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A fresh look at the Thessalian Neolithic osseous tools: The study from Mandra (Northern Greece, fifth millennium cal. BC)

Un regard nouveau sur les outils en os du Néolithique thessalien : l'étude de Mandra (nord de la Grèce, Ve millénaire av. J.-C.)

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Abstract: This paper presents preliminary results on the raw materials and manufacturing processes of osseous artefacts from the Neolithic settlement of Mandra in Thessaly, Northern Greece. The assemblage consists of 182 artefacts recovered during excavations between 1996 and 1998, most of which originate from later Late Neolithic deposits (dating to the first half of the 5th millennium cal. BC). The composition aligns with other Thessalian bone industries, primarily featuring cutting-edge tools, awls, and spatulas, alongside two sleeves, a bipoint, and a perforated flat point, possibly a needle.

Overall, the bone industry of Mandra provides strong evidence of structured production, based on consistent patterns emerging from the artisans' choices. A high degree of differential use of raw materials sourced almost exclusively from domesticated species is evident. It showcases a selective approach to animal size, species, and anatomical elements, which strongly correlates with specific artefact categories, the types of blanks used, and the reduction methods and techniques applied. By comparing these findings with previous research in the region, this study highlights regional and chronological trends in Neolithic bone working across Thessaly.
Keywords: Aegean Neolithic, Thessaly, Late Neolithic, Greek prehistory, bone technology, bone industry, technological analysis.

Résumé : Cet article présente des résultats préliminaires sur les matières premières et les procédés de fabrication des artefacts osseux du site néolithique de Mandra, en Thessalie, dans le nord de la Grèce. Un total de 182 objets en os a été récupéré lors des fouilles menées à Mandra entre 1996 et 1998. La majorité du mobilier provient des dépôts de la période tardive du Néolithique récent, datés de la première moitié du 5e millénaire av. J.-C. Ces objets comprennent principalement des outils tranchants, des poinçons et des spatules. Il y a également deux gaines à douille, une bipointe et une pointe plate perforée, peut-être une aiguille à chas. La composition de cet assemblage correspond aux descriptions des industries osseuses de Thessalie. Les gaines à douille revêtent une signification chronologique, car elles apparaissent pour la première fois durant le Néolithique récent.

L'analyse des matières premières de Mandra met en évidence une forte dépendance aux espèces domestiques ainsi qu'une sélection spécifique des éléments anatomiques. Ces pratiques semblent avoir connu peu de changement au fil du temps, comme l'indiquent les données d'autres sites thessaliens. Les plus grands outils tranchants ont été obtenus à partir de demi-métapodes de bœuf. La plupart des autres outils tranchants ont été fabriqués à partir de diaphyses de tibias de caprinés et, dans une moindre mesure de porcs, fracturées au niveau proximal ou mésial. Quelques spécimens ont été réalisés à partir d'esquilles représentant un quart ou moins de la circonférence des diaphyses de métapodes de bœuf. La grande majorité des poinçons a été fabriquée à partir de demi-métapodes de caprinés. L'utilisation systématique de ce support d'outil a également une signification chronologique : cette phase tardive du Néolithique récent est la première où les demi-métapodes sont plus souvent utilisés que les esquilles pour la fabrication des poinçons. Les outils tranchants façonnés à partir de demi-métapodes n'apparaissent qu'à cette période. D'autres catégories d'outils, comme les spatules, les gaines à douille et une bipointe, que l'on trouve fréquemment dans les assemblages néolithiques thessaliens, sont représentées à Mandra en quantités beaucoup plus faibles. Les spatules sont traditionnellement fabriquées à partir de côtes de bœuf, la bipointe à partir d'une esquille de tibia de capriné, et les gaines à douille, notamment, sont les seuls outils à avoir été produits à partir d'un matériau autre que l'os – le bois de cerf.

Les processus de débitage sont étroitement liés aux éléments anatomiques. Le rainurage bifacial a été utilisé spécifiquement pour débiter les métapodes. Dans tous les autres cas, les supports d'outils proviennent d'os fracturés transversalement, pouvant être issus de déchets alimentaires produits et rejetés au sein du site.

La faible diversité des espèces animales et des éléments anatomiques ne doit pas masquer la variabilité morphologique au sein des catégories d'outils. Le façonnage a joué un rôle important dans la détermination de la taille et de la forme des poinçons fabriqués à partir de demi-métapodes. Les outils tranchants réalisés à partir de fragments de tibias montrent des variations dans les dimensions des biseaux taillés pour former les tranchants, ainsi que dans leur longueur. En général, le degré de façonnage est faible à modéré, ce qui permet d'obtenir des outils qui conservent une morphologie du support d'origine. Cependant, la production de certains poinçons a demandé plus de temps et d'efforts, car leurs formes et dimensions spécifiques ne pouvaient pas être obtenues directement à partir des matières premières couramment utilisées.

Dans l'ensemble, les industries osseuses de Thessalie présentent un degré remarquable de continuité dans les formes et la production d'outils en os. Les changements chronologiques observés au cours du Néolithique récent reflètent un équilibre entre des traditions de longue durée et des adaptations technologiques progressives en réponse à de nouveaux besoins et circonstances.

Mots-clés : Néolithique égéen, Thessalie, Néolithique final, Préhistoire grecque, technologie osseuse, industrie osseuse, analyse technologique.

INTRODUCTION

The pioneering surveys and excavations conducted by C. Tsountas at Sesklo, Dimini and Argissa in the late 19th and early 20th centuries laid the foundation for systematic research on the Neolithic of Thessaly and the Aegean (c. 7000–3200 cal. BC). Thessaly, located in northern Greece, covered to most of its extent by two of the peninsula's largest plains, was densely inhabited from approximately 6300 to 3800 cal. BC, when settlement patterns shifted, leading to the dispersal of prehistoric populations across the wider southern Balkans and the Aegean.

The study of Neolithic bone industries from Thessaly is relatively well established. During the 1980s and 1990s two Ph.D. dissertations (Moundrea-Agrafioti, 1981; Stratouli, 1998), which follow more or less closely the works of European researchers (Camps-Fabrer, 1976 and 1977; Schibler, 1981), provided significant insights into this material. Additionally, site assemblages have been published in edited volumes and academic journals, employing comparable nomenclature and typological frameworks (Moundrea-Agrafioti, 1975; Weisshaar, 1978; Batziou, 1981; Wijnen, 1981; Winn and Shimabuku, 1989; Becker, 1991; Stratouli, 2000; Galik, 2015). Since 2016 research has increasingly focused on a more detailed examination of the technological features of these artefacts (Christidou, 2022), offering new perspectives on bone tool production and use.

Building on previous studies of Neolithic bone industries in Thessaly, this research focuses on the material from the settlement of Mandra, offering a detailed examination of its technological aspects. It aims to further our understanding of bone tool production within the context of Neolithic Thessaly. This research contributes to exploring local variations in material culture during the later Late and early Final Neolithic, with particular emphasis on manufacturing processes and their role in the emerging dynamics of the household during this transformative period.

1. THE SITE

The Neolithic site of Mandra is located in the eastern plain of Thessaly (fig. 1). Approximately 0.18 ha were explored during rescue excavations conducted between 1996 and 1998.

The settlement's chronology is based on radiocarbon dating and preliminary ceramic analysis, revealing five habitation phases, characterised by shallow stratigraphy. Phases Mandra I-IV correspond to the later part of the Late Neolithic, the so-called Late Neolithic II (the period between 4990/4800 and 4700/4500 cal. BC), with phase IV marking the transition into the Final Neolithic. The final phase, Mandra V, is poorly documented due to erosion and modern agricultural activities, but it can be tentatively dated to the early Final Neolithic (Toufexis, 2017, p. 44 and pp. 116–121; for information on the discussion about the periodisation of the Neolithic, see Tsirtsoni, 2016).

During the first three phases, excavation data and the widespread dispersion of pottery indicate the existence of a flat, extended settlement surrounded by encircling ditches. Architectural remains were sparsely distributed, interspersed with large open spaces. In the first two phases, habitation likely occurred in dwelling-pits, which evolved into above-ground structures with stone foundations in phase III. Phase IV brought significant changes: the settlement became more compact, covering approximately 2 ha, and was enclosed by a stone-built circuit wall. Positioned atop a low mound, the settlement exhibits characteristics of both a flat site and a tell, giv-

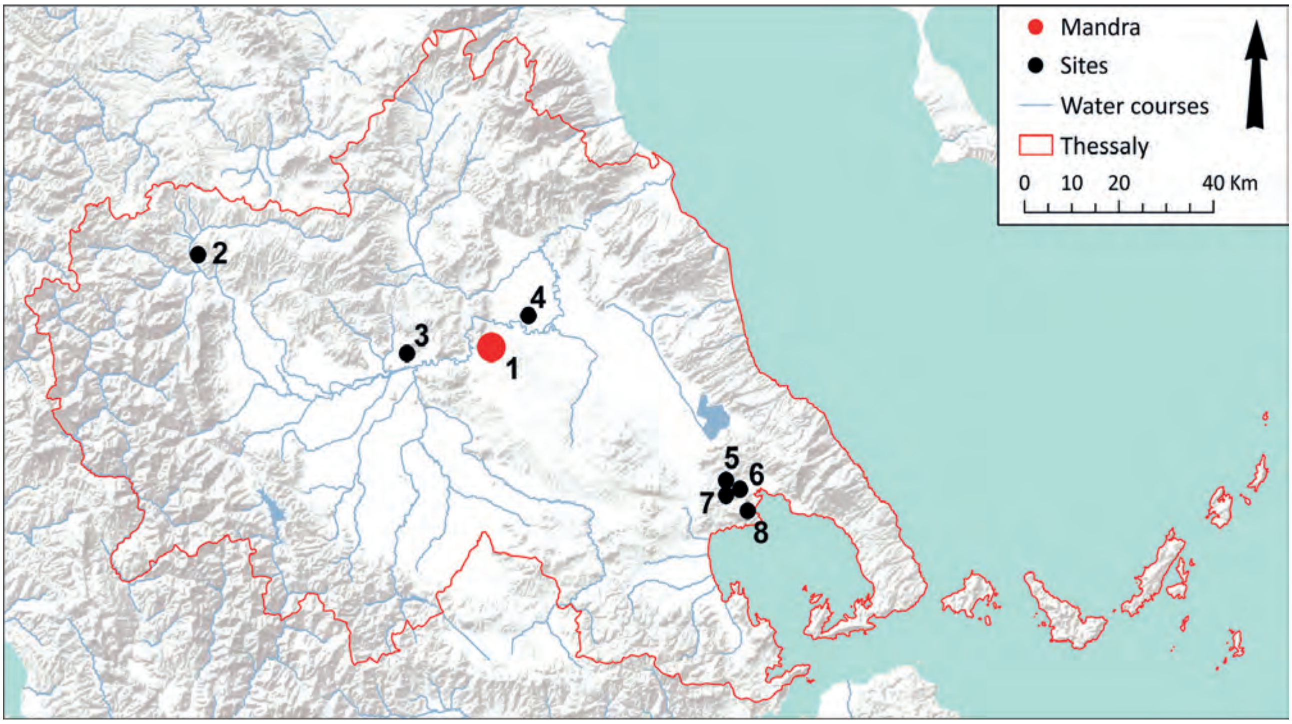

Fig. 1 – Map of Thessaly with locations of the sites mentioned in the text: (1) Mandra; (2) Theopetra Cave; (3) Platia Magoula Zarkou; (4) Argissa; (5) Pyrgos; (6) Dimini; (7) Sesklo; (8) Pevkakia-Magoula (Map M. Katsianis; vector data sources: OSM; Basemap data: ESRI, USGS, NOAA).

***Fig. 1** – Carte de la Thessalie avec les sites mentionnés dans le texte : (1) Mandra ; (2) grotte de Théopetra ; (3) Platia Magoula Zarkou ; (4) Argissa ; (5) Pyrgos ; (6) Dimini ; (7) Sesklo ; (8) Pevkakia-Magoula (carte M. Katsianis ; vector data sources : OSM ; basemap data : ESRI, USGS, NOAA).*

ing it a "hybrid" nature. The layout became denser and more structured, following a clear orientation. Above-ground structures persisted, with some, such as building A, increasing in size and storage capacity (Toufexis, 2017, pp. 351–353). This shift reflects a broader trend towards more "enclosed" and self-sufficient households by the end of the Late Neolithic, a pattern observed at other Thessalian settlements. These developments suggest evolving economic and social dynamics, marking a departure from habitation patterns of earlier periods.

2. ASSEMBLAGE AND METHODOLOGY

A total of 182 osseous artefacts—one of the largest collections from the Thessaly region—were recovered during excavation and subsequent sorting of part of the faunal bones by the author. As the study is ongoing, 157 artefacts are presented here. These derive from four building phases (I-IV), dated to the Late Neolithic II and the beginning of the Final Neolithic. For this analysis, they are treated as a single assemblage; further subdivision by phase and spatial distribution will be addressed in future research.

The assemblage is primarily composed of two tool categories: cutting-edge tools and awls. Additionally, it includes smaller numbers of spatulas, sleeves, a bipoint, and a perforated flat point, which could be classified as a needle. Manufacturing waste, albeit in limited quantities, provides valuable insights into raw material selection and production processes.

Each artefact was systematically documented, with data recorded on raw materials, manufacturing techniques, morphology and dimensions. Breakage patterns and surface damage were also documented to identify potential biases in the morphometric and technological analyses. The methodological framework employed follows established principles from similar studies in the Aegean and beyond (Christidou, 1999; Legrand and Sidéra, 2007; for orientation, characterisation, and morphological attributes, see particularly: Camps-Fabrer and Stordeur, 1979; Moundrea-Agrafioti, 1980). Artefacts were initially categorized according to the shape of their active end, followed by further classification according to blank type (Moundrea-Agrafioti, 1981; Stordeur, 1985; Camps-Fabrer et al., 1990).

Taxonomic and anatomical identifications were conducted with the assistance of a zooarchaeologist, osteological manuals (Schmid, 1972; Barone, 1986), and a comparative faunal collection. All artefacts were examined macroscopically and under low magnification (10×-55×) using a Leica stereoscopic microscope equipped with an integrated camera. Use-wear analysis is currently pending.

3. RESULTS

3.1. Preservation

Fragmentation affects a significant portion of the bone objects from Mandra, with 131 specimens (83.4% of the assemblage) being fragments. Most of them exhibit ancient fractures, while specimens with recent ones—almost half in number—originate from the upper excavation layers. In the latter category, 11 cases of refitting of fragments were achieved.

The majority of fragmented artefacts fall into two main groups: those preserving the tool's distal part along with a portion of the shaft (42 specimens) and those retaining only the distal part (29 specimens). Both awls and cutting-edge tools are represented with the latter being more numerous. Additionally, 14 fragments are shafts alone, while 12 preserve shaft and proximal part. Moreover, 18 fragments, mostly awls, are considered "almost complete", as their final form can be reconstructed despite breakage. The remaining 26 objects (16.6% of the assemblage) are intact and evenly distributed between the two dominant tool categories.

Root etching was the most common surface alteration, observed on nearly all artefacts. It formed dendritic patterns and was more widespread and intense on specimens preserving the bone epiphyses. Black surface staining, most likely due to manganese deposits from elevated humidity, affected two-thirds of the assemblage, generally covering small areas.

Light weathering (stages 1 and 2, Behrensmeyer, 1978) was recorded in 50 cases, primarily affecting the epiphyses and artefacts recovered from the upper excavation layers. The most vulnerable specimens were the two sleeves, the only examples made from cervid antler, a material prone to degradation. Cracking and surface flaking, often linked to weathering and root etching, affected over half of the material. The overall low intensity of weathering and the relatively small number of affected artefacts may indicate rapid burial of the material.

Burning and gnawing damage were rarely documented. Only two tool fragments exhibited limited heat-induced alterations on their exterior surfaces, in the form of black discoloration. The bones were charred, indicating their brief exposure to mild fire (Stiner et al., 1995; Chatzikonstantinou and Triantaphyllou, 2024). Similarly, 12 specimens had localized black traces of fire, probably from brief contact with a heated surface. Nine tools bore gnawing marks from carnivores, located mostly on the epiphyses or the metaphyses.

When assessing damage levels on complete and almost complete specimens for a clearer and more comprehensive picture, it is noted that more than two-thirds (35 out of 44) exhibited damage to less than 50% of their total surface, allowing for the identification of manufacturing traces.

3.2. Raw materials

Species and anatomical element identification was possible for 116 of the 157 (73.9%; table 1). In the remaining cases, fragmentation and post-depositional surface alterations obscured diagnostic features, resulting in 18 cases where only the animal size could be determined, and one with no distinguishing characteristics.

The selection of raw materials indicates a clear preference for bones from medium-sized animals (72%), primarily caprines, with a smaller presence of pigs. A few specimens from carnivores, most likely dogs, also fall into this category. Large-animal bones, mainly from cattle, appear less frequently (23.5%), while small game is entirely absent. Although deer bones have not been conclusively recognized, some unidentified large-animal remains may represent deer. Apart from bone, red deer antler was identified in only two cases, though five unexamined antler tines and two wild boar canines with manufacturing traces are also present.

Long bones dominate the assemblage (93.6%), with metapodials (38.2%) and tibias (33.8%) being the most common. Other long bones, such as femur, radius, and ulna, appear in low frequencies. The use of flat bones was quite limited (4.5%), with only nine recorded instances, all from cattle ribs.

As the faunal assemblage has yet to be analysed, direct comparisons between the bone tools and zooarchaeological data is not yet possible.

3.3. Artefact categories

3.3.1. Cutting-edge tools

The largest tool category in the assemblage is that of 54 cutting-edge tools, all featuring transverse active edges. Three types are distinguished according to the kind of blank used.

The most common type is represented by 22 tools manufactured on transversely broken bones, retaining a part of the shaft with complete circumference. Twenty of these were made on long bones from medium-sized animals, including 12 caprine tibias, seven pig tibias, and one pig radius (fig. 2a and b). The blanks were obtained from midshaft and proximal fractures which, when observable, exhibited a curved and spiral outline, indicating fresh bone breakage. Where no manufacturing marks were present, the fracture surfaces were smooth and regular. In most cases, these tools are single-beveled (n = 17), with the active end positioned on the posterior side of the bone and a cutting edge ranging from 6.9 to 14.6 mm in length. Of the eight tools with a proximal part, the distal epiphysis was present as the base: fused in three cases, fusing in two, and unfused in another three. The remaining two tools were made from large-sized animal bones, one on a cattle metapodial and the other on an ulna. The blanks were obtained from midshaft fractures with the proximal epiphyses left intact, serving as the base. These represent the most robust tools of the assemblage, featur-

Taxon	Element	Cutting-edge	Awl	Bipoint	Perforated fat point	Spatula	Sleeve	Manufacturing waste	Unclassified object	Total
Sheep	Metacarpal		2							2
	Tibia	4							5	9
	Metatarsal							1	1	2
	Metapodial							1		1
Sheep / goat	Radius	1								1
	Metacarpal		1						2	3
	Femur								1	1
	Tibia	13	4	1					11	29
	Metatarsal		16						2	18
	Metapodial		12					2		14
	Undetermined	2	4						2	8
Pig	Radius	1								1
	Tibia	8							2	10
Carnivore	Tibia	1								1
	Undetermined	1								1
Red deer	Antler						2			2
Cattle	Ribs					4			1	5
	Ulna	1								1
	Metacarpal	1								1
	Tibia	1								1
	Metatarsal	5						1		6
	Metapodial	5						4		9
	Undetermined	2							1	3
Large animal	Ribs								1	1
	Femur	1								1
	Metapodial								1	1
	Undetermined	3	1						4	8
Medium or large animal	Ribs				1					1
	Femur		1							1
	Tibia	1							2	3
	Metapodial		3							3
	Undetermined	3	3						3	9
Total		**54**	**47**	**1**	**1**	**4**	**2**	**9**	**39**	**157**

Table 1 – Animal species and anatomical elements for each artifact category.
***Tabl. 1** – Espèces animales et éléments anatomiques pour chaque catégorie d'artefacts.*

ing double-beveled cutting edges located around the mid-point of the bones. Notably, the specimen on the cattle metapodial exhibits the greatest overall dimensions, with maximum width and thickness measured at the epiphysis, and the longest cutting edge in the assemblage, reaching 20.8 mm.

The degree of shaping varies, focusing primarily on the creation of the active end. The caprine tibias, as well as the cattle metapodial and ulna, display a consistent shaping pattern: modification marks extend well beyond the fracture surface into the intact diaphysis—sometimes up to 50 mm—without significantly changing the blank's overall shape. In contrast, pig tibias show marked variability; some exhibit minimal modification along the margin of the fracture surface, extending only a few millimetres and limited to forming the cutting edge, while others are extensively thinned along their entire length, resulting in a pronounced flattening of the inferior side.

Coarse grinding was identified in all specimens, with transverse, oblique, and in a few cases longitudinal traces (fig. 2f). Scraping marks are rare, occurring exclusively on pig tibias, and always in combination with grinding, employed to smooth irregular surfaces of the shaft.

Fig. 2 – Cutting-edge tools: (a-b) made from transversely broken caprine tibias; (c) crafted from carnivore long bone, possibly a splinter; (d-e) fashioned from halved metapodials of cattle. Shaping traces: (f) coarse grinding striations on a tibia cutting-edge tool (captured at 10×). Manufacturing waste: (g) cattle metapodial halved by longitudinal grooving (red rectangle: grooved surface; CAD K. Chondros).

Fig. 2 *– Outils tranchants : (a-b) exemplaires fabriqués à partir de tibias de caprinés fracturés transversalement ; (c) exemplaire réalisé à partir d'un os long de carnivore, possiblement une esquille ; (d-e) exemplaires façonnés à partir de demi-métapodes de bœuf. Traces de façonnage : (f) stries grossières d'abrasion sur un outil tranchant en tibia (10×). Déchet de débitage : (g) demi-métapode de bœuf obtenu par rainurage longitudinal (rectangle rouge : pan de sillon ; DAO K. Chondros).*

Grinding was also applied to the bases of four specimens, all of them distal epiphyses, to achieve flattening.

The second type consists of tools made on splinters from long bones of medium- and large-sized animals. All are diaphyseal fragments preserving a quarter or less of the shaft circumference. Two tools were made on caprine bones, a radius and a tibia; these may be supplemented by four additional fragments of caprine tibias and a carnivore long bone that retain the distal portion of the shaft and display similar characteristics (fig. 2c). These specimens are thin and narrow, with single-beveled cutting edges measuring 4.3-5.2 mm in length. Their shaping was restricted solely to the formation of the beveled cutting edge, executed through oblique or transverse coarse grinding.

Another three tools were fashioned from splinters of two cattle metapodials and a cattle tibia. In contrast to the caprine splinters, these are more irregular in form and bear double-beveled cutting edges with greater lengths, reaching up to 9 mm. Furthermore, their shaping is more extensive, as it is not limited to the distal end but extends along the entire length of the tool to flatten the irregular fracture surface. In addition to oblique coarse grinding, traces of scraping are observed over a limited length on both the inferior and superior sides of the tools.

The third type is represented by six halved cattle metapodials produced by longitudinal grooving (fig. 2d and e), in three cases bifacial. The grooves extend to the epiphysis but do not reach the marrow cavity, suggesting that splitting by percussion was required to complete the reduction process. The distal and central portions of the bones were used, with the active end positioned at the centre and directed towards the proximal third. In the two complete tools, the distal epiphysis was preserved—fused in one case and unfused in the other. All specimens have double-beveled cutting edges, with lengths ranging from 12 to 20.6 mm. Shaping of these tools mainly aimed to flatten the elevated relief of the grooved surfaces, covering about two-thirds of their length, by means of transverse or oblique coarse grinding. In addition, all specimens exhibit short facets bearing traces of scraping, located on both the lateral and superior sides.

Of particular interest are five pieces of manufacturing waste, all made on cattle metapodials, associated with the third type (fig. 2g). Three of them may represent blanks in preparation or simple debris, while the others are roughouts. Comparative analysis of these fragments supports the hypothesis of a standardized production process: the same anatomical parts were consistently selected, with the distal epiphysis preserved as the proximal end of the tool; grooving was employed followed by splitting, with the grooves displaying similar characteristics; similar metrical traits are evidenced, as the lengths of the fragmented pieces (53.1-88.4 mm) align closely with those of the two complete tools (67.4 and 94.4 mm, respectively). The distal breakage observed on these fragments may reflect intentional modification aimed at achieving blanks of a specific size. As for the two possible roughouts, they bear traces of oblique coarse grinding over a short length of their distal end on the inferior side, indicating evidence for shaping in progress.

3.3.2. Awls

Awls constitute the second largest tool category, represented by 47 specimens, manufactured in their majority from caprine metapodials. The types identified among cutting-edge tools are also observed here, following the same blank-based classification, with the addition of a group of morphologically similar awls that may represent a distinct tool type.

Halved metapodials obtained through longitudinal grooving (fig. 3a-c) served as the preferred blanks, accounting for 12 examples. Bifacial grooving is present in six specimens with grooves typically extending to the epiphysis and cut down to the marrow cavity. With one exception, all blanks derive from the distal part of the bone. In seven tools where the proximal part is preserved, the epiphysis was used as the base.

Shaping was limited, preserving much of the blank's original form. Modifications were primarily concentrated on the distal part, particularly on the inferior and lateral sides, with edges converging towards the apex. Occasionally, shaping extended to the shaft and proximal part, especially on the inferior side, to flatten uneven surfaces. The superior side was rarely altered, except for slight adjustments at the distal end. Transverse and oblique grinding, using fine abrasives (fig. 3i), was consistently applied in combination with localized scraping (fig. 3j).

Awls shaped on transversely broken bones with complete shaft circumference (fig. 3g), as well as on splinters (fig. 3h), were recorded in small numbers—three and four cases, respectively. Caprine long bones, primarily metapodials, were used in all instances except for two tibias and a femur. Although the shaft's and proximal part's morphology reflect the unmodified form of the blanks, the distal parts were shaped following the same approach as the halved metapodials, quite resembling them in both form and dimensions.

Eight awls, all manufactured on caprine metapodials, are grouped together due to shared morphological traits (fig. 3d-f). They are characterised by a slender form, corresponding to less than a quarter of the metapodial shaft's cross-section. Different reduction processes or fragments thereof have been identified: one specimen (fig. 3f) was worked exclusively with transverse and oblique coarse grinding (known as *débitage par usure*, Poplin, 1976, pp. 89–91), whereas another combined the same technique with subsequent bisection by grooving. The remaining six awls bear sparse traces of longitudinal grooving along their shafts as well as coarse grinding marks, although the sequence of techniques cannot be reliably determined. With a single exception, all blanks derive from the distal part of the bone, with three preserving the metaphysis and two the distal epiphysis as the base of the tool. Six additional awls share similar morphological characteristics; they are represented by distal

Fig. 3 – Awls: (a-b-c) fashioned from halved caprine metapodials; (d-e-f) group of awls characterized by a slender form; (g) made from a transversely broken metapodial; (h) made from a splinter. Shaping traces: (i) fine grinding striations on a slender awl; (j) scraping striations on a halved metapodial awl (both captured at 20×; CAD K. Chondros).

***Fig. 3** – Poinçons : (a-b-c) façonnés à partir de demi-métapodes de caprinés ; (d-e- f) groupe de poinçons caractérisés par une forme fine ; (g) poinçon réalisé à partir d'un métapode fracturé transversalement ; (h) poinçon fabriqué à partir d'une esquille. Traces de façonnage : (i) stries fines d'abrasion sur un poinçon fin (20×) ; (j) stries de raclage sur un poinçon en demi-métapode (20×; DAO K. Chondros).*

and shaft fragments, yet their reduction process remains untraceable due to extensive shaping.

Coarse grinding played a central role in the final form of this group of tools, thinning the anterior and posterior faces of the bone to less than a quarter of its circumference. Aside from the two cases in which this technique was employed either alone or prior to grooving, it is not possible to determine whether it belongs to the reduction or shaping stage. In any case, the subsequent shaping was consistent across all 12 tools. Oblique and transverse grinding with fine abrasives was applied to the distal portion, producing narrow facets that converged towards the pointed tip. Scraping was also employed, particularly along the shaft and distal part, likely to refine profiles following coarse grinding. Consequently, all these awls share similar morphometric characteristics, exhibiting a slender overall form, straight profiles, and predominantly rectangular cross-sections with only slight variation in width and thickness along both the distal part and the shaft.

3.3.3. Bipoint and perforated flat point

The assemblage includes a single bipoint, crafted from a caprine tibia (fig. 4a). It is a narrow, spiral splinter, representing less than a quarter of the bone's circumference. Coarse grinding was applied exclusively to the tapering ends, while the central portion remained unmodified.

Additionally, a perforated flat point with an eye and notches at the proximal end was manufactured from a split rib (fig. 4b). This exceptionally thin artefact, with a slightly curved profile, exhibits extensive shaping, with coarse grinding marks visible along both faces. A biconical circular perforation, 3 mm in diameter, was made near the base. In the absence of a use-wear analysis, its function remains uncertain—it may have served as a needle, pin, pendant, or even an ornament recycled into a tool.

3.3.4. Spatulas

Four spatulas were identified in the assemblage; all preserved as fragments retaining the distal part and a portion of the shaft (fig. 4c). They were made from cattle ribs. One was fashioned from a split rib, while another was made from a transverse fragment of the rib corpus. For the remaining two, fragmentation prevented the identification of the blank used. The split rib and the two unidentified blanks underwent flattening of the cancellous surface and rounding of the ends, while the transverse fragment was shaped only at the active end. In all cases, coarse grinding was used.

3.3.5. Sleeves

Two artefacts are classified as socketed sleeves (fig. 4d and e; Arampatzis, 2019, p. 71). Both were made from transverse tine fragments, cut at both ends by peeling and thinning the compact bone using percussion and a cutting-edge lithic tool before breaking the bone.

Shaping involved scraping the cancellous tissue to create the two sockets and coarse grinding to flatten the broken ends of the blanks. The natural curvature of the bone remained intact.

4. DISCUSSION

The analysis of the osseous raw materials from Mandra reveals a strong preference for domesticated species, with caprines, pigs, and cattle comprising most of the assemblage. A selective approach to skeletal elements and specific blank types is evident across all artefact categories. Transversely broken tibias from caprines, and to a lesser extent pigs, were employed exclusively for cutting-edge tools, whereas halved cattle metapodials were used for the largest implements. Awls, for their part, were produced primarily from halved caprine metapodials. Splinters, although present in small numbers, were also utilized in both tool categories, derived from various long bones of medium- and large-sized animals. Spatulas were manufactured from cattle rib shafts, while sleeves were fashioned from red deer antlers.

The choice of reduction processes was closely linked to the skeletal elements selected. Bifacial longitudinal grooving was consistently applied to cattle and caprine metapodials, whereas for most other cases, blanks were obtained through fracturing. In a few isolated instances, coarse grinding was also employed on caprine metapodials, either as a stand-alone technique or in combination with longitudinal grooving.

As a general rule, the degree of shaping applied to the tools was low to moderate, primarily aiming at flattening grooved or fracture surfaces, with final products that remained morphologically close to their blanks. When the forms and sizes needed could not be provided by the raw materials employed, additional time and energy were invested, as in the case of the extensively worked slender awls. Grinding constituted the principal shaping technique. The use of coarse abrasives reflects the need for rapid removal of bone material. Fine abrasives, by contrast, were employed more selectively, restricted to the production of delicate forms with thin facets, such as tool points, thereby offering greater precision and control over shaping.

Overall, the bone artefact assemblage from Mandra provides strong evidence of structured production. Apart from the use of splinters with irregular morphology—which most likely represents a more opportunistic approach—the remainder of the assemblage reflects varying degrees of planning, aimed from the outset at producing specific final products. The consistent use of distal portions of tibias, with the active end regularly placed at the midshaft or the proximal third of the posterior side, indicates that fragment selection was not random but purposeful and deliberate, even when such pieces may have derived from food debris. Furthermore, in the case of metapodial awls, the manufacturing processes were

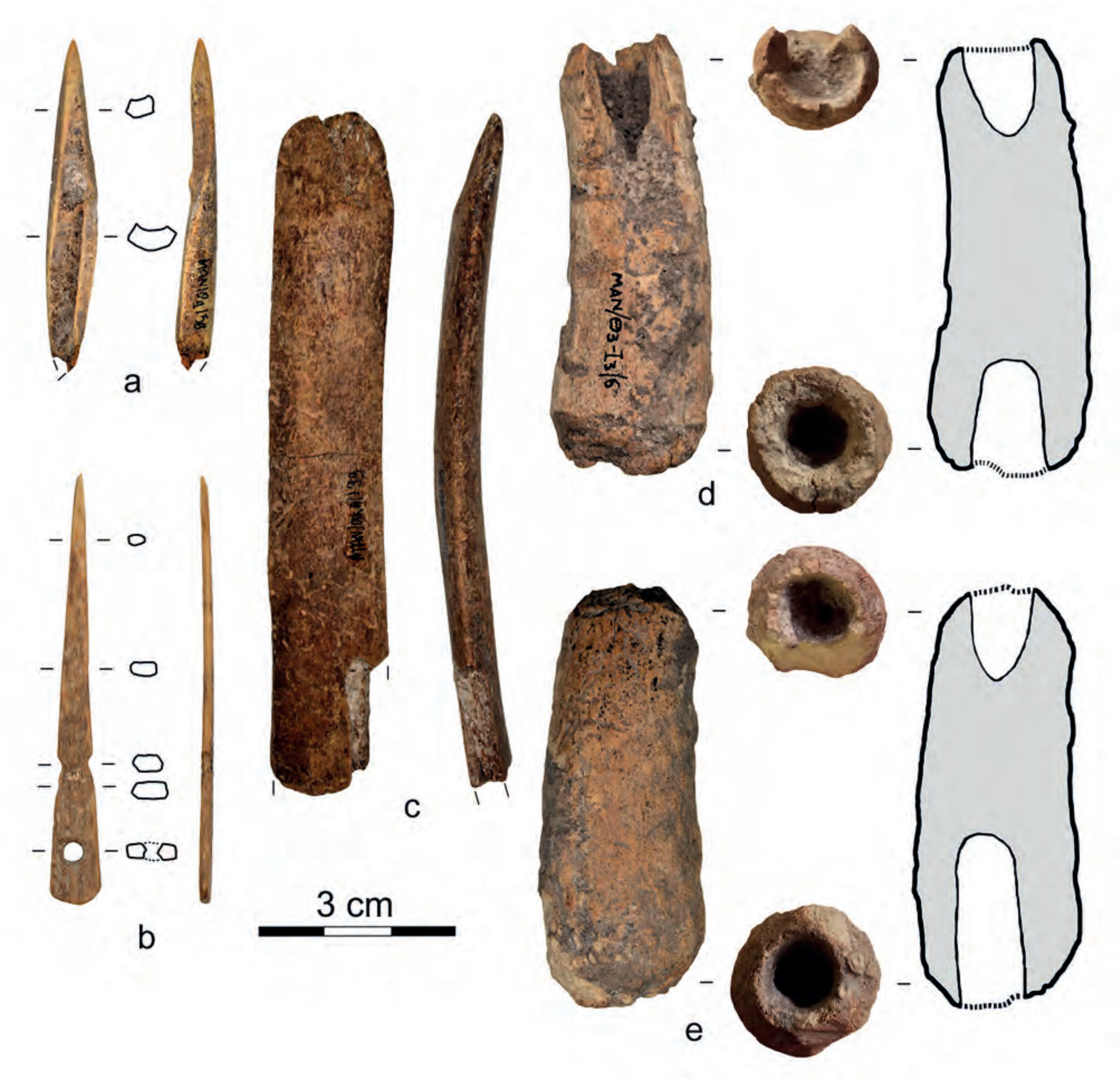

Fig. 4 – Other tool categories: (a) bipoint with a twisted profile, made from a splinter of caprine tibia; (b) perforated flat point on a rib, possibly a needle; (c) spatula crafted from a transverse fragment of cattle rib; (d-e) socketed sleeves made from red deer antler tines (CAD K. Chondros).

***Fig. 4** – Autres catégories d'outils : (a) bipoint à profil torsadé, fabriqué à partir d'une esquille de tibia de capriné ; (b) pointe plate perforée sur une côte, peut-être une aiguille à chas ; (c) spatule réalisée à partir d'un fragment transversal de côte de bœuf ; (d-e) gaines à douille fabriquées à partir de bois de cerf (DAO K. Chondros).*

longer and relatively more complex, involving multiple techniques and in some cases producing extensively worked specimens. This suggests the intention of maximizing the use of the available raw material through the production of the greatest possible number of tools from each bone.

Based on these observations, the Mandra assemblage shows close alignment with regional and chronological trends already observed in Neolithic Thessaly. This region displays a remarkable continuity in osseous tool production. In all Neolithic phases, a consistent pattern of differential use of raw materials emerges, with bones deriving predominantly, and often exclusively, from domestic species (Moundrea-Agrafioti, 1981, p. 268; Stratouli, 1998, p. 41; Christidou, 2022, p. 392). The absence or restricted use of wild animal bones and deer antlers further underscores the reliance of Thessalian households on the animals raised and consumed within their settlements for tool manufacture. Moreover, the systematic selection of particular skeletal elements and blank types for specific tool categories constitutes a recurrent pattern. For instance, fragments of caprine tibias retaining part of the shaft with complete circumference were consistently employed for the production of cutting-edge tools across all Neolithic phases of the region (Batziou, 1981, p. 114; Stratouli, 1998, pp. 110–111; Christidou, 2022, p. 357). A related trajectory can be observed in the manufacture of awls from halved caprine metapodials, outnumbering splinter awls in Late Neolithic contexts, whereas the latter were more frequently represented in Early and Middle Neolithic assemblages (Moundrea-Agrafioti, 1975 and 1981; Christidou, 2022, pp. 357–358).

Changes observed during the Late Neolithic were cumulative, with established tool types persisting at varying frequencies alongside new additions. A notable example is the introduction of deer antler sleeves, which appear during this period and onwards at multiple sites, including Dimini, Theopetra Cave, Pyrgos and Pefkakia-Magoula (Moundrea-Agrafioti, 1981; Stratouli, 1998 and 2000), serving as chronological markers. These developments reflect a balance between long-standing traditions and gradual technological adaptations.

At the same time, beyond the overall picture of a homogeneous osseous tool production in Neolithic Thessaly, local particularities do emerge. The Mandra assemblage provides such instances, although the number of relevant specimens is too limited to allow advancing hypotheses. Large double-bevelled cutting-edge tools made from halved cattle metapodials, together with specimens produced from splintered cattle diaphyses, appear in Thessaly only from the Late Neolithic onwards and always in small numbers (Moundrea-Agrafioti, 1981, pp. 310–311). Their comparatively higher occurrence at Mandra may reflect either greater availability of this raw material or a functional demand for particularly robust implements. Furthermore, the group of slender awls—characterised by their standardized form and size—is almost absent from other studied sites, where only isolated examples have been documented.

Alongside these local particularities, rare technological variations detected elsewhere are also documented at Mandra. Notably, in two instances, caprine metapodials were reduced to approximately a quarter of the bone, either through the exclusive use of grinding or in combination with grooving. These cases likely reflect a deliberate effort to produce predetermined blanks closely resembling slender awls—a practice that is not frequently observed at other Neolithic Thessalian sites (Moundrea-Agrafioti, 1981; Christidou, 2022, p. 360).

To conclude, the analysis of the Mandra assemblage reinforces the picture already established for Thessaly during the Late Neolithic: one of cultural homogeneity underpinned by technological practices that evolved gradually over time. Local particularities may reflect differing needs, economic conditions, or even collective preferences. These subtle departures from a broadly shared technological repertoire deserve closer examination, as they provide a window into a settlement's technological system and its social and cultural dimensions. A comprehensive use-wear study, combined with comparative research across other material categories, will be essential for developing a broader contextual understanding.

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