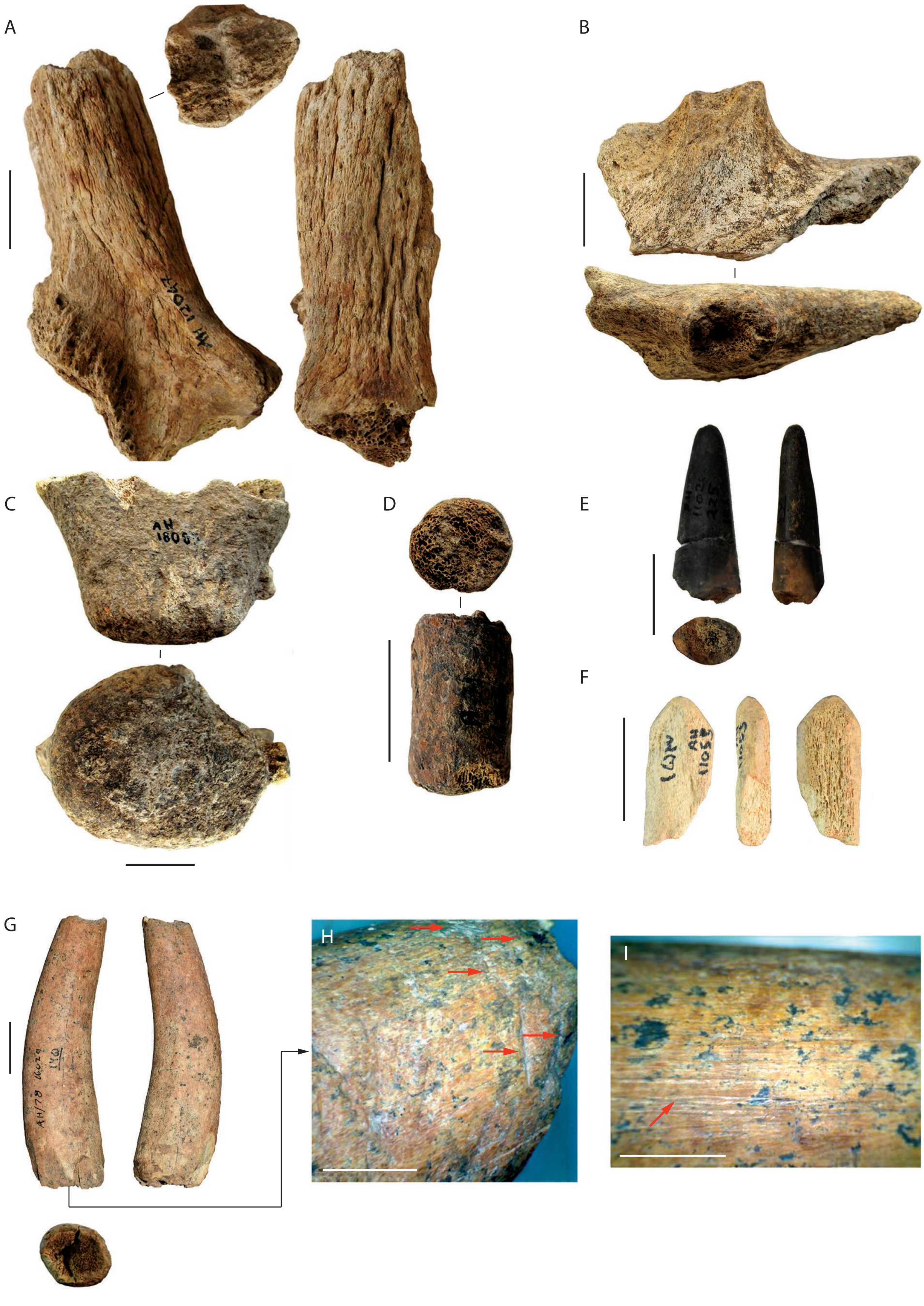

Fig. 4. — Antlers of *Cervus elaphus* Linnaeus, 1758 from Tepe Abdul Hosein: **A**, specimen AH78, 9G, 12047, Early Pre-Pottery Neolithic (EPPN), lateral, frontal, and sectional views; **B**, **D**, specimen AH78, 18L, 18005, Late Pre-Pottery Neolithic (LPPN), frontal, medial, and sectional views; **E**, specimen AH78, 10G, 11021 (LPPN), frontal, medial, and sectional views; **F**, specimen AH78, 10G, 11055 (EPPN), superior, lateral, and inferior views. Scale bars: A-G, 2 cm; H, I, 5 mm.

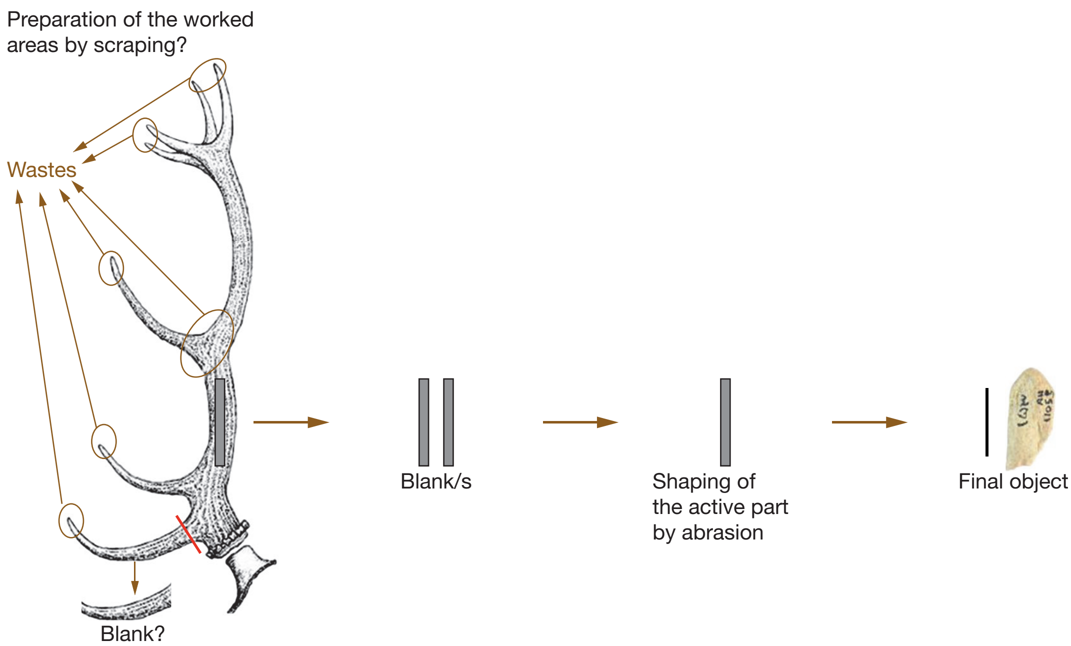

Fig. 5. — Technical exploitation of antlers at Tepe Abdul Hosein. Schematic representation of the sequential working phases and the intended objectives of debitage. Scale bar: 2 cm.

or less open and inclined grooves extending over the entire (Fig. 4D) or nearly the entire (Fig. 4G) circumference of the antler. The bottoms of these scars show mixed U-shaped and V-shaped cross-sections, indicating the use of at least two different types of tools. Their residual length (ranging from 3 to 7 mm) and angle of incidence (from vertical to oblique) also vary considerably. One waste displays surface regularization consistent with scraping, probably performed prior to the sectioning action (Fig. 4E). The burnisher fragment shows abrasion-based shaping on its active part (Fig. 4F).

Despite these indicators, the operational sequence at Tepe Abdul Hosein remains highly fragmentary (Fig. 5). The presence of only waste products and a single finished object suggests that raw material blocks were brought to the site and that debitage –at least its initial stages– was performed on-site. The anatomical parts represented among the wastes and potential wastes indicate that the aim of the debitage was to remove the tines by sectioning. Theoretically, this operation should have produced beams, which are absent from the assemblage. No evidence supports the stage of blank production: neither wastes associated with secondary debitage on beams nor unmodified blanks intended for shaping are present. It is therefore plausible that this stage occurred outside the excavated area, or even entirely off-site. Conversely, the single finished object (Fig. 4F), although fragmentary, informs us about the type of blanks sought rod-shaped, with an elliptical (or originally sub-rectangular) cross-section. Its width (55 mm) and thickness (15 mm) indicate the minimal dimensions required for such a blank.

In conclusion, the available evidence from Tepe Abdul Hosein points to a low-intensity, possibly opportunistic exploitation of cervid antler. Although the few identified technical traces suggest a recognizable operational logic –including debitage and abrasion-based shaping– the limited corpus greatly constrains our ability to reconstruct the full organization of antler craft practices at the site.

Tepe Sang-e Chakhmaq

A total of 18 antler artifacts were studied from Tepe Sang-e Chakhmaq. The majority originated from the eastern mound, attributed to the Ceramic Neolithic phase, while only three elements were recovered from the western mound, dated to the Pre-Pottery Neolithic occupation.

Technical analysis of the assemblage allowed the following identifications (Fig. 6A):

– West mound: one waste and two tools;

– East mound: one waste from a debitage operation, three blanks, and eleven tools.

We will describe a reconstructed operational sequence based mainly on the data from the East Mound remains, but we will also discuss the morpho-technical aspects of the older remains recovered in contexts from the West Mound. This is due to the technical and typological compatibility of the two assemblages which, at this stage of the research, do not present any notable differences or variations.

The assemblage is dominated by tools, such as smoothers (nr. 9), a beveled object (nr. 1), splintered tools (nr. 2), as well as one undetermined tool. The blanks (nr. 3) generally derive from elongated beam segments, while the waste (nr. 2) results from splitting operations and sectioning action (Fig. 6D, J). This composition demonstrates intentional and structured production practices.

A single specimen –a finished object retaining the basal portion– allows us to observe that the raw material block from which it was produced belonged to a young individual, and that it was obtained through simple collection (Fig. 6C). The

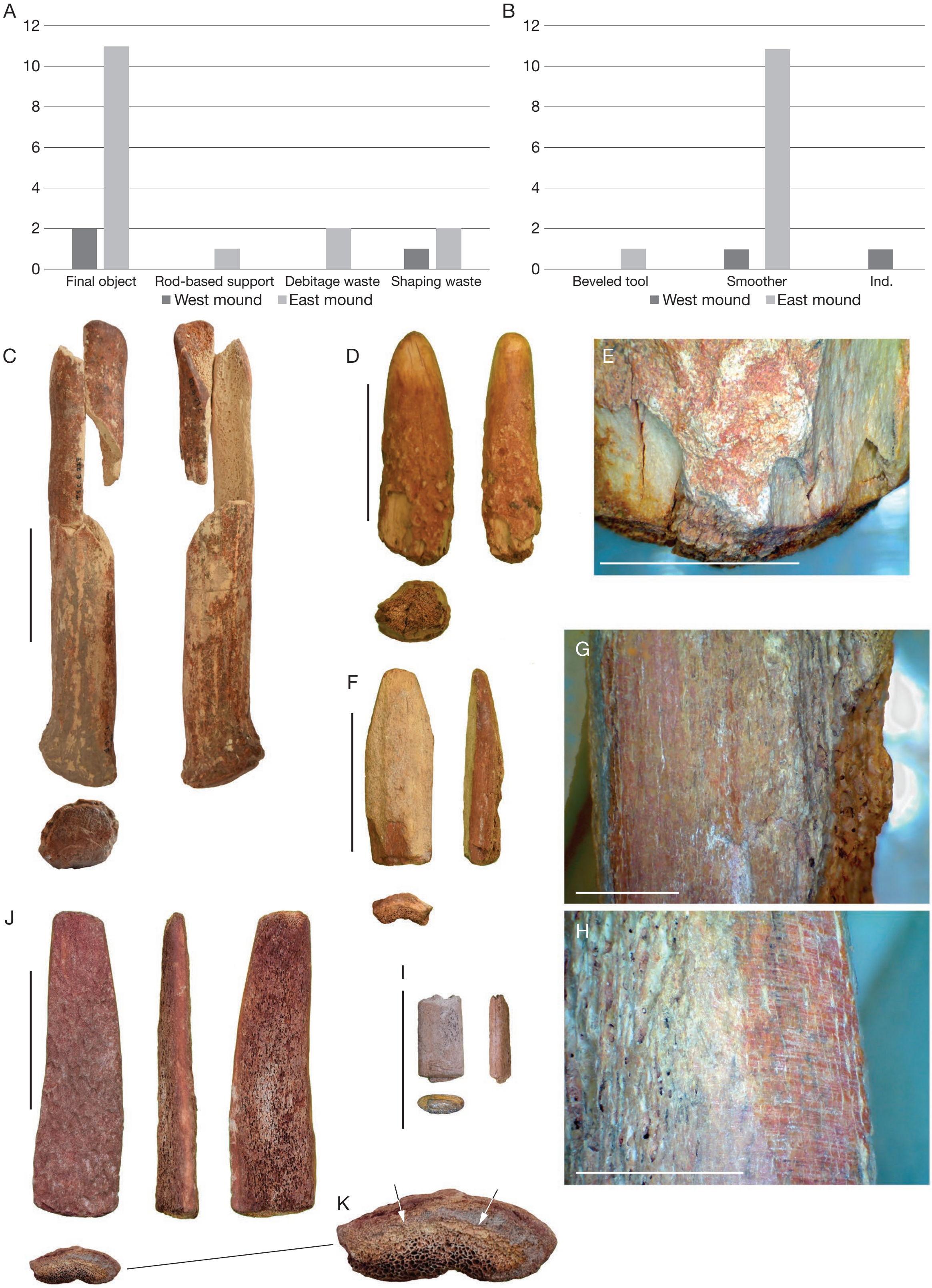

FIG. 6. — Bone and antler industry from Tepe Sang-e Chakhmaq: **A**, types of technical products; **B**, types of objects; **C**, specimen TSC232 (East mound), lateral, frontal, and cross-sectional views; **D**, specimen TSC1, level 4, 73-14 (East mound), frontal, lateral, and cross-sectional views; **E**, traces of direct percussion on the proximal part of specimen TSC1; **F**, specimen TSC5, level 4, 73-14 (East mound), frontal, lateral, and cross-sectional views; **G**, grooving marks on the right side of specimen TSC5; **H**, traces of abrasion on the left side of specimen TSC5; **I**, specimen TSC9, level 3 (West mound), frontal, lateral, and cross-sectional views; **J**, specimen TSC150a, level 6, H10-H11 (East mound), frontal, lateral, and cross-sectional views; **K**, grooving marks on the inferior face of specimen TSC150a. Scale bars: D, D, F, I J: 5 cm; E, G, H: 5 mm.

good state of preservation of its surfaces indicates that it was gathered shortly after being shed, that is, between late winter and early spring. The other archaeological remains represented come primarily from the beam (nr. 14; Fig. 6F, I, J). Their reconstructed diameter, inferred from the curvature of the visible compact tissue, suggests the exploitation of medium to large-sized antlers. This preference antlers contrasts with the low representation of the upper parts of the antler and of tines on the site. Few crown tines or brow tines (nr. 2; Fig. 6D) were identified, even though these are the most numerous elements on the antlers of adult stags. Finally, for one piece it was not possible to identify the anatomical part.

From the perspective of reconstructing the operational sequence, no complete transformation scheme could be re-established to illustrate how the secondary blocks on the beam were produced. Only a single element, a tool, attests to the sectioning of a tine by means of removal by direct percussion (Fig. 6D).

During the debitage of the beams, the craftspeople of Tepe Sang-e Chakhmaq employed deep-wear techniques (grooving and sawing) and breaking techniques (indirect percussion). During shaping, deep-wear techniques (sawing) and surface-wear techniques (scraping, abrasion) were implemented. Grooving, generally carried out with a lithic tool with a burin-like active part, removes material by a repeated unidirectional motion (Averbouh 2000). It leads to the creation of deep grooves cut into the cortical thickness of the antler, presenting two inclined faces (or one steep and the other inclined) covered by fine, mutually parallel striations, sometimes intercalated with deeper striations (Fig. 6G). At Tepe Sang-e Chakhmaq, grooving was identified on two waste pieces, on two blanks and on several objects. Sawing, carried out with a lithic tool having a sharp active part, creates a groove by a repeated bidirectional motion (Averbouh 2000). One object (Fig. 6K) and one shaping waste piece (Fig. 6I) attest to its application at the site. Indirect percussion is performed with a tool with a sharp active part, as shown by the removal scars observable on one object and on one blank. The striations identified on the surface of the remains correspond to scraping and abrasion. Scraping, identified by residual striations on the lower face of a shaping waste piece, was used to regularize the contours of a blank (Fig. 6I). Using abrasion, the craftspeople formed the active parts of the tools by scratching the surface with a longitudinal, transversal or oblique motion, generally unidirectional. The length, depth, outline of the striations and their arrangement suggest the use of a straight lithic cutting edge (Fig. 6H).

The debitage operations were carried out using a splitting procedure combining two techniques –grooving and indirect percussion– in two variants. In the first variant, the preparation of the fracture lines was achieved through deep, parallel double grooving, while the detachment of the blanks was carried out by indirect percussion. In the second variant, the double grooving is slightly convergent on the distal part (preparation of the final morphology of the object), and detachment is again performed by indirect percussion. The first variant is attested on seven pieces, including five objects, one blank, and one waste piece. The second variant is observable on two finished objects. Finally, percussion could also be used alone to split the beam, as observed on three pieces: two objects showing parallel fracture planes, and one blank on which an impact point was identified in association with a fracture plane. The preparation of the sectioning of the beams for the production of blanks was occasionally carried out by sawing, as observed on one object (Fig. 6K).

The splitting procedures described above fall within the method of blank production by partitioning, aimed at obtaining flat, elongated blanks with highly standardised sub-rectangular or sub-triangular outlines. These blanks can be divided into two groups on the basis of their morphometric characteristics. The first group includes standardised blanks (nr. 10), rectangular in shape, with parallel edges and systematically corresponding to one quarter of the beam volume. They are produced mainly through parallel double grooving combined with indirect percussion (nr. 9), although splitting by percussion alone could occasionally be employed (nr. 1). Their maximum width and thickness range between 19 and 24 mm in width and between 8.6 and 15 mm in thickness. Among the ten pieces, only one blank displays larger dimensions (29 mm in width and 18.1 mm in thickness). These blanks were used for the production of smoothers and splintered tools. The second group of blanks (nr. 5) has an outline falling within a sub-triangular shape, with sub-parallel edges along the mesio-proximal part that become convergent toward the distal end.

These blanks anatomically correspond to a larger portion of the beam compared to the first group, ranging from half (nr. 1) to about 1/3 (nr. 3) of its circumference. For a fragmentary piece, membership in this group was established in relation to its morphological affinities with the distal part of the other remains. The blanks are obtained by splitting operated by a double grooving slightly convergent on the distal part and the detachment is operated by an indirect percussion. The sectioning of the base of the blanks could be implemented by sawing (nr. 1; Fig. 6J, K). As for the first group, percussion splitting could marginally be implemented (nr. 2). The maximum width and thickness of the supports are between 27 and 34 mm wide and between 9.3 and 15 mm thick. They were used exclusively for the production of massive smoothers. These morpho-metric differences between the two groups of blanks and the slight variations in the application of the various techniques used to obtain them correspond perfectly to the dimensions and mechanical qualities of the desired objects.

Within the entire assemblage, only three pieces reflect an intention to produce objects on volumetric blanks, thereby preserving the full original volume of the raw material block. Two of these elements have been discussed above: one in the context of raw material acquisition strategies (Fig. 6C), and the other in relation to removal scars indicating sectioning action (Fig. 6D). A third, fragmentary object was produced on an tine tip. In these instances, it was only possible to partially reconstruct the technical operations employed during the sectioning involved in the debitage phase.

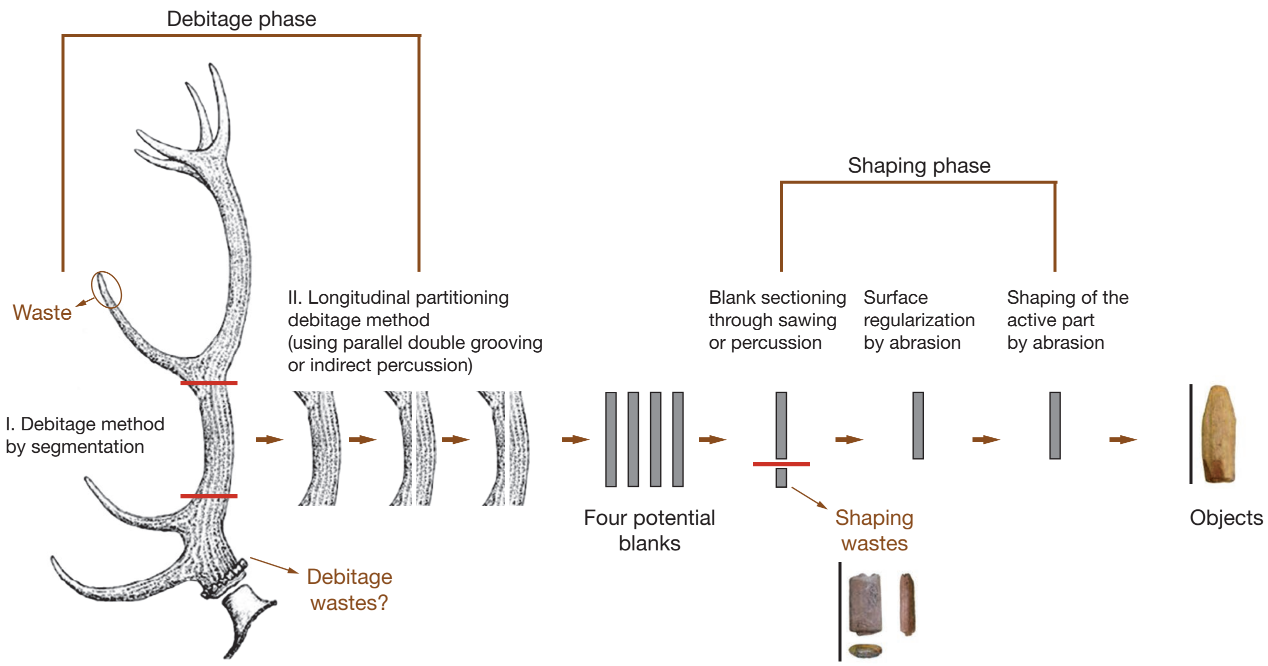

Fig. 7. — Technical exploitation of antlers at Tepe Sang-e Chakhmaq. Schematic representation of the sequential working phases and the intended objectives of debitage. Scale bars: 5 cm.

Once the flat blanks on *baguette* (obtained through the partitioning debitage method) and volumetric blanks were produced, they underwent further modification to produce tools. During the shaping of the flat blanks, technical traces were identified on 12 pieces. Only a single shaping waste piece attests to the sectioning of a blank carried out by sawing (Fig. 6I). More frequently, the blanks underwent less invasive shaping, affecting only their outlines and profiles through peripheral abrasion, as indicated by the previously described striations. Abrasion was performed obliquely or perpendicularly to the main axis of the blanks. In a single case, unifacial scraping was employed. Regarding the volumetric blanks, only one object preserves abrasion striations, oblique relative to the main axis of the piece, produced during shaping.

This reconstruction demonstrates the high degree of technical knowledge and standardization involved in antler tool production at Tepe Sang-e Chakhmaq (Fig. 7). The evidence suggests that antler working was not a casual or opportunistic activity but rather a structured practice embedded in broader Neolithic, craft traditions on this site.

Tepe Zagheh

At Tepe Zagheh, in the Qazvin Plain, evidence for the presence of red deer is minimal, limited to a four antler pieces. Despite the scarcity of elements, the site yielded a notable assemblage of massif tools (nr. 4; Fig. 8), comprising two hammers (Fig. 8B) and two axes (Fig. 8C, D), feature transverse perforations near the central zone of the active part. These perforations were likely intended for the insertion of wooden handles, improving both grip and efficiency in use. In contrast, a fourth implement preserves the natural base, which served simultaneously as the grip and the functional end, thereby negating the need for hafting (Fig. 8A).

All documented tools were obtained from shed antler rather than obtained through hunting. These specimens were likely collected from more forested regions to the north, potentially near the Caspian Sea, where red deer populations would have been more prevalent. Concerning the size of raw material blocks, it seems that large antlers are only selected, indicating a deliberate preference for robust specimens capable of supporting heavy-duty use. This choice aligns with the nature of the implements themselves, which are described as “massive” in both morphology and presumed function. Exploited anatomical segments include the basal portion of beam A, the area between the eye and bez tines, and the superior part of beam B at the crown base (Fig. 8). These zones matching the dimensions and mechanical properties required for the intended object. The preservation of natural bases in some implements illustrates functional adaptation and maximization of raw material properties.

The frequently fragmentary condition of the objects, particularly in anatomical parts that would be most likely to preserve technical traces related to debitage, together with the apparent obliteration of such traces presumably resulting from prolonged use or extensive shaping prevented a clear identification of the techniques employed during debitage. The surfaces are entirely opaque and retain only partial evidence of the original texture of the raw material. On a single piece (Fig. 8B), the morphology of the plane corresponding to the detachment of the tine (edge inclination and flaring) could be compatible with a fracturation technique such as removal by direct percussion. However, the absence of discern-

Fig. 8. — Antler industry from Tepe Zagheh: types of objects. **A**, Hammer, frontal, superior, inferior and cross-sectional views; **B**, hammerhead, frontal, lateral, and cross-sectional views; **C**, **D**, axes, laterals, frontal, and cross-sectional views. Scale bars: 5 cm.

ible removal scars precludes a definitive interpretation. With regard to shaping, vestigial abrasion striations were observed on the active area of one object (Fig. 8D), associated with small flat surfaces, supporting the identification of this technique. No technical traces could be observed in connection with perforations.

While the specific technical procedures employed in the antler industry at Tepe Zagheh remain unidentified, the anatomical parts represented by the objects suggest that sectioning actions were likely used during debitage. These procedures would have aimed to produce the desired volumetric blanks, each preserving the full initial volume of the selected raw material. The craftsmen appear to have deliberately chosen large deer antler size class, carefully adapting the morphology and mechanical properties of the selected anatomical parts to the types of tools being produced and their intended functional purposes. The absence of debitage waste raises questions regarding on-site manufacture. During her doctoral research, one of the authors (Mashkour 2001) identified two antler fragments (offcuts) showing no apparent traces of transformation, suggesting that raw material may have been transported to the site. This observation prompts consideration of alternative explanations for the lack of additional production wastes (see paragraph "General remarks on these excavations").

Antler working at Tepe Zagheh demonstrates planned, specialized production (Fig. 9). Selection of robust antlers,

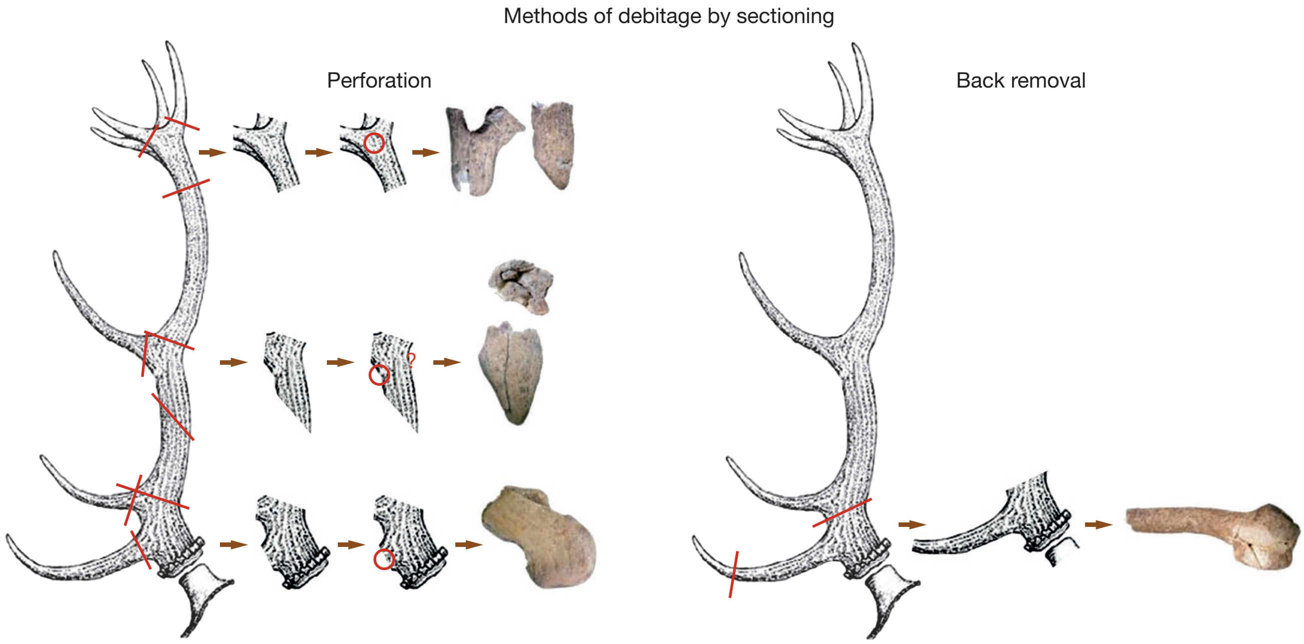

Fig. 9. — Technical exploitation of antlers at Tepe Zagheh. Schematic representation of the sequential working phases and the intended objectives of debitage.

careful shaping, and functional adaptation suggest integration of antler exploitation into a broader toolkit for heavy-duty tasks, rather than opportunistic collection.

CONCLUSIONS

Overall, the three sites Tepe Abdul Hosein, Tepe Sang-e Chakhmaq, and Tepe Zagheh produced a total of 34 antler items, including wastes, blanks, and finished tools. At Tepe Abdul Hosein, 12 pieces were recovered, comprising 10 wastes and potential wastes, and a single tool. Tepe Sang-e Chakhmaq yielded 18 technical products, including two wastes, three blanks, and 13 tools. At Tepe Zagheh, four massive tools were documented. The exploitation of red deer antler at these sites appears to have been a marginal activity. Nonetheless, it offers valuable insights into the craft practices and subsistence strategies of Neolithic and Transitional Chalcolithic communities of the Iranian Plateau. Through the analysis of remains and manufacturing techniques, several key observations and conclusions can be drawn.

First and foremost, the exploitation of antler appears to have been primarily opportunistic. Materials were mainly collected from shed antlers, typically gathered following the natural moulting process of deer, a practice largely dictated by seasonal resource availability (see the issue of skeletal part representation). In this regard, it is noteworthy that larger antlers seem to have been preferentially selected, particularly in the eastern regions of the Iranian Plateau where red deer are generally larger. Such opportunistic exploitation suggests that antlers were not acquired through the targeted hunting of deer for this specific resource, but rather through the occasional and secondary collection of materials readily accessible in the local environment. The faunal evidence from Tepe Abdul Hosein and Tepe Sang-e Chakhmaq further supports this interpretation. The presence of post-cranial remains at both sites indicates that a limited number of animals were hunted and consumed within the settlements. Yet, at Tepe Abdul Hosein the absence of cranial fragments corresponding to the pedicle provides no indication of antler exploitation from hunted individuals. In contrast, Tepe Sang-e Chakhmaq has yielded clear evidence for the use of collected antlers, consistent with the broader pattern of opportunistic gathering. From a morphometric perspective, the remains generally correspond to medium to large-sized adult individuals, whose dimensions align with those of the worked antlers recovered at both sites. By contrast, the worked deer antlers from Tepe Zagheh appear to reflect a more systematic economic strategy, based on the selective collection of large-sized antlers. This suggests that, unlike at Tepe Abdul Hosein and Tepe Sang-e Chakhmaq, the procurement of antlers at Tepe Zagheh was not merely opportunistic but rather guided by deliberate choices aimed at securing specific raw materials for craft production.

Furthermore, the technical and conceptual principles techniques employed in antler processing vary significantly across the sites, reflecting specific regional objectives. At Tepe Abdul Hosein, the evidence points to low-intensity, opportunistic use of red deer antler, with few debitage wastes and only a single finished object, suggesting that initial stages of blank production may have occurred off-site. By contrast, Tepe Sang-e Chakhmaq exhibits a highly structured and standardized antler industry, characterized by systematic debitage through partitioning and controlled shaping of blanks into specialized implements. Moreover, the antler industry at

Tepe Sang-e Chakhmaq appears to be oriented toward the manufacture of tools used for processing soft materials, such as leather, suggesting a degree of craft specialization and an adaptation to local functional needs. Finally, at Tepe Zagheh, antler working reflects planned and specialized production for heavy-duty tools, with deliberate selection of robust antlers, careful adaptation to anatomical morphology, and functional optimization, even though the absence of production waste leaves certain stages of the operational sequence unclear. Here, antler seems to have been primarily used to make tools for working soil and soft wood, possibly in connection with local craft practices.

A significant trend observed is the increase in antler exploitation during the Ceramic Neolithic, particularly at Tepe Sang-e Chakhmaq. This period may correspond to a growing demand for specialized tools, especially in relation to agricultural and ceramic-related activities, suggesting that the antler industry gained importance as these practices became more diversified and structured. Thus, antler exploitation was not an isolated activity but part of a broader network of economic and social practices.

Socio-cultural factors likely played a crucial role in shaping antler exploitation. Taboos or ritual practices may have influenced both material selection and transformation techniques, although these aspects remain underexplored. A broader dataset incorporating wider social and cultural contexts would be necessary to better understand these dimensions.

It is also important to note that, although wild vertebrate fauna remains are identified at these sites the exploitation of red deer seems limited mainly to their antlers. The heavy modification of the bones and antlers into tools or object makes it often difficult to make taxonomic allocation. Recent technical and methodological developments through Zooarchaeology by Mass Spectrometry (ZooMS) analyses using preserved proteins for species-level determination from small or degraded bone fragments (Bray et al. 2023; Mashkour *et al.* 2025), or genetic analysis (Tejero *et al.* 2024) could provide complementary data on other forms of animal resource exploitation that are not easily accessible through conventional methods. Finally, the growing collaboration between zooarchaeology and modern technological approaches –particularly the technical analysis of tools and faunal remains– offers new perspectives for reconstructing production and transformation processes associated with antler exploitation. This multidisciplinary approach is essential for deepening our understanding of subsistence strategies, craft practices, and the development of Neolithic societies.

In conclusion, while antler exploitation was relatively marginal compared to other resources such as caprine bones, it nevertheless represents a noteworthy aspect of Neolithic economies. It reflects an opportunistic strategy driven by practical considerations related to resource availability and specific tool production needs. The evolution of techniques, regional variability, and socio-cultural influences are key factors in understanding this activity, which, although seemingly secondary, was integrated into a complex system of economic and craft practices during the Neolithic and first Chalcolithic.

Credits

Conceptualization, methodology: formal analysis, writing (original draft and review & editing), formal analysis and validation: all autors. Data curation: L.M.

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