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The manufacture of the Aegean boar's tusk helmets: A case study from Middle Bronze Age Kolonna on Aegina, Greece

La fabrication des casques égéens en défense de sanglier : étude de cas de Kolonna (âge du Bronze moyen) sur l'île d'Égine, Grèce

Quentin Zarka

Abstract: The following paper examines production methods of Middle Bronze Age Aegean boar's tusk helmets. The study is based on the technological analysis conducted on the Kolonna helmet (Aegina). Previous research on boar's tusk helmets has primarily adopted a typological and comparative approach. Much less attention has been given to the typological variations of the individual plaques within a single helmet, as well as to their manufacturing techniques.

The present study first examines the acquisition of the raw materials required to produce this helmet (hunting, animal husbandry and trade). It then addresses the manufacturing processes of these materials. A sample of 18 shaped tusk plates from the helmet was selected and examined using a digital microscope (×20 and ×50 magnification) to identify manufacturing and wear traces. This analysis highlighted variability in the technical choices made by the artisans, reflecting both the characteristics and constraints of the raw material, as well as the intended form of the final products.

This research represents the first stage of a broader study of boar's tusk helmets from the Middle Bronze Age and the Late Bronze Age (1600–1200 BCE), discovered in mainland Greece and Crete. Expanding technological studies on artefacts from different sites has the potential to illuminate cultural and technological developments across regions and chronological phases during the Aegean Late Bronze Age.

Keywords: Aegean Bronze Age, boar's tusk helmet, manufacturing techniques, weaponry, artisans.

Résumé : Dans cet article, nous proposons des hypothèses sur les modes de production des casques égéens en défense de sanglier du IIe millénaire avant J.-C., en nous basant sur l'analyse technologique menée sur le casque de Kolonna (HM II, Égine).

Objets emblématiques de l'âge du Bronze égéen dans les civilisations mycénienne et minoenne, les casques en défenses de sangliers sont largement attestés par les découvertes archéologiques de casques, les représentations artistiques et le récit homérique (*Iliade*).

Depuis les premières découvertes à la fin du XIXe siècle, ces artefacts ont suscité une attention particulière de la part des archéologues spécialisés en protohistoire égéenne. Pourtant, leurs modes de fabrication et d'utilisation sont restés jusqu'à aujourd'hui relativement méconnus. Les travaux de recherche antérieurs, principalement basés sur des classifications typologiques, ont souvent mis en évidence une certaine « standardisation » de ces artefacts et se sont focalisés sur leurs possibles liens symboliques avec la chasse et l'aristocratie guerrière de l'époque. Toutefois, la réalité des procédés de fabrication et d'utilisation de ces casques est plus nuancée. L'analyse tracéologique des plaquettes qui composent le casque d'Égine permet aujourd'hui de révéler d'importantes variations morphologiques et techno-fonctionnelles au sein d'un même assemblage de pièces façonnées. Cette approche nous offre également la possibilité de formuler des hypothèses sur les différentes étapes de fabrication de ce type de casque.

Dans un premier temps, nous avons porté notre attention sur la présentation du matériel dans son contexte archéologique, ainsi que sur l'approche méthodologique adoptée pour notre étude. De plus, il s'est révélé indispensable de cerner rapidement le support de matière

brute animale dans notre étude, pour mieux appréhender les différentes étapes de transformation dans le cadre de la fabrication du casque.
Puis, nous nous sommes intéressés aux modes d'acquisition des matières premières nécessaires à la confection de ce casque. En intégrant les données archéozoologiques disponibles sur le site à notre analyse, plusieurs hypothèses sur les modes d'acquisition de la matière première ont pu être établies. Dans le cas du casque de Kolonna, il paraît peu probable que des sangliers furent chassés sur l'île et que l'extraction des défenses fut exécutée sur place.
Une grande partie de cet article a été consacrée à l'examen des procédés de transformation de ces matières premières. À cette fin, un échantillon de 18 plaquettes façonnées qui compose le casque a été sélectionné et analysé macroscopiquement à l'aide d'une caméra optique DinoLite (grossissements x20 et x50). Les observations relevées par cette méthode d'analyse ont permis d'identifier et de caractériser plusieurs types de stigmates résultant de gestes humains. Les résultats de cette analyse ont permis, en premier lieu, de proposer des hypothèses sur les séquences de travail, les techniques, les outils et les gestes opérés dans la fabrication des plaquettes qui constituent le casque. En outre, l'analyse tracéologique des plaquettes a mis en évidence une variabilité des choix techniques réalisés par la ou les personnes ayant fabriqué ce casque. Ces choix pouvaient dépendre des caractéristiques et des contraintes liées à la morphologie du support de travail, ainsi que des exigences esthétiques ou fonctionnelles du produit fin.
Le dernier élément abordé dans cette étude, et qui souligne la singularité du casque de Kolonna, est la présence d'un cimier en ivoire d'éléphant. Pièce unique dans le bassin égéen, cet artefact présente plusieurs types de décorations incisées et sculptées. La complexité des décors montre qu'ils ont fait l'objet d'une attention particulière et d'un savoir-faire technique approfondi de la part de l'artisan qui l'a réalisé.
Ainsi, l'exemple de Kolonna met en évidence une chaîne opératoire complexe dans la fabrication de ce type de casque. Plusieurs étapes de production requièrent un savoir-faire technique, des outils spécialisés et des gestes issus d'un artisanat spécialisé. Appartenant à la phase HM II, le casque de Kolonna est l'un des premiers attestés dans le bassin égéen. Il apparaît crucial de comprendre l'émergence technologique de ce type d'objet avant son importante diffusion au Bronze Récent.
Cette étude de cas représente le premier jalon d'une étude plus vaste des casques en défenses de sanglier datant de l'âge du Bronze égéen découverts en Grèce continentale et en Crète. En effet, elle illustre la nécessité de multiplier les analyses technologiques sur des artefacts issus de différents contextes archéologiques. Une telle approche permettrait de mieux appréhender les dynamiques culturelles et techniques dans ces régions, ainsi que d'étudier ces évolutions à travers les différentes phases chronologiques de l'âge du Bronze.
Mots-clés : Âge du Bronze égéen, casque en défenses de sangliers, étude technologique, armes, artisanat.

INTRODUCTION

This paper presents the results of an analysis of the boar's tusk helmet discovered at Kolonna (Aegina) dating to the Middle Helladic II (1850–1700 BCE) and introduces a technological approach to the study of the production systems of these helmets in the Aegean Bronze Age.

Discovered at numerous sites in mainland Greece, Crete, and the Cyclades, boar's tusk helmets are emblematic objects of the Aegean Late Bronze Age (1700–1200 BCE). Since the emergence of Aegean prehistory as a field of study, these helmets, each composed of around a hundred boar's tusk plates attached to a backing made of perishable material, have consistently attracted significant attention in scholarly literature. However, most studies have focused primarily on typological classifications. Indeed, G. Mylonas developed an initial typology of ten types of helmets based on the type and form of the crest, without considering the shape of the plates (Mylonas, 1951, pp. 143–146). J. Borchhardt later proposed an advanced typological classification comprising five types, based exclusively on the number and placement of the perforations on the plates. (Borchhardt, 1972, p. 21). Finally, in his overview of boar's tusk helmets, A. Varvarigos discussed various aspects of their fabrication, including the arrangement of perforations and the methods by which the plates were affixed to a perishable backing, such as leather or textile (Varvarigos, 1981, pp. 129–144).

This contribution, in turn, presents the first technological analysis applied on Aegean Bronze Age boar's tusk helmets. Its aim is to reconstruct the techniques, gestures, tools, know-how, and skills employed in their manufacture, aspects that have, until now, been only marginally documented.

1. KOLONNA AND THE CONTEXT OF THE HELMET'S DISCOVERY: A BRIEF OVERVIEW

The Kolonna site on the island of Aegina is situated in the Saronic Gulf, between the regions of Argolis and Attica. The first archaeological investigation took place in 1811, although the earliest traces of the Bronze Age settlement were only discovered in 1878 (Welter, 1938, pp. 116–119). Between 1966 and 1987, a major excavation campaign directed by H. Walter uncovered a large Middle Bronze Age settlement (Walter and Felten, 1981). During the 1982 campaign, a "warrior tomb" containing a boar's tusk helmet was discovered near the fortification wall (Walter, 1983; Kilian-Dirlmeier, 1997).

This shaft grave was constructed of dry stone and measures 1 m width by 2.90 m length. Inside the grave, a man was buried, lying on his back with his arms folded over his chest. The funerary assemblage associated with this tomb includes a gold diadem, a sword, several daggers, spearheads, bronze razors, arrowheads (bronze and obsidian), several vases and a boar's tusk helmet. The latter was found on the right side of the deceased, positioned between his body and a sword.

Based on the funerary assemblage associated with the deceased, this tomb was initially identified as a "rich warrior's tomb" from the Middle Helladic period (Walter, 1983, p. 184). It was later the focus of a detailed study by I. Kilian-Dirlmeier, who attributed it to the end of the Middle Helladic II period (Kilian-Dirlmeier, 1997, p. 66). A recent study, based on ceramic phasing and the presence of Minoan pottery from Middle Minoan III has confirmed this MH II attribution (Kilian-Dirlmeier, 1997, p. 114; Gauß, 2024, pp. 278–280).

2. MATERIAL AND METHODS

2.1. Selection of the corpus

This helmet comprises 80 plates in boar's tusk and one worked piece in elephant ivory (85 fragments in total; fig. 1) with a total weight of 230 g. Two types of hard animal material were used in its manufacture: lower canines of wild boars for the plates, and elephant ivory for the knob of the helmet. The 80 plates composing the helmet can be divided into three length categories: 25 "large-module" plates, ranging from 5 to 8.8 cm; 46 "medium-module" plates, measuring between 3 and 5 cm; and 10 "small-module" plates, less than 3 cm in length.

Although the plates comprising this helmet belong to the same archaeological assemblage, the boar's tusk plates exhibit varying degrees of taphonomic alteration and preservation. Overall, the colour of the outer surfaces of the plates ranges between whitish, yellowish, brownish or greenish. These colour differences are attributed to contact with bronze material deposited in the tomb, particularly the bronze sword. In addition to the colour, the state of preservation of the plates also varies. Some are intact, retaining their preserved surface, while others show traces of concretions, flaking, or even extensive fractures. Such taphonomic contrasts raise questions regarding their origin.

They may result solely from the taphonomic conditions within the tomb (e.g. the colour of the plates and traces of concretions). Alternatively, they may reflect differences associated with the manufacture and use of the plates, such as the different positions of perforations, which can lead to cracks and fractures.

Thus, the studied assemblage comprises a sample of 18 pieces, selected as the most representative of the entire corpus based on their morphology, state of preservation, and observable technical marks. The assemblage consists of complete plates exhibiting triangular and quadrangular shapes, with lengths ranging from 3.0 to 8.8 cm and weights from 1.02 to 8.8 g.

The methodology employed to reconstruct the technical steps involved in the manufacture of this boar's tusk helmet is based on a macroscopic and low-magnification (20× to 50×) analysis using a digital microscope, focusing on the manufacture and wear marks present on the archaeological material. To identify and characterise these marks, we relied on previous studies of worked boar's tusks from prehistoric contexts in the Balkans and France (Chiquet, 1997; Maigrot, 2005; Marquebielle, 2014; Marquebielle and Fabre, 2021). These observations were then complemented by experimental work (Loescher and Zarka, 2024).

2.2. Boar's tusk as raw material

To manufacture this boar's tusk helmet, artisans could select lower canines from male wild (or feral) boars or from domestic pigs. These lower canines are hollow teeth that continue to grow throughout the animal's lifetime. They have a triangular cross-section and a tapered form, typically curving backward and upward as the tooth grows (fig. 2; Habermehl, 1985; p. 101).

The lower canine consists of three sides. The posterior side is located on the buccal surface of the mandible, the vestibular side faces the premolars and molars, and the lingual side forms the inner surface of the mandible. It was this lingual side that was used to produce the plates.

This lingual side is bordered on each side by edges (fig. 2). An internal edge at the front of the mandible connects the lingual and posterior sides, and an anterior edge located inside the jaw connects the lingual side to the vestibular side. The first is an active part of the tusk, used by the boar to dig the ground and search for food. The second, although situated inside the jaw, also displays significant wear marks resulting from friction with the animal's upper canine.

The lower canines are composed of material that varies in hardness. The surface of the lingual side is covered by a fine layer of enamel (7 on the Mohs scale; Krzyszkowska, 1990, p. 84). The bulk of the canine is composed of dentine (3 on the Mohs scale), which is more compact in the medial and distal parts of the tusk, and less compact in the proximal part. This variation can be explained by the presence of the pulp cavity at the centre of the tooth, which is broad at the base and narrows towards the tip.

3. RECONSTRUCTION OF THE *CHAÎNE OPÉRATOIRE* OF MANUFACTURE

3.1. Acquisition of the raw material

Only lower canines from specimens older than 24 months were selected to make the helmet.[1] Younger animals do not have sufficiently developed canines to be used as a working material for the plates. Several hypotheses can be considered:

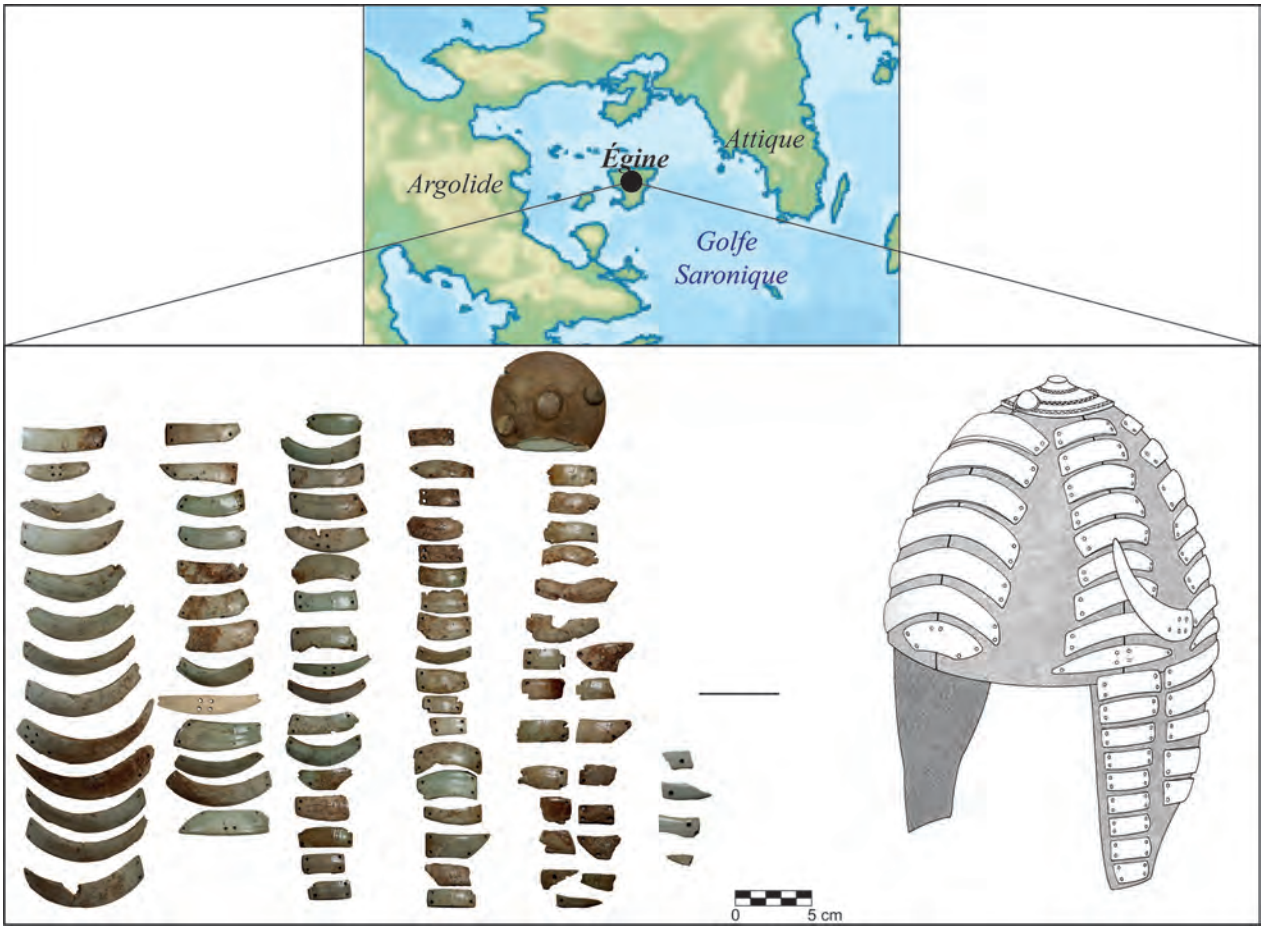

Fig. 1 – Map of Aegina, Boar's tusk helmet elements from Kolonna
(Aegina; Archaeological Museum of Aegina, Inv. No. 118366; restitution of helmet Kilian-Dirlmeier, 1997, p. 39, fig. 18).
Fig. 1 *– Carte d'Aegina, éléments de casque en défenses de sanglier provenant de Kolonna*
(Égine ; musée archéologique d'Égine, inv. no 118366 ; restitution du casque Kilian-Dirlmeier, 1997, p. 39, fig. 18).

- The raw material came from specimens that were either hunted (wild or feral) or raised on the island (domestic). In a second phase, the helmet may have been manufactured on the island. While this hypothesis cannot be entirely dismissed, it remains unlikely, as only a single mandible and a few bones of *Sus scrofa* were discovered in the MBA level at Kolonna (Forstenpointner et al., 2006, p. 178). To date, no workshop devoted to ivory working has been identified, nor any assemblage of unworked boar tusks that would indicate a deliberate strategy for the storage and management of this raw material in the context of craft production. Furthermore, even though a significant number of pig bones were discovered, they mostly belonged to juvenile animals (Galik et al., 2013, p. 165), which excludes the use of domestic pig canines to produce this helmet.
- The raw material came from specimens that were either hunted or raised on the mainland**.** The canines were extracted from specimens elsewhere (human processing method), then imported to and worked on at Aegina.
- The helmet was made elsewhere on the mainland,[2] then imported and deposited at Kolonna.

One of the initial technical steps in the *chaîne opératoire* is to extract a canine from the wild boar. Unfortunately, no traces remain that can be attributed to the extraction technique. However, extraction by fracturing or boiling the skull has been documented since prehistory in Europe, where this technique proved was both effective and widely practised (Marquebielle, 2014, p. 62).

It was crucial that the lower canines remained in good condition after extraction to allow the subsequent steps in the *chaîne opératoire*.

3.2. Reduction and shaping

3.2.1. Débitage *for extract a plate (lingual side)*

The first step in the reduction and shaping of the raw material involved splitting the lower canine in order to extract a plate that would subsequently be shaped. In the case of helmet production, it is the lingual side of the tusk that undergoes reduction (fig. 2). Given that the lower canine of a wild boar has a sub-conical morphology with a triangular cross-section (fig. 2), the splitting may have been facilitated both by this natural shape and by the wear or structural fragility at the tusk's edges. The internal edge

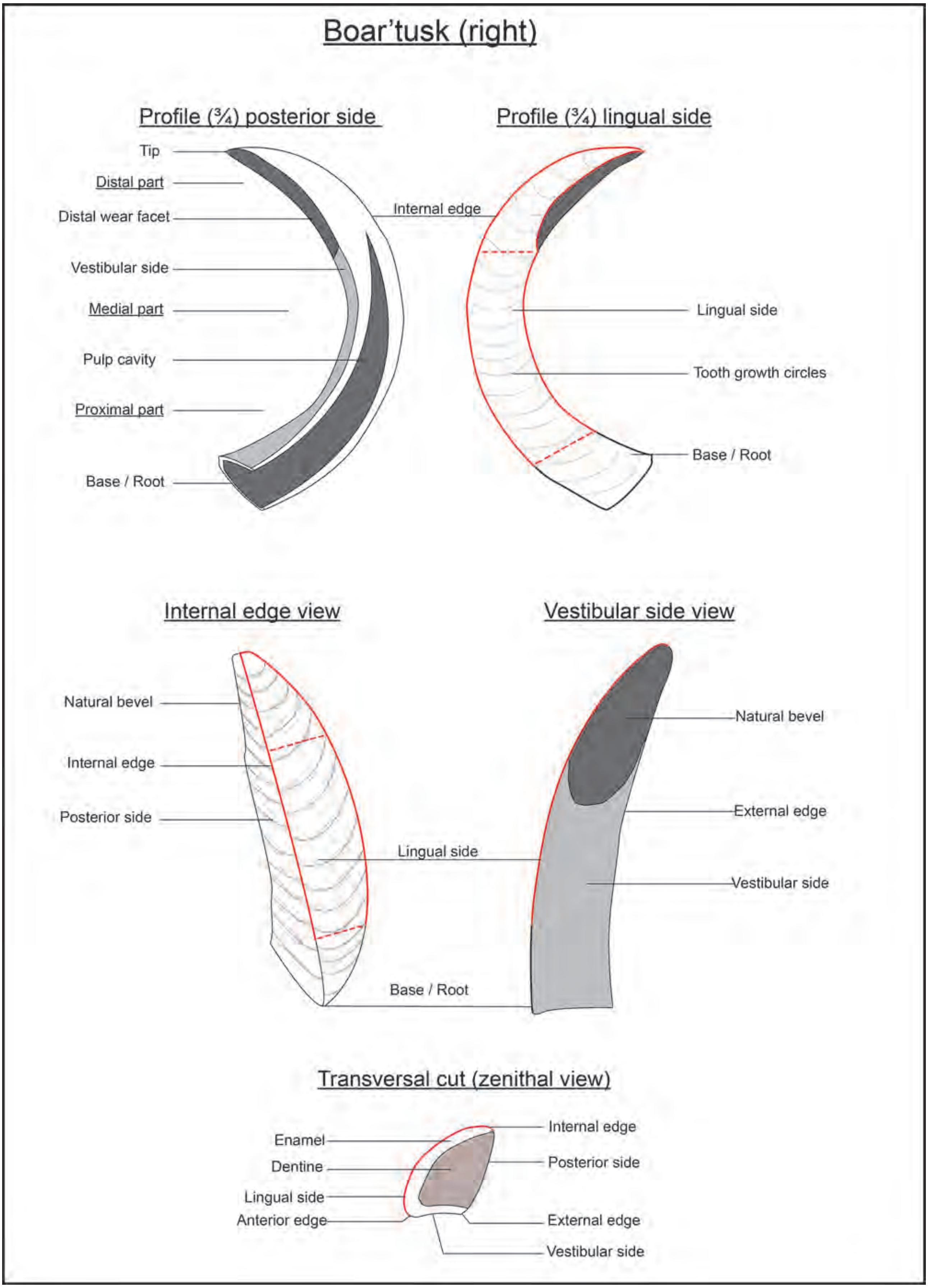

Fig. 2 – Scheme of boar's tusk (after Marquebielle and Fabre 2015).
***Fig. 2** – Schéma d'une défense de sanglier (d'après Marquebielle et Fabre, 2015).*

naturally exhibits traces of wear, such as fissures or minor material loss, resulting from the animal's rooting activity. The anterior edge is similarly amenable to working, as the vestibular side remains very thin along the first two-thirds of the tusk due to the presence of the pulp cavity.

To identify traces of splitting, attention was focused on the lateral sides of the plates, corresponding to the internal and anterior edges of the canine. These lateral surfaces exhibit areas with dense, straight, regular, and parallel striations (fig. 3b, fig. 3e, fig. 3g, fig. 3h). On each side, the striations vary in orientation from vertical to oblique relative to the long axis of tusk growth (fig. 3b and fig. 3e). The attribution of these striations to a tusk-splitting technique remains uncertain; they are more plausibly associated with abrasion processes.

In summary, the traces observed on the plates of the Kolonna helmet do not allow for the precise identification of the techniques or tools used to split the tusks. A technological study of Mycenaean boar's tusk helmets from the Middle Helladic III period (1700–1600 BCE) could help to clarify this sequence of manufacture. Combined with experimental approaches, such an analysis would provide valuable insights into the operational gestures and methods employed by the artisans.

3.2.2. Shaping the inner surface

The second step undertaken by the artisans was to regularise the inner surface of the plate. Since this surface naturally contains the pulp cavity of the tusk, the aim of this stage was to reduce or remove this concavity and to regularise the inner face. Each plate examined exhibits several areas of striations distributed across the inner surface. Their multidirectional orientations, along with overlapping zones (fig. 4a-d), indicate that multiple scraping sequences and repositioning of the working tool edge were carried out on each plate. When the hollow of the pulp cavity is still preserved, the striations are mainly concentrated around it (fig. 4c). In contrast, plates in which the pulp cavity is absent exhibit extensive striations covering the entire surface of the inner surface (fig. 3c).

The striations observed on the plates can be classified Into two main types. The first comprises broad, deep striations, sometimes overlapping (fig. 4a and fig. 4c). The second is characterised by finer, narrower striations that run parallel to one another (fig. 4e, fig. 4f, and fig. 4h). Both types of striations coexist on the plates, indicating the performance of two distinct operations. The sequence of their formation is variable: some broad, deep striations intersect areas of finer striations (fig. 4b). This observation suggests that a scraping stage may have been followed by a finishing operation, such as polishing.

Flint or obsidian scrapers may have been employed to create deep striations and reduce the concavity of the pulp cavity. Abraders, such as sandstone and emery, or abrasive powders such as quartzite or emery sands, known from this period (Boleti, 2017), may have been used to produce the finer striations observed on the inner surface of the plate.

3.2.3. Shaping of proximal and distal parts

The scraping striations identified on the inner surface of the plates appear to have been interrupted by the initial cutting of the proximal and distal ends (fig. 4a). This superimposition of traces indicates that scraping occurred before the cutting of the extremities.

The shaping of the proximal part of a plate served to remove the thinner, less compact portion at the base of the tusk, thereby preserving only the denser and mechanically more durable section suitable for further working and use. The morphology of the plate may also have been adjusted according to the artisan's aesthetic preferences or as a response to technical constraints, such as significant wear at the tip of the tusks, commonly observed in older wild boars. This point is particularly noteworthy, as the plates from the Kolonna helmet exhibit considerable morphological variability (see Section 3.2), with the distal parts of some remaining unshaped. In contrast, the proximal part of every plate was deliberately transformed. Although the base of the tusks was removed from all the plates, the presence and morphology of the pulp cavity suggest that most plates were shaped along the section extending from the end of the first third to the end of the second third of the total tusk length.

The proximal and distal parts of all plates exhibit striations that are regular, unidirectional, fine, and parallel. These marks are comparable to those observed on the lateral sides and suggest an abrasion process, which tends to erase traces of cutting. Several initial cutting marks display a V-shaped profile, suggesting the use of a grooving or sawing technique (fig. 4c and fig. 4d).

3.2.4. Perforations

Each plate of the helmet features several perforations, with the number varying between four and six, mostly located near the corners. Two plates are noteworthy because the tip of the tusk was preserved and because of the presence of five perforations on their proximal part (fig. 2). These perforations were made to allow the plates to be assembled onto a lining made of perishable material.[3]

The plates of the Kolonna helmet feature exclusively transverse perforations, each measuring between 1.7 mm and 2.2 mm in diameter. The central portions of the longitudinal profiles of several perforations exhibit convexities (fig. 4e, 4f, and 4j). Moreover, an unfinished perforation initiated from both sides (fig. 4 h) provides evidence for a perforation technique in which drilling was carried out from both sides, with the drill holes meeting at the centre.

Some perforation profiles still exhibit fine, regular striations that are slightly concentric and continuous. In addition, the regular vertical incidence angles and the absence of shoulder angles along the edges of the profiles similarly suggest the use of a mechanical drill. These marks may be attributed to a bow drill or a pump drill (Evely, 1993, pp. 77–82). Different materials may have been used for the drill bits: flint, copper alloy, bones, and

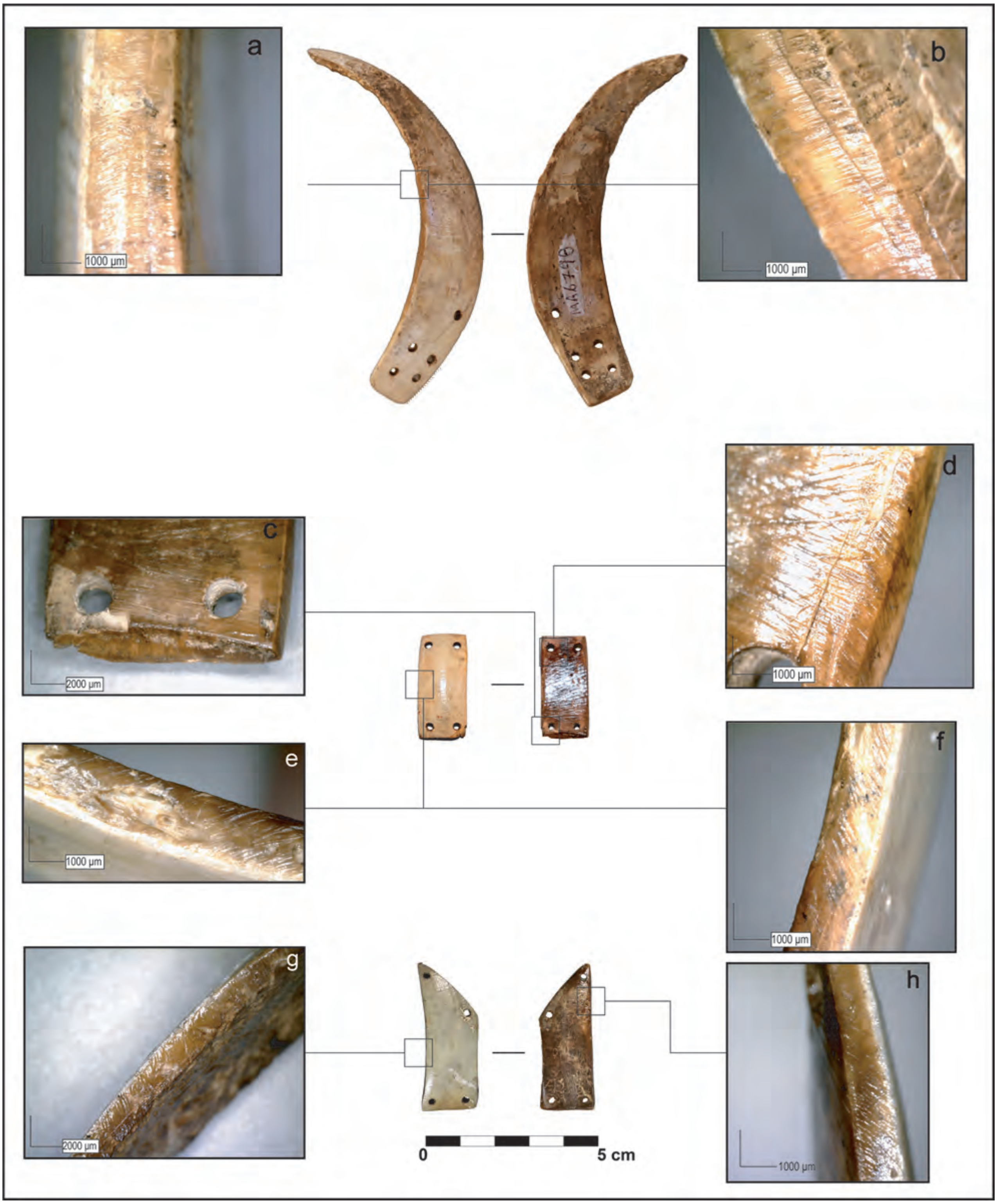

Fig. 3 – Boar's tusk helmet from Kolonna: Traces of splitting and shaping of proximal and distal parts (Archaeological Museum of Aegina, Inv. No. 118366; photos and CAD Q. Zarka).

Fig. 3 *– Casque de Kolonna en défense de sanglier : traces de fente et de façonnage des parties proximale et distale (musée archéologique d'Égine, inv. no 118366 ; clichés et DAO Q. Zarka).*

wood. Furthermore, abrasive sand or emery powder may also have been employed to enhance the efficiency of the drilling process.

The first sequence in this manufacturing step involves preparing an area to accommodate the drill bit and prevent it from slipping. While a simple surface marking using a chisel or a chipped stone tool could have sufficed, no marks of this procedure were observed on the studied artefacts. However, several plates exhibit marks of holes that were initiated but not completed. These dentine per-

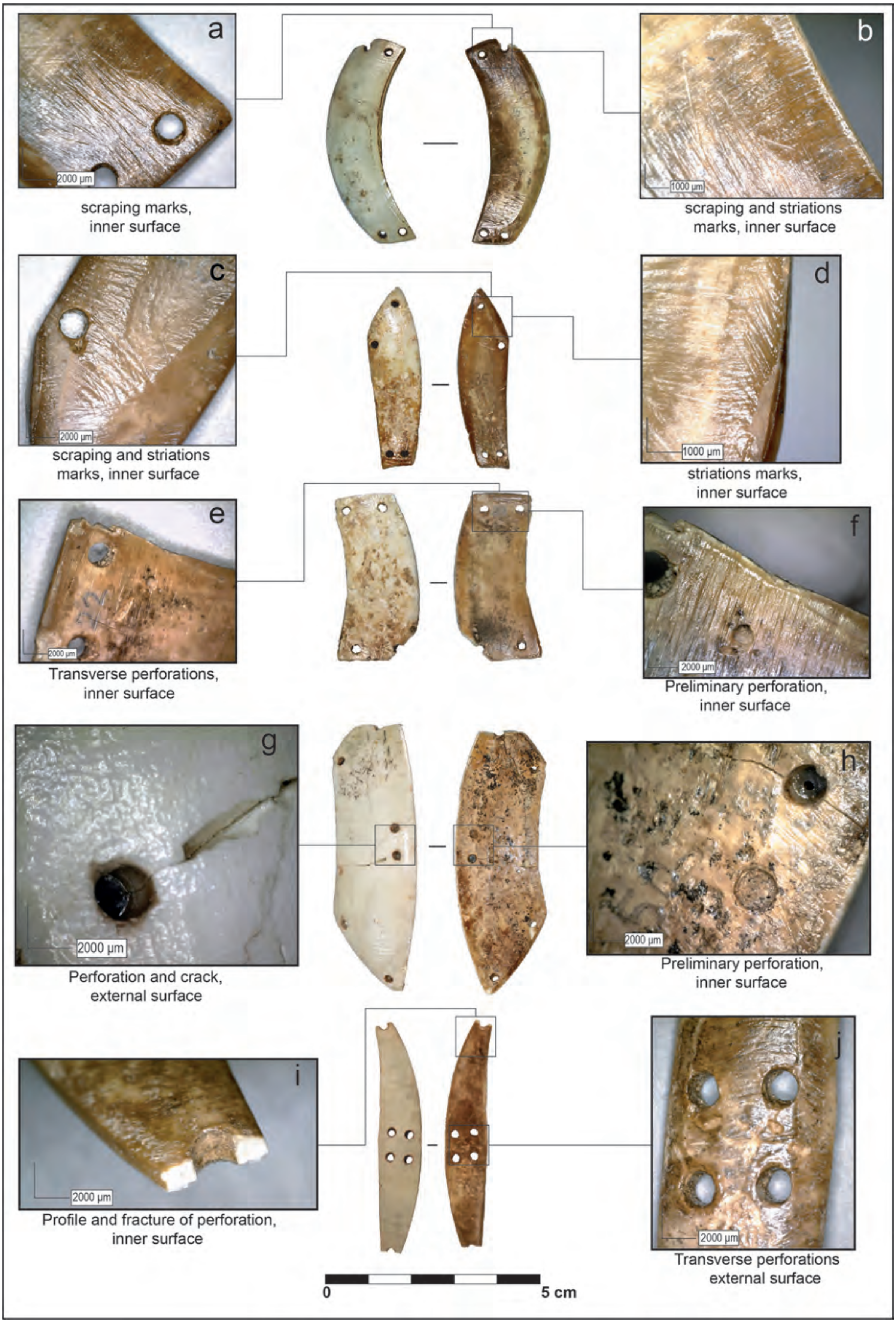

Fig. 4 – Boar's tusk helmet from Kolonna: Scraping striation and perforation marks (Archaeological Museum of Aegina, Inv. No. 118366; photos and CAD Q. Zarka).

Fig. 4 *– Casque de Kolonna en défense de sanglier : stries de raclage et marques de perforation (musée archéologique d'Égine, inv. n° 118366; clichés et DAO Q. Zarka).*

forations are characterised by irregular internal surfaces, with some located close to the final, fully perforated holes (fig. 4e, 4f, and 4h).

Traces of drilling near the final perforations reveal both errors and technical adjustments made by the artisans to ensure that the two perforation cones met correctly. The cause underlying the interruption of a perforation on one of the plates remains uncertain (fig. 4g-4h). The presence of a fissure adjoining another perforation suggests that it developed during the shaping process of the plate, compelling the artisans to alter the positioning of the perforations to minimise the risk of fracture. This choice may also have been prompted by a deliberate revision of the plate's arrangement on the helmet. Moreover, some perforations exhibit traces of material removal on the surface, which may have occurred during their manufacture or reflect wear over time (fig. 4c and 4j).

The marks identified on the plates of the Kolonna helmet indicate that the perforation step was a delicate and technically demanding part of the *chaîne opératoire*, requiring both precision and careful control of the force exerted by the artisans while using the tool. Furthermore, while one plate demonstrates that the artisans were able to work around a significant crack, this observation raises questions regarding the degree of error tolerated during production, as well as the failure rate and the abandonment of workpieces throughout the helmet-making process.

3.3. Sewing and assembly of the helmet

Bringing together the seams of the underlying material onto which the tusks were sewn, and assembling the plates onto a framework constituted the final step in the *chaîne opératoire* for the manufacture of the helmet. In the case of Kolonna, no frameworks or strips have been observed on the surface of the plates or inside the perforations. However, the polished or glossy appearance, along with the colour differences of certain areas between the perforations (fig. 3c and fig. 4e) and the wear observed in and around them (fig. 4i), represent the main indicators. These features may be linked to the application or use of some form of binding.

The morphological variety of the plates, together with the number and positioning of the perforations, suggest the use of an "individual" mode of joining, in which each plate was attached by at least two ties. Although no direct archaeological evidence has survived, braided fibres of either animal origin, such as wool, horsehair, or twisted sinew, or of plant origin, such as flax or nettle, may have been employed during the Bronze Age. This is particularly plausible given that wool, flax, and nettle are documented in the archaeological record (Nosch, 2014, p. 5; Nosch, 2020, pp. 589–591; Spantidaki et Moulherat, 2015).

The final point concerns the arrangement of the plates during the assembly of the helmet. Unfortunately, the publication of the tomb provides no information regarding the taphonomic conditions. Nevertheless, K. Kilian-Dirlmeier proposes a convincing assembly model (Kilian-Dirlmeier, 1997, pp. 39–42, figs. 19–21) based on the morphology of the plates and the number and positioning of the perforations on each plate. Additionally, it draws on comparisons with helmets discovered at other archaeological sites in Greece and Crete during the Late Bronze Age, as well as representations of boar's tusk helmets.[4]

3.4. Elephant ivory knob on top of the helmet

The last element examined in this paper is the knob positioned at the top of the helmet. Unlike the other components, it is a unique piece, being crafted from a cross-section of an elephant's tusk.

The presence of a worked piece of elephant ivory in this tomb at Aegina constitutes an exceptional find for the Middle Bronze Age. While the circulation of ivory is well attested in the Aegean during the Late Bronze Age, it is far less documented for the preceding period, unlike hippopotamus ivory (Poursat, 2018, pp. 176–177). Two sources of supply are identified for the Late Bronze Age (Krzyszkowska, 1988, pp. 225–228). The first source, probably secondary, was located in southern Egypt and Sudan, as the species had already disappeared from the northern regions of Egypt by the end of the First Dynasty (c. 2900 BCE). The second, and principal, source was situated along the Syro-Palestinian coast, as attested by references to large-scale elephant hunts organised under Thutmose I and III for the procurement of tusks. Whether originating from the Syro-Palestinian coast or from Egypt, this ivory most likely transited through Minoan Crete before reaching the shores of mainland Greece.

The knob is relatively well preserved, retaining its original profile, and with some of its ornaments and decorative elements still visible (fig. 5).

The absence of a cavity formed by the pulp, together with the arrangement of the tusk's concentric growth rings, indicates that the piece derives from the medial or distal section near the centre of the tusk (Luciañez-Triviño, 2023). This element lacks the cementum and enamel layers that normally cover the tusk, suggesting that these were deliberately removed, as evidenced by the fine parallel striations (fig. 5f) resulting from abrasive working.

No marks directly resulting from the *débitage* of the raw material could be identified. The flat underside, which might have revealed the techniques and tools used to extract the block, has been polished by abrasion, as evidenced by the presence of fine, shallow, parallel striations. The same applies to the contouring of the piece: one or more shaping stages were likely carried out on the cross-section of the tusk to produce this element, which has a disc-like morphology and lacks cementum and enamel. Nevertheless, fine, longitudinal, parallel striations resulting from deliberate polishing are observable in this area, effectively erasing any traces of earlier manufacturing steps.

The upper surface of the knob is decorated with three sculpted protuberances. Two are hemispherical projections located at the ends of the disc, one of which is now missing. The preserved hemisphere measures 0.9 cm in

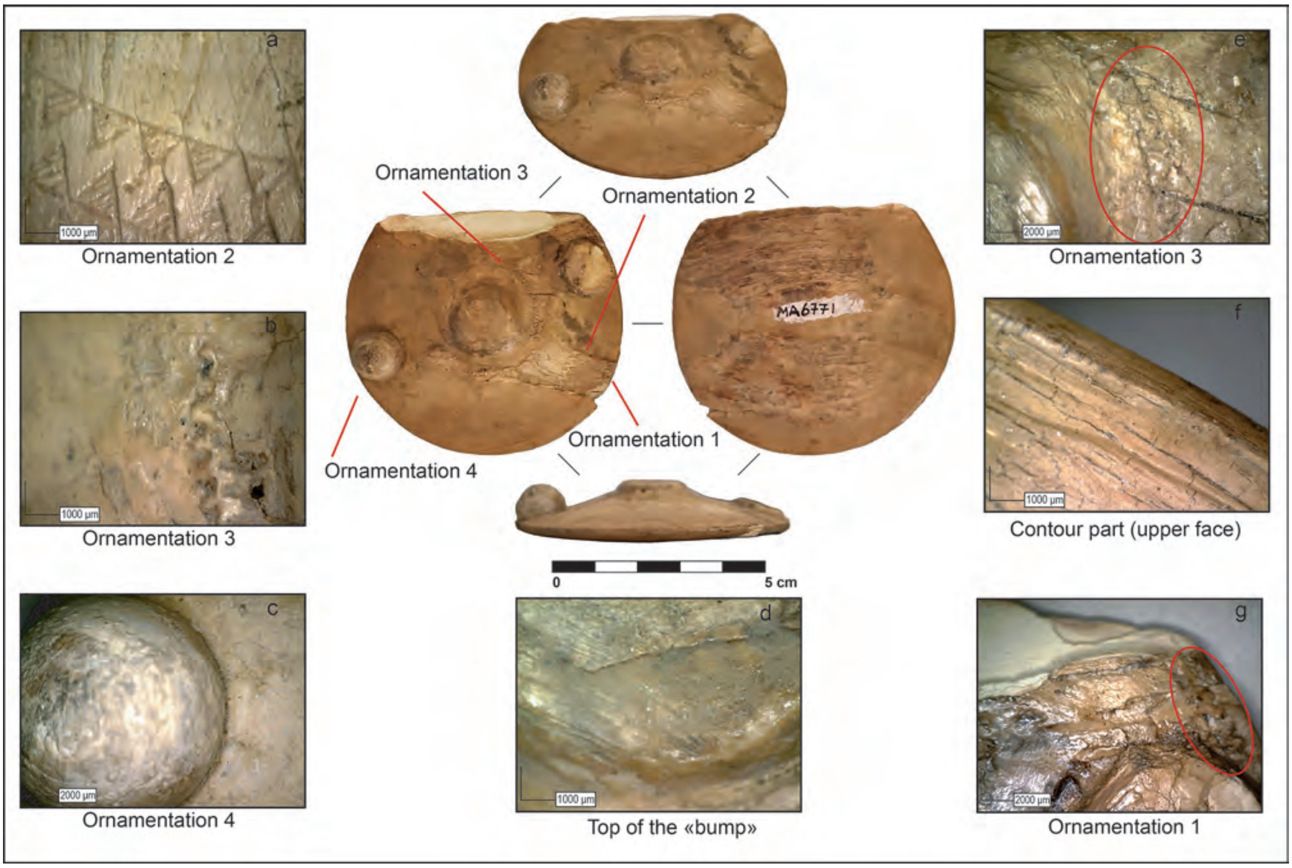

Fig. 5 – Boar's tusk helmet from Kolonna: Elephant ivory knob on the top of the helmet, ornamentation 1 (g), ornamentation 2 (a), ornamentation 3 (b and e) and ornamentation 4 (c; Archaeological Museum of Aegina, Inv. No. 118366; photos and CAD Q. Zarka).
Fig. 5 *– Casque de Kolonna en défense de sanglier : bouton en ivoire d'éléphant au sommet du casque, ornementation 1 (g), ornementation 2 (a), ornementation 3 (b et e) et ornementation 4 (c ; musée archéologique d'Égine, inv. n° 118366, clichés et DAO Q. Zarka).*

height and 1.2 cm in diameter. Fine, shallow, longitudinal striations cover the entire hemisphere, produced by polishing during the object's shaping. The base of the hemisphere exhibits a duller and darker surface, as does a thin surrounding band. This wear pattern may indicate the use of a binding or attachment connecting these decorations to another part of the helmet structure. A flat bump at the centre of the knob forms the final sculpted element of the piece and marks the top of the helmet. Its flat surface is covered with fine, shallow, parallel striations resulting from one of the final polishing stages.

This upper surface also displays three types of carved and incised decorations arranged concentrically:

- The first type of relief decoration is located near the edge of the upper surface of the knob. It is poorly preserved and damaged. It consists of a circular band containing a low-relief zigzag motif, measuring approximately 2 mm in height.
- The second type of incised decoration is situated around the sculpted hemispheres. Also highly fragmentary, it comprises an incised circular band featuring a frieze of opposing triangular zigzags. The band measures about 3 mm in height.
- The last decoration surrounds the top of the knob. Like the first, it takes the form of a circular band, but in a low relief featuring a zigzag pattern. The band's height is about 1 mm.

CONCLUSION

The technological analysis of the Kolonna helmet revealed that it was produced through a complex manufacturing process, with several steps in the *chaîne opératoire* requiring specialised skills and specific tools. The helmet bears traces of adaptations, technical choices, and repairs on the perforations, likely reflecting the actions of both the artisans and, perhaps, the owner as the helmet was used, damaged, and repaired. These perforations inherently weakened the structure of the plates, potentially causing cracks or fractures. It was therefore essential to design and position them carefully to preserve the integrity of the material.

Kolonna's helmet is among the oldest boar's tusk helmets discovered in Greece. Understanding the steps involved in the manufacture of these early helmets from the end of the Middle Helladic period and comparing them with examples from the Late Bronze Age, is essential. Such a comparative approach would enable the identification of developments in both techniques and the types of tools employed across these two periods.

The tusk plates of the Kolonna helmet display several morphological types and perforation placements. This considerable variability in plate production appears to be less pronounced in Mycenaean examples from the Late Bronze Age. The same applies to the polishing of the external and internal surfaces. In the Kolonna helmet, the external surface of the plates (the enamel portion) was left unpolished, while the internal surface was polished using abraders. In contrast, some Mycenaean examples show plates with both surfaces more finely polished.

The increase in the number of boar's tusk helmets during the Late Bronze Age in mainland Greece and Crete, together with the results of this study, raises important questions regarding the sourcing and management of raw materials, and, more broadly, workshop practices. The analysis of the Kolonna helmet shows that male tusks from boars older than two years were specifically selected, and that at least 40 boars would have been needed to craft it. By comparison, some helmets from the Late Bronze Age contained more than 150 plates, requiring tusks from approximately 75 individuals over two years old. (Buchholz and Wiesner, 1977, p. 62). These observations highlight the significant economic and societal implications of the production of such helmets. Firstly, it can be suggested that hunting was not the sole means of obtaining these raw materials. Indeed, the number and selection of tusks required to assemble a helmet suggest the possible use of animals raised in captivity. This practice would, on the one hand, allow for better economic control over the procurement of raw materials and, on the other, provide tusks of a suitable size for the artisan's needs.

The case of the Kolonna helmet highlights the importance of expanding technological studies on boar's tusk helmets. This type of production evidently demanded specialised technical knowledge, encompassing specific techniques, gestures, and tools, applied to a raw material that was difficult to work due to its toughness, elasticity, fragility, and complex morphology. Although these boar's tusk helmets plates have long been considered standardised objects, an analysis of their manufacturing stages demonstrates that their production was not fully standardised. Individual variations, as well as technical choices and mistakes, can be observed among the plates of the Kolonna helmet. Moreover, extending technological analyses to helmets from different sites could help identify workshops or regional particularities in the methods of helmet manufacture on the Greek mainland and Crete.

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FOOTNOTES

1. Study of the animal raw material conducted at the National Museum of Natural History in Paris, currently under publication.
2. Two boar's tusk helmets are attested from the end of the Middle Bronze Age (Middle Helladic III) at Eleusis and Thebes on the Greek mainland (Steinmann, 2012 ; 359-60).
3. The use of a lining made from perishable materials is attested in the *Iliad* (Book X, 260–265) in relation to the boar's tusk helmet. It is further suggested by depictions of helmets from the Late Aegean Bronze Age (including frescoes, ivory reliefs, and other motifs), which indicate features such as linings, neck guards, and chin straps.
4. Depictions of boar's tusk helmets are numerous on frescoes, seals, ivory reliefs, and painted vases during the Aegean Bronze Age. Although later than the chronological phases studied, *Iliad* also provides clues about the composition of this type of helmet. The combination of direct and indirect archaeological sources now makes it possible to better understand this type of object.

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