BONES AT A CROSSROADS

INTEGRATING WORKED BONE RESEARCH WITH ARCHAEOMETRY AND SOCIAL ZOOARCHAEOLOGY

EDITED BY

MARKUS WILD, BEVERLY A. THURBER
STEPHEN RHODES & CHRISTIAN GATES ST-PIERRE

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Introduction

Christian Gates St-Pierre, Markus Wild, Beverly A. Thurber, and Stephen Rhodes

The 13th meeting of the Worked Bone Research Group (WBRG), which took place on October 7th-13th, 2019 at the Département d'anthropologie, Université de Montréal, Canada, featured a variety of activities and participants from many different backgrounds. This collection of 14 of the 48 communications presented at the conference can be seen as a reflection of current trends in the study of worked faunal remains.

The WBRG was founded in 1997 during an informal meeting and became an official working group of the International Council for Archaeozoology (ICAZ) in 2000. The main purposes and overall themes of the WBRG are the improvement of communication between specialists studying past modifications and uses of animal hard tissues (bone, antler, tooth, and shell), as well as the promotion of diachronic, transcultural, and transdisciplinary approaches to osseous industries.[1]

These objectives and approaches promoted by the WBRG provided the blueprint for its 13th meeting, which was organized around the idea that worked bone studies are currently at a crossroads where "archaeozoology meets archaeometry." It allowed researchers from many different continents and working on the most diverse periods and topics to meet and discuss their ideas and discoveries. The 78 conference participants – 46% of them students – from 22 countries presented altogether 48 communications, many adopting various forms of dialogue and integration between the methods and approaches applied in the study of worked bones. Multidisciplinarity comes to mind here. However, worked bone studies should go beyond the mere addition or juxtaposition of a couple of methods or concepts borrowed from other disciplines and aim instead at a truly integrated vision that is more in line with the objectives of interdisciplinary and transdisciplinary research. While important from an epistemological point of view, discussing the distinctions, respective values, and frequent confusions between the related concepts of multi-, inter-, and transdisciplinarity is beyond the scope of our discussion. What should be retained, however, is the necessity to adopt approaches that are increasingly integrative. While such

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[1] Visit the WBRG web site (https://www.wbrg.net/) for more information about the group, including a list of past meetings, publications, forthcoming events, and research resources.

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a call has been made many times before, we feel that it is only beginning to take shape in worked bone studies, and has yet to become standard practice. Fortunately, many papers in this volume exemplify recent and rewarding efforts in that direction. Indeed, most of them discuss bone technology through the lens of various combinations of methods and approaches that are part of a broad definition of what constitutes archaeological science (or archaeometry), which is not limited to the use of quantitative methods borrowed from the hard sciences but makes room for zooarchaeological analysis, microwear analysis, stable isotope analysis, experimental archaeology, and geographic information systems (GIS), to name only those used in the present papers.

This volume also presents a mixture of papers dealing with case studies and methodological discussions alongside approaches to larger cultural and historical phenomena that span thousands of years and many parts of the world: two papers are on South Asia (Vinayak; Shankar), one is on the Near East (Richardson *et al.*), two are on Eastern Europe (Vitezović; Březinová and Hrnčiarik), four are on South America (Buc *et al.*; Klokler; Inostroza Rojas; Gilson and Lessa), two are on Central America (Freiwald *et al.*; Martínez-Polanco *et al.*), and three are on North America (Siebrecht *et al.*; Waselkov *et al.*; Boisvert *et al.*), including the Arctic. Many papers dealing with other topics and other regions, such as Africa, Western Europe, and East Asia, were also presented at the Montréal meeting, and we regret that they could not be included in this volume. This conference, one that was previously held in China, and the next one, to be held in South Africa, are most welcome efforts to hear the voices of Latin American, Asian, and African researchers working on osseous industries. This heralds a continued integration of worldwide colleagues among the WBRG.

While typology is a tool regularly used in these papers to address temporal and spatial changes and continuities, the most frequent themes of the papers are technological and functional approaches. The latter are used to study raw material procurement patterns and strategies (Gilson and Lessa; Martinez-Polanco *et al.*), to address the reconstruction of specific production techniques and *chaînes opératoires* (Boisvert *et al.*; Březinová and Hrnčiarik; Buc *et al.*; Freiwald *et al.*; Gilson and Lessa; Klokler *et al.*; Shankar *et al.*; Waselkov *et al.*), to identify craft specialization or standardization and corresponding activity areas or workshops (Březinová and Hrnčiarik; Freiwald *et al.*; Klokler *et al.*; Martinez-Polanco *et al.*; Richardson *et al.*; Siebrecht *et al.*), to identify specific functions of bone artifacts (Boisvert *et al.*; Březinová and Hrnčiarik; Freiwald *et al.*; Inostroza Rojas; Siebrecht *et al.*; Vinayak; Vitezović *et al.*), and even to identify hidden or hardly visible activities such as bone tool recycling (Freiwald *et al.*) and the use or transformation of non-osseous organic materials, such as textiles (Inostroza Rojas) and asphaltum (Waselkov *et al.*). Despite preservation issues and the associated challenges, the engagement with such rare finds has substantial potential to improve our understanding of past human behavior and societies, including fundamental topics such as knowledge transmission and decision making.

Interestingly, most authors actually use more than just one method, and very often it is the integration of these that lead to the identification and understanding of the social aspects lying behind or within worked bones. This is where social zooarchaeology blends in. Inspired by social archaeology, social zooarchaeology seeks to bring the focus of zooarchaeological analysis and interpretation to the social dimension of the groups, communities, cultures, or civilizations under study, including the social organization of labor and domestic life; power relations; bodies, gender and identity; knowledge transmission; enculturation processes; inter-group and inter-species relations; symbolic behavior and rituals; emotions, senses and lived experiences; *etc*. (Gates St-Pierre *et al.* 2018; Marciniak 2005; Overton and Hamilakis 2013; N. Russell 2012, 2020). In this volume, the authors explore the social context of bone tool production and use (Inostroza Rojas; Richardson *et al.*), technological learning processes (Martinez-Polanco *et al.*), the symbolic dimension of osseous artifacts (Boisvert *et al.*; Klokler; Siebrecht *et al.*; Vitezović *et al.*), intergroup relations (Waselkov *et al.*; Siebrecht *et al.*), and warfare and state formation processes (Vinayak), for example.

Social archaeology is a beast with two heads. In addition to a focus on the social dimension of sites and artifacts, including osseous ones, there is interest in the social meaning, impact, and relevance of archaeology, including worked bone studies, in today's world. This other facet of social archaeology highlights and questions the active role of the archaeologist as an agent of action and change regarding contemporary social issues. This archaeological praxis necessitates a certain dose of reflexivity and can take many different forms, be it public archaeology, Indigenous archaeology, reconciliation and decolonization endeavors, an archaeology of the contemporary past, disclosing the politics of archaeology, as well as critically evaluating archaeological heritage management, the ways we exhibit archaeology at the museum, or how archaeology is depicted in popular culture, among many other examples (Cipolla 2020; Loewen *et al.* 2010; Meskell and Preucel 2007; Meskell *et al.* 2001). Our decision to let the authors have a second abstract in a language of their choice in this volume is an additional small step to make our research more accessible and relevant to a wider audience.

The organizers of the Montréal conference were concerned with this other half of social archaeology as they tried to include the voices of Indigenous people in the conference programming. They were honored to have the new Commissioner of Indigenous Affairs of the City of Montréal, Me Marie-Ève Bordeleau (Cree), deliver an opening address to the conference attendees. They also combined a visit of an Indigenous archeological site with a visit of a thriving contemporary Indigenous community, the Mohawk community of Kahnawà:ke. This enabled the attendees to converse with a community that is more than ever involved in archaeological research through decolonized and collaborative projects. However, the voices of Indigenous archaeologists in the conference scientific programme itself were nearly absent. This should not be interpreted as denoting a lack of will or effort from the organizers in that direction, but rather as an actual lack of Indigenous archaeologists trained in worked bone studies. Clearly, more will have to be done to make our WBRG more inclusive of Indigenous people and other minorities, not only from the Americas but also from the rest of the globe.

The organizers of the meeting also regret that the Indigenous artists they invited to present their work during the conference were not able to make it. Contemporary Indigenous artists such as Euroma Awashish (Attikamekw), Mattiusi Iyaituk (Inuit) and Sonia Robertson (Innu) regularly include animal skeletal elements in their artwork in very personal and creative ways (see Igloliorte 2016; Marcoux 2016). This allows the exploration of yet another dimension of what it means "to work bone." It should also serve as a reminder that integrative approaches should not be limited to the integration of scientific disciplines but also include artistic ones. The arts and sciences are not antithetical, incompatible opposites: they are simply different yet complementary ways

Figure 1. WBRG conference participants.

of making sense of the world we live in (Hamilakis 2007; Jameson *et al.* 2003; Pearson and Shanks 2001; Renfrew 2003; Renfrew *et al*. 2004; Russell and Cochrane 2014). It is our hope that archaeologists in general, and worked bone specialists in particular, will continue to be creative in their explorations of the connections within and among the sciences as well as between their discipline and other ways of knowing or talking about the world, such as the arts and oral traditions, without being afraid of sounding less scientific to their peers.

Having this plurality of approaches, methods, periods, and geographical areas in mind, we decided to avoid ordering the papers simply by chronology or geography. The first papers deal with large scale analyses of different phenomena. They are followed by papers presenting more specific case studies, while the final papers carry a more general message supporting the application of integrated approaches. However, these "parts" do not form isolated entities, which is why there are no sections inside this volume. The papers speak to each other in multiple ways, and we were actually surprised to realize how much they have in common despite their uniqueness and specificity. The chosen order of presentation follows what we think is a more fluid and organic path that reflects these multiple interconnections. We hope that the essence and new directions characterizing these papers and current research in worked bone studies will prosper in our community and beyond.

Finally, we would like to thank the authors for their contributions to this volume and their much appreciated collaboration and enthusiasm; the reviewers of the papers for their invaluable feedback; Karsten Wentink and the staff of Sidestone Press for their technical and editorial assistance; and the *Fond de recherche du Québec – Société et Culture (FRQSC)* as well as the *Groupe de recherche ArchéoScience/ArchéoSociale (AS2)* for their financial support. We also acknowledge that the 2019 WBRG meeting was held at a multi-millennial crossroads located on unceded Indigenous territory, later to be known as Montréal, where different Indigenous peoples lived and interacted long before the establishment of the French, and we express our gratitude to these Indigenous peoples and their descendants.

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Osseous arrowheads in the Iron Age of the Upper Ganga Plains

Vinayak

Abstract

The worked osseous industry has played an important part in human history for a very long time, but has not yet found an appropriate space in history and archaeological texts. To attract more attention and signify the importance of this industry, in this paper, the osseous arrowheads from the Iron Age found on the Upper Ganga Plains are statistically analyzed and studied from a techno-functional perspective. Then, the analysis is discussed with various contextual backdrops of this period and area to identify the larger implications of these arrowheads within the history of this region. The outcome of this study highlights an increase in the production of osseous arrowheads and their possible use in warfare, which was probably accelerated due to various changes in the sphere of society, religion, economy, and politics.

हदिी सारांश

अस्थमिय वनिर्मिति उद्योग ने बहुत लंबे समय तक मानव इतिहास में एक महत्वपूर्ण भूमकिा नभिाई है, लेकनि उसे अभी तक इतिहास और पुरातात्वकि ग्रंथों में एक उपयुक्त स्थान प्राप्त नहीं हुआ है. इस लेख में, इस उद्योग की ओर अधकि ध्यान आकर्षति करने और इसके महत्व को इंगति करने के लिए, ऊपरी गंगा के मैदानों में पाए जाने वाले लौह युग के अस्थमिय तीरों का सांख्यकिीय वश्लिेषण और एक तकनीकी-कार्यात्मक दृष्टकिोण से अध्ययन कयिा गया है. फरि, इस क्षेत्र के इतिहास के भीतर इन तीरों के बड़े आशयों की पहचानने लिए, इस अध्ययन के वश्लिेषणों को इस काल और क्षेत्र के वभिन्नि संदर्भगत पृष्ठभूमयिों के साथ चर्चा की गई है. इस अध्ययन के नतीजों से अस्थमिय तीरों के उत्पादन में वृद्धि पर प्रकाश पड़ता है, और शायद इनका उपयोग युद्ध में हुआ हो, जन्हिोंने मुमकनि है उस समय समाज, धर्म, अर्थव्यवस्था और राजनीति के क्षेत्र में हुए वभिन्नि परविर्तनों के कारण तेजी पकड़ी थी.

Keywords: warfare, bone, antler, function

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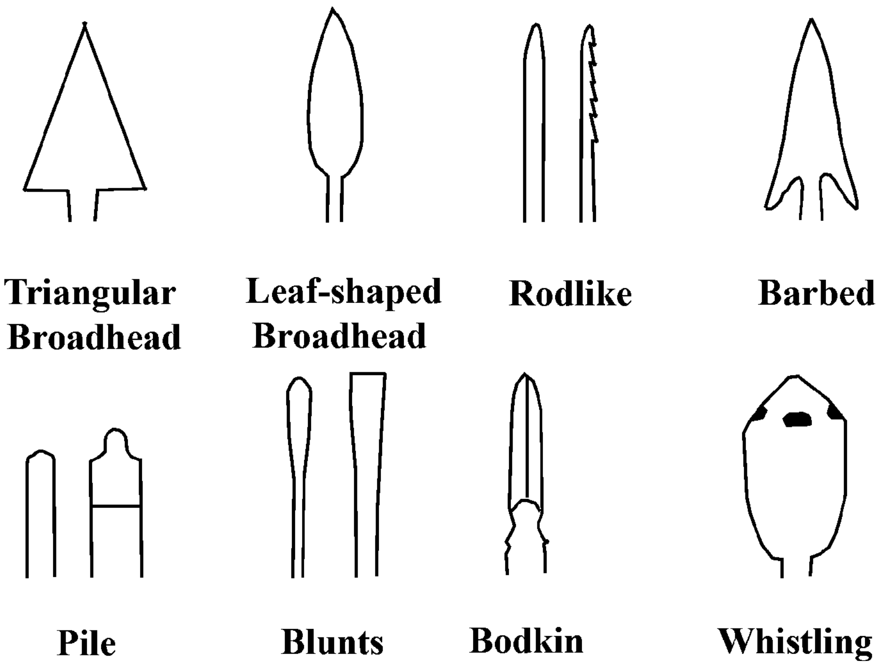

Figure 1. Arrowhead forms (after Grayson *et al.* 2007).

Introduction

Arrowheads made from diverse materials found in distinctive archaeological deposits of different ages are always contentious for archaeologists. They debate their exact function in the past, as weapons for hunting or war (Gottlieb 2016, 1202; Ferencz and Barbu 2012, 66; Vass 2010, 58; Luik 2006, 132; Jensen 2017, 372; Sperling and Luik 2010, 140; Ashkenazi *et al.* 2013). Extensive context-specific research on the functions of a particular tool based on its morphology has been conducted using historical, ethnographic, and experimental data (Pétillon *et al.* 2013; Ferencz and Barbu 2012, 66; Vass 2010, 58; Bosc-Zanardo *et al.* 2009, 341; Knecht 1997; Luik 2006; Jensen 2017; Sperling and Luik 2010; Grayson *et al.* 2007; Yeshurun 2014). However, most of these studies remain inconclusive, unless the contextual details are remarkably clear (Gottlieb 2004, 2016). On techno-functional grounds, most of these studies reach a consensus over the use of needle-shaped or rodlike arrowheads (with a narrow blade used to create puncture wounds) as weapons of war and broadhead arrowheads (usually with a triangular or leaf-shaped blade and a cutting edge that causes profuse bleeding) as hunting weapons (Figure 1). They may have been used interchangeably under different circumstances (Grayson *et al.* 2007; Ferencz and Barbu 2012; Vass 2010; Bosc-Zanardo *et al.* 2009; Luik 2006; Jensen 2017).

The reasoning behind such inferences is that warriors would prefer weapons with greater penetrating power to pin down their opponents as quickly as possible, while hunters would prefer slow death and draining of as much blood as possible from their targets. This would preserve the meat better and make it lighter and easier to carry in the field (Jensen 2017; Grayson *et al.* 2007; Gottlieb 2004, 1951; Ferencz and Barbu 2012, 66). Agreeing with such inferences would imply that most of the osseous arrowheads found in archaeological deposits can be placed in the former category because of their morphology. However, mere morphological analogy should not be enough to decide the function of such objects. There is a need to carefully observe and critically analyze other contextual details, such as the time and

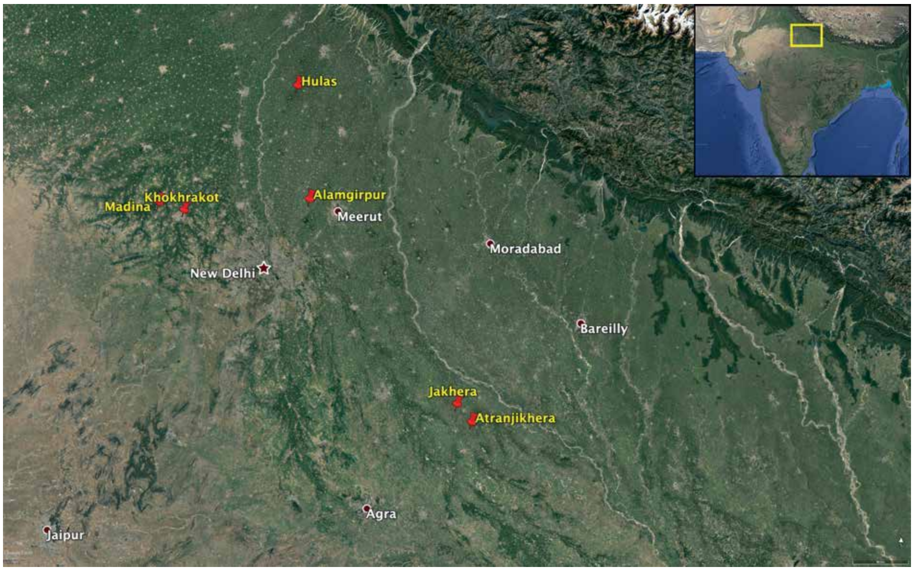

Figure 2. General outline of the Upper Ganga Plains and locations of the archaeological sites studied.

place, *i.e.*, the spatio-temporal context, of the discovery, the historical setting, and so on. Within this framework, an attempt is made in the present paper to understand the function and role played by osseous arrowheads within the Iron Age cultures of the Upper Ganga Plains.

The archaeological finds from various sites on the Ganga Plains, in which the Upper Ganga Plains fall, include osseous arrowheads used from the Stone Age and into the Iron Age (Figure 2) (Pandey 1990; Vikrama and Chattopadhyaya 2002; Gaur 1983; A. K. Narain 1968; A. L. Narain 1974; Salahuddin and Alam 2000; Singh 1979, 1994; Banerjee 1965; Srivastava 1986; Tripathi 1976, 2001; Chattopadhyay and Bandyopadhyay 2015; Vinayak 2016). They, therefore, have a long history of use in this region. However, as is the case with other regions of the Indian subcontinent, little attention has been paid to these artifacts by scholars. As a result, related studies are rare (but see, *e.g.*, Narain 1974).

These arrowheads are commonly listed as minor finds in excavation reports. The reports may not contain the exact numbers of arrowheads. Furthermore, the number of reports published is very low. This situation has come about due to a number of reasons highlighted by Vinayak (2016). The reasons include that osseous arrowheads are considered weak and incapable of disabling or killing large creatures (Singh 1994; Sharma 1960) and that they may have been produced and used by marginalized groups in society. On the contrary, if we look at other areas of the world, we find that osseous arrowheads have received considerable attention from scholars, for instance, within Europe (Luik 2006; Sperling and Luik 2010). Therefore, further research on the osseous arrowheads from the Iron Age of the Upper Ganga Plains was undertaken.

A preliminary statistical survey conducted by the author at the Iron Age archaeological sites of the Upper Ganga Plains indicated the use of osseous arrowheads on a considerable scale during the Iron Age compared with the preceding and succeeding periods (Gaur 1983; Salahuddin and Alam 2000; Vinayak 2016). However, due to various limitations on the available data, the number of osseous arrowheads used per capita during different periods could not be established (Vinayak 2016). However, the extent of their use indicates that they played important roles in their respective fields of use, specifically hunting, warfare, and sport. An attempt has been made in this paper to look at their functional role on a larger scale, and answers have been sought for the question "which activity was predominantly kept in mind at the time of their production?" through a techno-statistical analysis. To begin answering this question, it is necessary to look into the Iron Age of this region. The next section does so.

The Iron Age of the Upper Ganga Plains

The Early Iron Age in India is marked by the beginning of the use of iron technology, subsequent production and its widespread cultural use across the subcontinent (Vaidya 2014). The prevalence and chronology of iron use remain the topics of debate among various scholars (Tewari 2003; Tripathi 2001; Sahu 2006). Despite this, for the Upper Ganga Plains, the commonly accepted dates are from the eleventh to the sixth century BC. Overall, on the basis of archaeological data, chronology, and the first signs of ironworking, Tripathi (2001) divided the early ironworking of the Indian subcontinent into seven different zones. The Iron Age of the Upper Ganga Plains falls in zone B and has been associated with Later Vedic literature and the Painted Grey Ware (PGW) culture of this region with important sites like Jakhera, Atranjikhera, Ahhichhatra, and Hastinapur (Gaur 1983; Sharma 2007; Lal 1984, 1986) The subsequent phase of the Iron Age in this region is considered contemporary with Post-Vedic literature and the emergence of the Northern Black Polished Ware (NBPW) culture, which roughly dates from the sixth to the second or first century BC (Gaur 1983; Sharma 2007).

It is commonly assumed that the use of iron led to changes in the cultural milieu of this region around the first millennium BC. The use of iron is considered an important aspect of state formation in this region. The process of transition "from janapadas to mahajanapadas" culminated in the supremacy of Magadha. Initially, there were sixteen mahajanapadas. In 600 BC, they were reorganized as the four large states of Magadha, Kashi, Anga, and Vatsa, and by 321 BC, the great Mauryan Empire emerged. This millennium is also marked by surplus agricultural production, the rise of urban centers and the consolidation of stratified societies (Chakravarti 2010). While iron technology might have had an edge over other technologies, it does not mean that other technologies or factors did not play their part in these changes. Largely, it seems that the role of iron technology in these changes has been overemphasized. As a result, in recent times, the role played by this technology in these changes has come under serious scrutiny (Chakravarti 2010; Singh 2008). In this context, a small attempt is made here to examine the role of osseous arrowheads in the Iron Age so that the role of osseous technology within these changes can be initially assessed.

Materials and methods

To document every bone and antler arrowhead found at every excavated Iron Age sites of the Upper Ganga Plains is a herculean task. Thus, only six sites were chosen for documentation: Atranjikhera, Jakhera, Madina, Almgirpur, Hulas and Khokhrakot (Figure 2). Their selection was influenced by a number of factors, such as the accessibility of the region, familiarity with the local dialect, and access to archaeological material. A total of 1115 osseous objects were examined using a number of techniques to understand how they functioned and were manufactured (Table 1) (Vinayak 2016).

The methodology applied during the study takes into account the registration and analysis of all essential data regarding the artifacts' identification, and morphometry

	Number of Osseous Artifacts Examined		Arrowheads and By-products	
Site	Number	Percentage	Number	Percentage
AGR	13	1.2	8	0.8
ARJ	310	27.8	226	23.0
HLS	1	0.1	1	0.1
JKR	769	69.0	732	74.5
KKT	2	0.2	2	0.2
MDN	20	1.8	15	1.5
Total	1115	100	984	100

Table 1: Total number of osseous artifacts examined. Abbreviations: AGR: Alamgirpur, ARJ: Atranjikhera, HLS: Hulas, JKR: Jakhera, KKT: Khokhrakot, MDN: Madina.

(Beldiman *et al.* 2011, 178). The morphological, physical, and metric aspects (Scheinsohn 2010), macrofracture patterns (Bradfield and Brand 2012), and microscopic structures (Buc 2010) of all the bone and antler arrowheads and their by-products were analyzed. In this way, a database was developed to document all the available osseous products from these sites on the basis of the following properties (reproduced here after Vinayak 2016).

The physical structure (anatomical and taxonomical identification of the raw material) was determined using actual databases. It includes the following entries:

1) Discovery context
(this information is directly documented on the artifact's tag)

a. Trench: Trench number
b. Layer: Layer number
c. Depth: Depth in centimeters

2) Type of raw material used for producing the artifact

a. Animal group: Large/Medium/Small
b. Material: Bone/Antler
c. Animal species: Deer/Buffalo/Horse *etc.*
d. Type of animal species: Wild/Domesticated
e. Skeletal element used for producing the artifact: Metacarpal/Metatarsal/Antler/Rib *etc.*

3) Production stage

Following the international classification scheme for the process of producing osseous artifacts (Skochina 2010, 25; Horwitz *et al.*, 2006, 170; Ashby 2005; MacGregor 1985; Christidou 2001, 41), the arrowhead production process used on the Upper Ganga Plains is divided into three stages. The primary stage involves the initial processing of raw material (removing marrow and meat particles, softening through soaking, *etc.*) and chopping or sawing up complete bones into smaller, workable pieces. The secondary stage involves the conversion of these pieces into blanks and roughouts. The tertiary stage includes the final operations in manufacturing of the object, such as the shaping of pin heads and tips or cutting the teeth of a comb, and finally trimming, smoothing, and finishing.

Color Code	Description
0	Not burned (cream/tan)
1	Slightly burned; localized and < half carbonized
2	Lightly burned; > half carbonized
3	Fully carbonized (completely black)
4	Localized < half calcined (more black than white)
5	> half calcined (more white than black)
6	Fully calcined (completely white)

Table 2. Color codes.

4) Cross-section shape (at the distal end, in the mesial area, and at the proximal end)

Irregular/Circular/Semi-Circular/Oval *etc*.

5) Carbonization status

Yes/No. Color is a deciding factor in determining the carbonization status of osseous materials (Choyke and Daroczi-Szabo 2010). As for ceramics, the temperature of bone roasting (firing) can be measured through their color (Table 2) (Stiner *et al.* 1995, 226; Clark and Ligouis, 2010, 2651). Therefore, a Munsell Soil Color Chart (2009) was used to record the color of each artifact during the analysis.

6) Status of artifact: Intact/Broken (if broken, include when: Manufacture/Use/Post-Depositional Activity/Excavation)

7) Curation and curated area: Distal end/Mesial area/Proximal end

8) Tang type: Well-Defined Tang (WDT)/Not Well-Defined Tang (NWDT)

The metric structure was established on the basis of standard criteria for bone tool analysis (Scheinsohn 2010). Generally, the maximum length, maximum width, maximum height, and weight of each artifact are recorded. However, for arrowheads, the length and width of the mesio-distal part (the pointed end) and the proximal end (the tang length and width or the socket depth and diameter) were also recorded, as was the tip angle. To measure all these details, manual calipers and a protractor were used.

Stone states that

> "*functional studies based on performance characteristics and fracture patterns have been particularly useful in understanding tool forms, where use is indicated by form, such as projectile points.*" (Stone 2011a, 37)

Therefore, arrowheads and their by-products found at selected archaeological sites of the Upper Ganga Plains were analyzed to identify their macrofractures.

To analyze their microscopic structure, I used the criteria initially proposed by Semenov (1964) and developed by LeMoine ((1994); see also Averbouh 2001; Legrand and Sidéra 2007; Sidéra and Legrand 2006, among others (synthesized in Buc 2011)).

For the functional interpretation, a previous experimental database (Buc 2010) and published images and information were used (Fernandez and Buc 2013). Around 11,500 micro and macro photographs and videos were taken during the examination with a

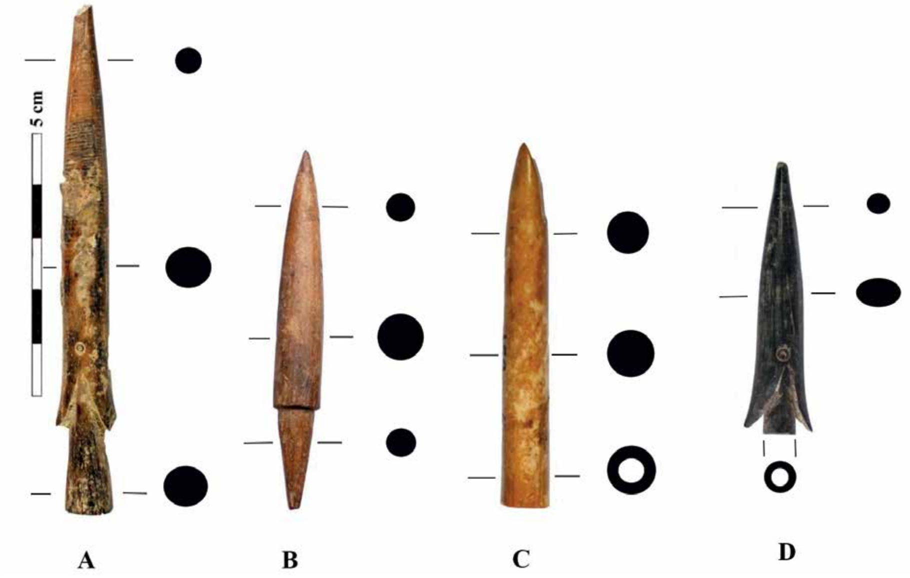

Figure 3. Types of arrowhead reported on the Upper Ganga Plains (a) Barbed Tanged (b) Tanged (c) Socketed (d) Barbed Socketed.

DSLR camera (Canon EOS 550D) and a handheld Dino-Lite digital microscope (AM-413T Pro) at a magnification of 230x. The manufacturing and functional details were recorded on two separate recording forms (for details, see appendix 1 in Vinayak (2016)). to avoid any confusion between manufacturing wear and usewear as well as to obtain a positive result in the investigation. They were designed on the basis of information derived from d'Errico and Backwell 2003; Blumenschine *et al.* 1996; Domınguez-Rodrigo and Yravedra 2009; Bello and Soligo 2008; Greenfield 1999; Lyman 2005; and Averbouh *et al.* 2016.

Results

The use of the methods detailed above revealed various hidden aspects of the osseous industry of the Upper Ganga Plains. A detailed discussion is given in Vinayak (2016). A brief summary of the results follows.

The statistical analysis of bone and antler arrowheads from the archaeological deposits of the first millennium BC, *i.e.*, the Iron Age, shows that they are the most common osseous objects on the Upper Ganga Plains. A rough estimate of the numbers of osseous objects from the selected sites suggests that nearly 55% of them are bone and antler arrowheads (Table 1). Of the 1115 osseous items, 983 were directly or indirectly identified as arrowheads or their by-products in the form of raw material, blanks, debitage, or finished items[1] created at the time of production or use (Table 1). For more details, see appendix 2 of Vinayak (2016).

The morphological analysis of the osseous arrowheads from the Upper Ganga Plains shows that four main types of arrowhead were in use during the first millennium BC.[2]

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[1] Morphologically, these by-products show traits of arrowheads but, due to the lack of any clear identifying feature, they have been placed in the unidentified category.

[2] This classification was performed on the basis of regional categorizations followed by such archaeologists as Gaur (1983) instead of the standardized classification scheme followed globally, which would classify them as "needle" or "broadhead" based on their morphology (Grayson *et al.* 2007).

They are identified as "Tanged," "Socketed," "Barbed Tanged," and "Barbed Socketed" types (Figure 3). Because the length of the tip influences the penetration of a projectile into its target, all the intact arrowheads reported from this region were divided into three groups – short, medium, and long – on the basis of their length (except potential arrowheads).

1) Tanged arrowheads

Tang-shaped arrowheads were the most common osseous arrowheads in the Upper Ganga Plains in the first millennium BC, *i.e.,* the Iron Age. Morphologically, they comprise two segments. The distal segment is known as the point, and the proximal segment is known the tang. The main identifying feature of these arrowheads is the tang. Lengthwise tangs are normally shorter than points, but in exceptional cases, they can be longer. In projectile vocabulary, the place where the segments meet is called the shoulder. In this paper, these arrowheads have been classified into two groups, "Well-Defined Tanged" (WDT) arrowheads and "Not Well-Defined Tanged" (NWDT) arrowheads on the basis of their shoulder shapes (Figure 4). The shoulders of WDT arrowheads are strongly demarcated through a straightened point edge and a narrow tang. For NWDT arrowheads, this demarcation is not clearly visible. The statistical analysis shows that WDT arrowheads might be preferred over NWDT arrowheads by their users due to certain advantages. The well-defined shoulders of WDT arrowheads might prevent them from sinking into their shafts, making the arrows more lethal on impact. Moreover, they might be easier to mount on shafts than NWDT arrowheads.

Both types of arrowhead (WDT and NWDT) are found with various pointed shapes, cross-sections, and lengths. It is difficult to classify these arrowheads according to their point shapes and cross-sections because there are too many variations. As a result, length has been taken as a defining feature for further classification. Out of the 476 tanged arrowheads, only 97 were intact at the time of documentation. These have been divided into three categories: short (less than 42 mm), medium (43-84 mm) and long (above 84 mm). According to this categorization, four tanged arrowheads are short, 60 are medium, and 33 are long.

2) Socketed arrowheads

The second-most popular type of osseous arrowhead in this region is the socketed arrowhead. These arrowheads are mainly robust in their morphology. Except for variation in their lengths, I did not find any difference in their shapes, although, like tanged arrowheads, they exhibit many variations in their tips. Therefore, they have been only classified by length as short (less than 30 mm), medium (31-60 mm), or long (above 60 mm). Out of the 47 socketed arrowheads, only 19 were found intact at the time of documentation. Like tanged arrowheads, they are dominated by medium-size arrowheads, with 13 arrowheads falling in this category, while the short and long categories each have 3 arrowheads.

The arrowheads from this region are known for their good finish and uniform cross-sections. These arrowheads could not be grouped on the basis of their lengths (like pointed and tanged arrowheads) because the point makes up the entire length. However, a statistical analysis of the depth and diameter of their sockets can give us significant information about various aspects of these arrowheads. Of the 47 socketed arrowheads, the depths of 16 sockets and the diameters of 11 arrowheads were measured.

Figure 4. Well-Defined Tanged and Not Well-Defined Tanged arrowheads.

3) Barbed tanged arrowheads

The least-common type of osseous arrowhead from this region is the barbed tanged arrowhead. These arrowheads are also found with different shapes, sizes, and cross-sections. Morphologically, they are identical to socketed arrowheads except for the tang. They are known for their two barbs, which are located opposite each other at the proximal end. The barbs are normally curved outwards from the axis. Longitudinal grooves are normally used to separate the barbs from the main structure. The tangs of these arrowheads are morphologically similar to the tangs of tanged arrowheads. They normally begin at the proximal end of the barb. For decoration, concentric circles were sometimes carved over them. These arrowheads were divided into two categories based on whether they included these circles. All six of the barbed tanged arrowheads were broken, making it impossible to categorize them by length.

4) Barbed socketed arrowheads

After tanged and socketed arrowheads, barbed socketed arrowheads were the third-most common osseous arrowheads in this region. These arrowheads are also found with different shapes, sizes, and cross-sections. They are also known for their two barbs, located opposite each other at the proximal end, but in some cases, there are three barbs. These barbs were created by longitudinal grooves. A total of 12 barbed socketed arrowheads have been documented. Except one, all were broken when found. Therefore, it was not possible to categorize them by length. Instead, they were classified on the basis of the concentric circles used for decorating these arrowheads. Four variations have been noticed: zero, two, three, or four concentric circles. Normally, these concentric circles are located at the edge of the meeting points of the grooves used to create the barbs.

5) Potential and unidentified arrowheads

These are fragments of arrowheads that were separated at the time of production, use, post-depositional activity, excavation, or storage. They are identified as arrowheads on the basis of manufacturing wear and the usewear observed on their surfaces (Table 3). The wear patterns resemble those of arrowheads found at archaeological sites on the Upper Ganga Plains. However, they could not be classified morphologically (as, *e.g.*, tanged, socketed, barbed socketed, or barbed tanged arrowheads) because they do not show any particular signature that is similar to other arrowheads. Therefore, they are listed under the "Potential/Unidentified" category in this study.

6) Blunt/flat-tipped arrowheads

Except for a few cases, the tips of all the documented arrowheads from the sites are conical in shape. In these cases, the tips are either blunt/half circular or completely horizontal (flat) along their axis (Figure 5). The tips were intentionally made this way.

7) Carbonization

Some archaeologists have argued that fire makes bone and antler harder and, in earlier times, it might have been used for strengthening artifacts (Bar-Yosef and Tchernow 1970, 142; Narain 1974). Many arrowheads from the six archaeological sites of this region show signs of various degrees of burning (Table 4) (for more details, see appendix 3 in Vinayak (2016)). This aspect was described by the color, and the six color codes proposed by Stiner *et al.* (1995: 226) were used to identify the degree to which these materials had been burned (Table 2). Therefore, the possibility of intentional fire heating for strength and durability cannot be entirely rejected. However, the timing of the burning is not known; it could have happened during the preparation, utilization, post-utilization, or burial phase.

	Site						
Object Type	AGR	ARJ	HLS	JKR	KKT	MDN	Total
Barbed Socketed Arrowhead	0	3	0	9	0	0	12
Barbed Tanged Arrowhead	0	1	0	5	0	0	6
Blank or Segment	0	3	0	66	0	0	69
Debitage	1	9	0	49	0	0	59
Unidentified	2	32	0	209	0	3	246
Potential Arrowhead	3	15	0	48	0	2	68
Socketed Arrowhead	0	21	0	25	0	1	47
Tanged Arrowhead	2	141	1	321	2	9	476
Total	8	225	1	732	2	15	983

Table 3. Arrowheads from all sites. Abbreviations: AGR: Alamgirpur, ARJ: Atranjikhera, HLS: Hulas, JKR: Jakhera, KKT: Khokhrakot, MDN: Madina.

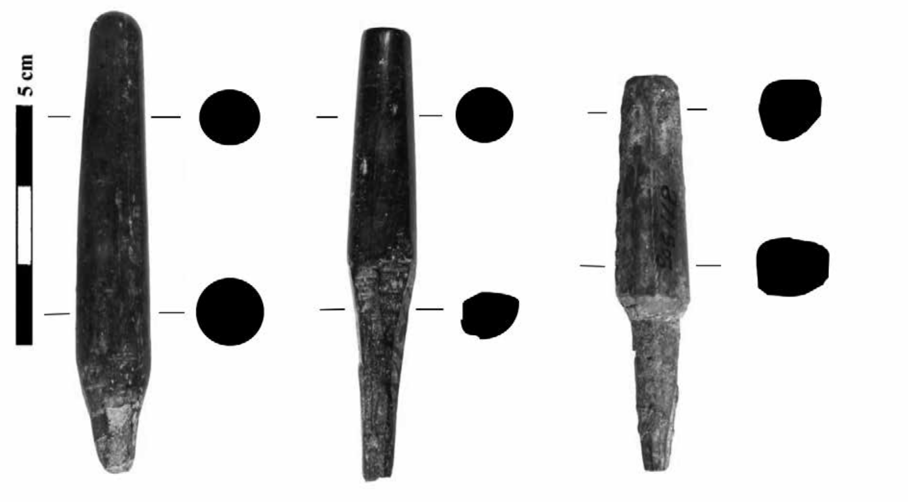

Figure 5. Types of blunt arrowhead.

8) Function

In the absence of human burials and projectile trauma-based studies of animal bones within the study area, it is difficult to know whether these arrowheads were used for warfare, hunting, or entertainment. Moreover, without an experimental study, it is not possible to know how effective they were or how many times they were used. Through a usewear analysis of the arrowheads from the archaeological sites of the Upper Ganga Plains, the author could only gain partial information. Macrofractures on the arrowheads can be easily traced with the naked eye, while the help of a microscope is required to trace microfractures and surface microwear (made by multiple uses). However, neither type of analysis could determine whether they were used as weapons of war or hunting.

Object Type	Burnt	Unburnt	Unknown	Total
Tanged Arrowhead	334	40	102	476
Socketed Arrowhead	32	4	11	47
Barbed Tanged Arrowhead	4	-	2	6
Barbed Socketed Arrowhead	11	-	1	12
Potential Arrowhead	53	3	12	68
Total	434	46	128	609

Table 4. Heating by fire.

Discussion

The present analysis of archaeological bone and antler arrowheads from this region produced several significant results. However, as noted earlier, due to various limitations, it was not possible to determine whether they were used for warfare, hunting, sport, trade, ceremony, symbolism, or other activities (Grayson *et al.* 2007). The little that has been written about the function of these arrowheads in various excavation reports and a few specific research papers is mostly dominated by the bias that they are weak from a technical point of view and incapable of disabling or killing large creatures (Singh 1994; Sharma 1960). This bias has come under serious criticism through the experimental program of the present author (Vinayak 2016). Through a series of experiments, I have demonstrated that bone arrowheads can disable or kill large creatures. Ethnographic and experimental research conducted in different parts of the world has also established that osseous arrowheads can pin down sizable creatures. Therefore, the use of osseous arrowheads from the Iron Age of the Upper Ganga Plains in warfare cannot be entirely ignored. In order to understand the broader intent behind their manufacture in this region, it is necessary to correlate the contextual evidence or details found with these objects and to try to connect them with the historical setting of this period.

Morphologically, if we compare the osseous arrowheads from the Iron Age of the Upper Ganga Plains with the standard classification developed on the basis of various historical, ethnographic and experimental studies from different parts of the world (Grayson *et al.* 2007; Gottlieb 2004), most arrowheads are in the “needle-shaped” or “rodlike” category, some are in the “barbed” category, and a few are in the “blunt” category. In contrast, not a single “broadhead” or “leaf-shaped” arrowhead has been recorded or discovered in this region. Furthermore, when we speak of their functional aspects, needle-shaped and rodlike arrowheads are generally assumed to be meant for war, barbed arrowheads are assumed to be for war as well as for hunting, and broadhead or leaf-shaped arrowheads are assumed to be for hunting; they are blunt to stun or kill birds or small game (Grayson *et al.* 2007). In this respect, most of the osseous arrowheads from this area can be straightforwardly considered war arrowheads. However, as argued in this paper, mere morphological standards should not be the only criterion used to determine the function of these arrowheads.

A better method, may be to examine their functionality by making statistical comparisons with osseous arrowheads from the preceding and following periods. In particular, the excavation of Atranjikhera and Jakhera (Gaur 1983; Sahi 1978; Salahuddin and Alam 2000; Vinayak 2016) revealed that the number of osseous arrowheads recovered from the phases preceding and following the first millennium BC or the Iron Age is so small they can be counted on finger tips. However, due to various limitations (such as the volume of excavated material from archaeological sites, *i.e.*, the dirt excavated, and the exact number of people inhabiting the region at various points *i.e.*, the population) it is difficult to compare them in different periods on the basis of their per capita availability within this region. Still, it is natural to ask why osseous arrowheads were produced on such a scale. Why were they suddenly produced by the hundreds? The answer to this question can be sought within the socio-economic setting as well as the socio-political backdrop of this time.

As pointed out by R. S. Sharma (2007), R. Thapar (2019), R. Chakaravarti (2010), and many others who have written the history of this region, the period under consideration has been marked for various dynamic changes in terms of religion, culture, politics, economy, and society. In the first phase of this period, which extended from the eleventh to the sixth century BC and was marked by the development of the PGW culture and the composition of Later Vedic texts, a demographic shift of Indo-Aryan speakers has been noticed by archaeologists and historians from the undivided Punjab toward the plains of the Indo-Gangetic divide and the Upper Ganga. With this, Brahmanical culture spread into the area, and people who lived there before the shift came into contact with this culture. As noted by Claessen (2006), migration from one region to another can lead to tension, conflict, and war, as it has been observed at many occasions across time and space. This may be seen in migrations from rural to urban areas, from one linguistic area to another, such as the Bihari migration to the Marathi-speaking area or, for a more recent example on the global level, the present-day migration issue in the USA and its politicization by President Donald Trump. In the subsequent phase, which is marked by the emergence of the NBPW culture and the composition of Post-Vedic, Buddhist, and Jain literature, Brahmanical culture continued in this region and further spread into the Middle Ganga Plains and adjoining areas. Therefore, it is possible that when Indo-Aryan speaking people migrated to the Upper Ganga Plains and further east, tensions and conflicts increased in this area, with some turning into war.

On the economic front, various changes in this period have been noted. With the advent and limited use of iron technology in the first phase and large-scale production and use in the subsequent phase, people started living more sedentary lifestyles. Agriculture became more popular than hunting, gathering, and pastoralism. As a result, the dependence on hunting, gathering, and pastoralism decreased. Moreover, the improving agricultural activities resulted in a surplus of agricultural items and encouraged trade. Consequently, the first urban center of the Ganga Plains initially emerged in the Middle Ganga Plains and later spread to the Upper Ganga Plains. Even so, it is assumed that the population grew substantially due to favorable conditions. All these factors led to land becoming more important. Therefore, it is possible that tensions and conflicts grew, and again, some might have been resolved by violence or wars.

In place of the more egalitarian society of earlier times, a hierarchical society began to form in the shape of the Varna Order in the first phase of this period. It was followed by the more complex social hierarchy of the caste system in the second phase. As is well known from various ethno-historical studies, the scale and frequency of conflict are far higher in complex hierarchical societies than in egalitarian societies based on tribal social structures. Therefore, it is once more possible that conflict might have increased in the Upper Ganga Plains during the first millennium BC/Iron Age.

All these changes and circumstances prepared a favorable environment for state formation. How this process occurred in the Ganga Plains is discussed in the earlier part of this paper. However, when these factors are found together, the emergence of an early state is not automatic; some action or event – internal or external – is needed to trigger this development (Claessen 2006). Once again, the process of state formation can lead to conflict. Many other important changes occurred during this period, and they might have led to an increase in the number of conflicts, but discussing them all is beyond the scope of this paper.

The archaeological record does not give much indication of increasing conflict during this period, but various literary texts do. However, the author did not come across any statistical study that could highlight this aspect. Future studies based on a survey of these wars in contemporary texts will be quite helpful.

Conclusion

We return to the primary research question of why the number of osseous arrowheads increased suddenly during the Iron Age of the Upper Ganga Plains. In light of the preceding discussion, it is possible that these arrowheads were used in interpersonal conflicts. However, the mere presence of many weapons does not necessarily mean there was warfare; for instance, during the Cold War, many weapons were possessed by the superpowers, but none were used. Yet, if we try to draw a larger picture of an economy where hunting, gathering, and pastoralism were diminishing and agricultural activities were proliferating, then it is possible that fewer projectiles were produced for hunting. Thus, there is a chance that most of them were produced for war or to maintain peace. This assumption may be applicable to the Iron Age of the Upper Ganga Plains, but more tangible evidence is necessary to establish it firmly. Such evidence will be sought in a future course of research.

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A typo-technological study of bone artifacts from Agiabir, India (*c.* 2300-600 BC/BCE)

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Abstract

The multi-cultural site of Agiabir, located on the left bank of the River Ganga in the Mirzapur district in eastern Uttar Pradesh (India), was discovered in the late 1990s and excavated for eight seasons between 1999 and 2018 by the Department of Ancient Indian History, Culture and Archaeology, Banaras Hindu University (India). Six successive periods of cultural habitation at the site have yielded a rich bone and ivory assemblage comprising 416 artifacts. This paper presents an archaeozoological and experimental study focusing on 124 of them, recovered between 2014 and 2018, predominantly from periods without iron (I-Neolithic and II-Chalcolithic) and periods with iron (III-Pre-Northern Black Polished Ware). The beginning of a longer study, presented here, attempts to trace their *chaîne opératoire* and the role they played in the site's different cultures while addressing the vital question regarding their continued production even with the advent of metal technology. Potentially, every skeletal part could have been optimally exploited; still, this study indicates that certain hard parts (long bones and ivory) of large adult mammals were consistently preferred for a plethora of artifacts. Interestingly, the artifacts' occurrence continued not only to increase but also to diversify through Periods I to III. Therefore, arguably, these bygone craftsmen and consumers alike probably valued bone as highly as other seemingly rarer raw materials like semi-precious stones and metal. The manufacturing techniques involved removing the epiphyses and flaking the diaphyseal blanks to desired shapes followed by retouching and abrading or polishing the working edges by grinding against whetstones in earlier periods and metal in later periods. The remnants of every step in these processes are well-represented in Agiabir's faunal and antiquity assemblages. The nature of their use ranged from tools to styli, hair ornaments, pendants, inscribing pencils, and needles, many of which continue to be made with different raw materials and in present-day India.

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Résumé

Le site multiculturel d'Agiabir, situé sur la rive gauche du Gange dans le district de Mirzapur, à l'est de l'Uttar Pradesh (Inde), a été découvert à la fin des années 1990 et fouillé pendant huit saisons entre 1999 et 2018 par le Département « Histoire ancienne de l'Inde, Culture et Archéologie » de l'Université Hindoue de Bénarès (Inde). Six périodes successives d'occupation culturelle sur le site ont produit un riche assemblage de restes osseux et d'ivoire comprenant 416 artefacts. Cet article présente une étude archéozoologique et expérimentale portant sur 124 d'entre eux, mis au jour entre 2014 et 2018, et principalement issus des périodes dites sans fer (I-Néolithique et II-Chalcolithique) et avec fer (III-Pre-Northern Black Polished Ware). Cette étude préliminaire, présentée ici, tente de retracer la chaîne opératoire de ces divers artefacts et le rôle qu'ils ont joué dans les différentes cultures du site tout en se posant la question fondamentale sur leur production continue même avec l'avènement de la technologie du métal. Potentiellement, chaque partie squelettique aurait pu être exploitée de manière optimale; cependant, cette étude indique que certaines parties dures (os longs et ivoire) de grands mammifères adultes ont toujours été préférés pour la plupart des artefacts. Il est intéressant de noter que l'occurrence des artefacts a continué non seulement d'augmenter, mais également de se diversifier à travers les périodes I à III. Par conséquent, on peut soutenir que ces anciens artisans et consommateurs, appréciaient probablement l'os autant que d'autres matières premières apparemment plus rares comme les pierres semi-précieuses et le métal.

Les techniques de fabrication impliquaient l'élimination de l'épiphyse et le débitage des portions diaphysaires aux formes souhaitées, puis la retouche et l'abrasion ou le polissage des bords travaillés par affutage sur des meules en pierre pour les périodes les plus anciennes et sur du métal pour les périodes ultérieures.

Les vestiges de chaque étape de ces processus sont bien représentés dans les assemblages fauniques et antiques d'Agiabir. La nature de leur utilisation allait des outils de type stylet aux parures de coiffe, pendentifs, crayons pour écrire et aiguilles, dont beaucoup continuent à être fabriqués avec différentes matières premières dans l'Inde actuelle.

Mots clés: Artefacts osseux, Chalcolithique, Vallée du Gange , pré-NBPW

Introduction

Animal remains contribute to the archaeological record in different cultural time frames across the world in fairly large numbers. A range of possibilities can explain their presence: as remnants of leftover food, rituals, or burials, as the debris and end products of manufacturing processes, or simply as post-death assemblages. Also termed "hard animal material," they comprise bones, teeth, antlers, horn cores, carapaces, and shells, and undoubtedly served as a ubiquitous raw material source for past cultures. Their value was enhanced not only by their favourable physical and mechanical properties but also by their availability when there was a shortage or insufficiency of other raw materials, such as stone, metal, or wood. Worked bones (hereafter bone artifacts), specifically, those made from archaeological ivory and bone, are fascinating because unlike lithics, metals, and ceramics, organic artifacts were once part of living animals, and their complexity reflects their origin (Choyke 2005; Cronyn 1990). Despite their ubiquity and the recognition of their utilitarian, social, aesthetic, and symbolic value in antiquity (Tiley-Nel and Antonites

2015; Vercoutere *et al.* 2007; Vitezović 2013), archaeological sites are not the best places for their preservation, partially owing to their perishable nature. From the time of their loss or discard, they undergo many post-depositional alterations. These processes damage the artifacts in permutations and combinations to the extent that their original numbers are either reduced or augmented, leading to under- or overestimation of their frequency. There is a subsequent variable loss of crucial morphological characteristics, which renders them unidentifiable in some cases.

In ancient times, some of the bones could have hypothetically been utilized optimally for the production of various artifacts with diverse functions, such as ornaments, musical instruments, toys, and tools. In endeavours to reconstruct the human-animal inter-relationships of the past, the data gathered from bone artifact studies could be considered supplementary or complementary, adding credence to the faunal analysis from the same site, region, or culture. Occasionally, in the absence or inadequacy of a well-preserved faunal assemblage, they can reveal exclusive clues to recreating, for instance, the paleoecology or faunal diversity of their provenance, differential patterns of utilization (subsistence strategies), the development of craft specialization among the local inhabitants, trading practices, and the socio-economic and political organization of ancient societies. They can tell us about which animals and what skeletal parts were being exploited and how and why the artifacts were manufactured, utilized, and eventually discarded. Furthermore, they can also help to explain why they flourished alongside a conspicuous lithic and/or metal (copper, bronze, iron) industry in the past when the non-osseous ones clearly survived better and served many purposes more efficiently.

Bone artifact studies in India and why Agiabir?

On the Indian subcontinent, bone artifacts have been discovered and documented from prehistoric to historical contexts, giving more-or-less continuous and contiguous evidence of their evolution in terms of style, production, and function. However, they come with their own set of theoretical and methodological issues that have not been satisfactorily explored or resolved by researchers, archaeologists and archaeozoologists alike, in the academic sphere. Emerging and persistently earmarked concerns include rare reporting of assemblages, which results in a focus on attractive or identifiable artifacts, a methodology designed to suit the archaeologist’s perception and a lack of association with faunal assemblages. A typical pattern of reporting is that important numbers from only a handful of sites of different cultural periods are mentioned. These limited details are interspersed with a barrage of information on other “important” antiquities or relegated to the end of the publication, where they are rarely accompanied by photographs. There exists a lack of cohesive and tangible consensus on the terminology to be employed and the descriptive terms for characteristics to create typological or technological categories. In the existing literature, there is inconsistency in descriptions of the type or function of bone artifacts, and cursory reconstructions of the probable *chaîne opératoire* remain, at best, untested general conjectures. For instance, a pointed conical polished or unpolished bone is labelled a projectile, a point, a needle, an awl, and a stylus by different researchers. Typo-technological studies aside, the domain and scope of experimental and traceological studies, which, in general, are not unknown in Indian archaeology, have also not been justifiably applied to bone artifact studies.

As J. Mungur-Medhi *et al.* (2016, 353) observe, existing reports on bone tools in the Indian subcontinent "*do not give a full idea of the technology of tool making, and their overall importance in the culture or the past society.*"

Exceptions are few and far between, with the first in the 1970s, when two attempts at a more profound and broader analysis of bone and antler artifacts were made for Nasik (Banerji 1955), Allahpur (Dikshit 1974), and Chirand (Narain 1974). The authors elucidated possible manufacturing processes based on experiments and ethnographic analogy. After nearly three decades, bone artifact studies witnessed a re-emergence for the sites of Senuwar (Thakur and Jayaswal 1991), Agiabir (A. K. Singh 2009), and Anai (Mungur-Medhi *et al.* 2016). R. K. Chattopadhyay and K. Bandopadhyay (2015) compiled studies of the bone artifacts from the Middle and Lower Ganga Valleys from prehistoric to early historical times in a comprehensive review. Vinayak (2016a; b) was the first to employ an amalgamation of archaeological, ethnographical, experimental, and traceological approaches to the bone and antler arrowheads from Upper Ganga Iron Age sites such as Atranjikhera, Jakhera, Madina, Alamgirpur, Hulas, and Khokhrakot, temporally spanning *c.* 1100-200 BC.

Such studies warrant relatively undisturbed stratigraphic sequences of successive chrono-cultural phases and contribute both faunal remains and bone artifacts to the overall archaeological record. To maintain verity in interpretations of such artifacts, well-conserved contextual units are also important. In the given scenario, which archaeological site or region in India would be a fitting candidate around whose bone artifact assemblages experiments can be designed to explore and bridge the missing links? Earlier studies situated this research theme in the Ganga Plains, an archaeologically rich tri-zonal area divided into the Upper, Middle, and Lower Ganga Plains (Gaur 1983) but chiefly restricted to the upper zone. The Middle Ganga Valley alone (24°30′ N-27°50′ N and 81°47’ E-87°50’ E), flanked by the Ganga-Yamuna river confluence in the west, the border of West Bengal and Bihar in the east, the Himalayas in the north and the Vindhyas in the south, has 41 excavated sites from the Mesolithic to the Early Historic period (Chattopadhyay and Bandopadhyay 2015, 228). Among them, the site of Agiabir fulfilled the criteria and was chosen for a study along these lines. A site with prehistoric, protohistoric, and historical antecedents that has been subjected to systematic and scientific digs, it is one of the few archaeological sites in India whose cultural layers have yielded both faunal and bone and ivory artifact assemblages, with the latter comprising 416 artifacts. The research presented in this paper is based on a study of a select repertoire of 124 of them. They were recovered predominantly from periods without and with iron during the 2014-2019 field seasons since with the advent of iron technology and tools, the frequency and variety of bone artifacts decreased in successive cultural periods. Traditionally, the signatures of bone and antler have been studied through formal analogy, experimentation, and manufacture and usewear analysis (Stone 2011). However, here, since this study has just commenced, the results reported are mainly preliminary. The investigation has two parts. The first focuses on describing the selected archaeological bone artifacts, and the second discusses the experiments performed to recreate some representative types to understand some typo-technological aspects of the archaeologically congruent ones.

Agiabir: Site location and past cultures

The site (25°13’52” N; 82°38’41” E), is spread over 1 km² (main mound: 500 m² with 70 cm of deposit) on the left bank of the River Ganga in the Mirzapur district of eastern Uttar Pradesh (India) and partly eroded by the River Ganga (A. K. Singh 2009, 51) (see Figure 1.1). Katka, the nearest railway station on the Varanasi-Allahabad section of the Northern Railway, is around 2 km southeast of the site. Discovered by A. K. Singh in 1998 (A. K. Singh 1999, 51-56), the western and eastern portions of the mound were initially excavated for three field seasons between 1999 and 2001 (P. Singh and A. K. Singh 2001, 2004) under the aegis of the Department of Ancient Indian History and Archaeology, Banaras Hindu University (Uttar Pradesh, India) by P. Singh and A. K. Singh. From 2005 to 2007, it was subjected to the second round of excavations (Tripathi and Upadhyay 2006-2007, 2008-2009) to probe the later period of occupation of the site. More recently, a third round of excavations was conducted by A. K. Singh (A. K. Singh and Ravi Shankar 2018, 2019) for three field seasons from 2014 to 2019 to obtain a complete cultural sequence from different localities and to procure evidence for the earliest phase of occupation at the site (see Figure 1.2). These digs brought to the forefront six phases of habitation (see Figure 1.3), which represent the site’s growth from a rural hamlet with the beginnings of Neolithic farming in small pockets to a well-developed semi-urban middle Ganga settlement coming under the rule of the early dynasties of historical India.

Period I or the Neolithic Culture [*c.* 2300-1500 BCE/BC], contained within 50 cm of deposit, was discovered and documented in one of the four mounds, *i.e.,* Mound I. The material culture comprised ceramic cookware such as Cord-Impressed Red, Rusticated, Burnished Red, and Gray and Plain Red Ware; small, polished stone celts; and lithic food processing implements employed for incipient agriculture in aggregation with large-scale food collection, both floral and faunal. Terracotta beads, pottery discs, grinding stones, sharpeners, querns, and hopscotches (flat, small, roundish terracotta or stone objects used in play) were also recorded.

The evidence for Period II or the Chalcolithic Culture [*c.* 1500-900 BC] was identified by coarse and medium variants of Black-and-Red, Black-Slipped, and Red Ware. The inhabitants lived in wattle-and-daub structures represented by fragments of burnt clay with reed marks, floor fragments, ovens, and postholes. Smaller antiquities characteristic of this culture included net sinkers, bone points, and clay lamps alongside stone and terracotta beads, which grew into a trading industry. Metal artifacts were found either in singular numbers, such as a copper fish hook, or not at all. The lithic industry comprised microliths, mainly blades, bladelets, flakes, chips, and nodules made of chert, quartz, jasper, and chalcedony.

Period III or the Pre-Northern Black Polished Ware period (henceforth Pre-NBPW), temporally spanning 900-600 BC, saw the advent of iron on a limited non-economic scale accompanied by an expansion of the settlement southwards due to a demographic increase (Das 2016, 162). Burnt floor patches, ovens, silos, post-holes, and ceramics such as Black-Slipped and Red Ware with a conspicuous absence of Black-and-Red Ware were documented. Stone beads and bone points were representative antiquities recovered from these layers.

Period IV or the NBPW period [*c.* 600-200 BC] produced evidence similar to that of the preceding period but was slightly more urbanized, as indicated by rammed floors, post holes, ovens, and kilns along with burnt bricks, which were used in the construction of pipe drains. Potsherds were mainly Black-Slipped Ware and NBPW, a luxury style of burnished pottery used by elites, collected over a larger area. All four mounds were inhabited during this period. Beads of terracotta, faience, and semiprecious stones; bone points; terracotta discs; and copper and iron artifacts comprised the antiquity repertoire.

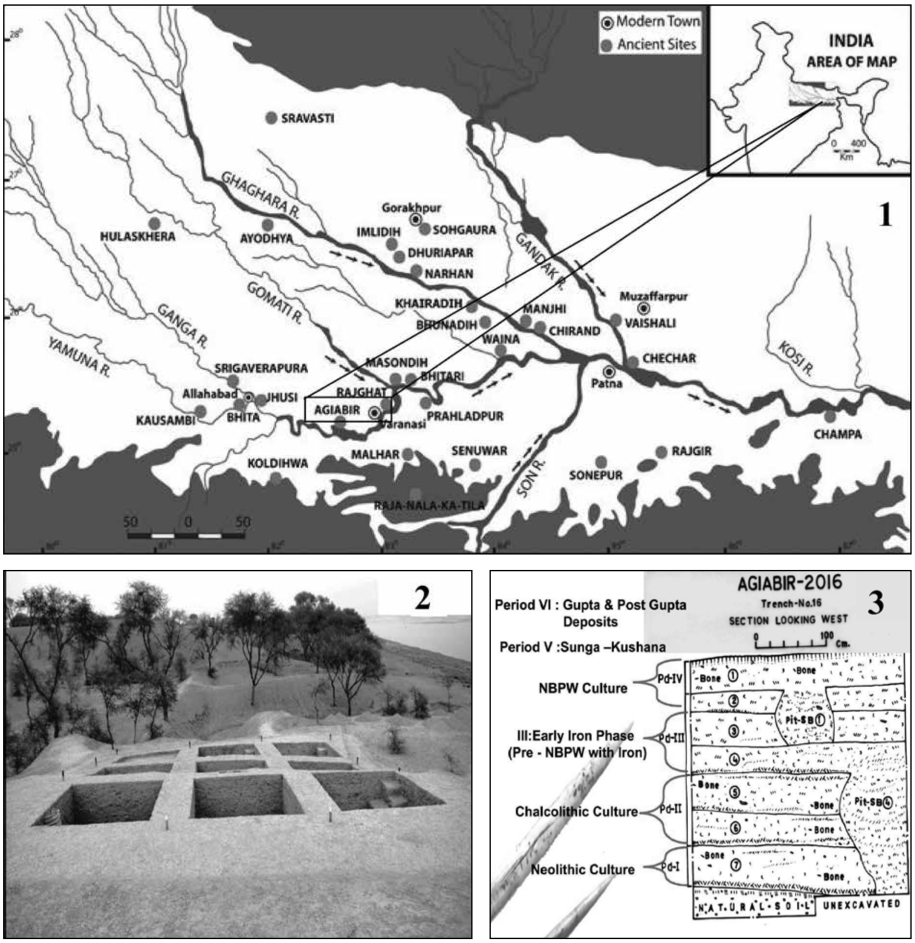


Figure 1. Agiabir. A- Location of the archaeological mound at Agiabir (Uttar Pradesh, India), B- General view of the excavations at Agiabir, C- Section of Trench 16 showing the cultural chronology in sequence.

Period V, the Sunga-Kushana period [*c.* 200 BC- 300 AD], yielded Red Ware used as vases and sprinklers, copper coins, terracotta figurines, iron artifacts, and an ivory seal. Wattle-and-daub structures gave way to more permanent and concrete multi-roomed abodes made of bricks, which were sometimes even reused by later inhabitants. The last cultural period, Period VI, also termed the Gupta/Post-Gupta period [*c.* 300-700 AD], uncovered structural remains in a disturbed state with plenty of antiquities, such as clay seals, beads, stone balls, and iron artifacts.

Archaeofaunal assemblages: Research and results

It is imperative to broadly review the current understanding of Agiabir's faunal repertoire (published in four reports) before delving deeper into the site's bone artifact assemblages and associating these two collections, since the former was most definitely the source of raw material for the production of the latter. A. Deshpande-Mukherjee *et al.* (2006) inspected some of the recovered faunal remains (total number

Culture/Period	**Neolithic Period I***		**Chalcolithic Period II****		**Pre-NBPW with Iron Period III*****	
Species	NISP	NISP%	NISP	NISP%	NISP	NISP%
Cattle (*Bos indicus*)	85	75.9	45	17.3	80	34.8
Buffalo (*Bubalus bubalis*)			2	0.8	8	3.5
Cattle/buffalo (*Bos/Bubalus*)			168	64.6	103	44.8
Goat (*Capra hircus*)			18	6.9	1	0.4
Sheep (*Ovis aries*)	8	7.1				
Goat/sheep (*Capra/Ovis*)			1	0.4	5	2.2
Domestic pig (*Sus domesticus*)			2	0.8	6	2.6
Horse (*Equus caballus*)					1	0.4
Donkey (*Equus asinus*)			1	0.4	4	1.7
Indian gaur (*Bos gaurus*)					6	2.6
Wild pig (*Sus scrofa*)	3	2.7	1	0.4	2	0.9
Nilgai (*Boselaphus tragocamelus*)					5	2.2
Blackbuck (*Antilope cervicapra*)					1	0.4
Four-horned antelope (*Tetracerus quadricornis*)			2	0.8		
Indian gazelle (*Gazella bennetti*)					1	0.4
Spotted deer (*Axis axis*)	1	0.9			1	0.4
Sambar (*Cervus unicolor*)	8	7.1			2	0.9
Barking deer (*Muntiacus muntjak*)	3	2.7	1	0.4		
Dog/jackal/wolf (*Canis familiaris/C. aureas/C. lupis*)	1	0.9				
Indian hare (*Lepus nigricollis*)			2	0.8		
Common house rat (*Rattus rattus*)			2	0.8		
Ganges softshell turtle (*Trionyx gangeticus*)			2	0.8	3	1.3
Indian roofed turtle (*Kachuga tecta*)			1	0.4		
Crane (*Grus grus*)			1	0.4		
River catfish (*Sperata seenghala*)	2	1.8				
Catfish (*Wattagoattu*)			1	0.4		
Freshwater mussel (*Lamellidens* sp.)	1	0.9			1	0.4
Small ruminant			4	1.5		
Carnivore			1	0.4		
Bird			2	0.8		
Fish			1	0.4		
Number of identified specimens (NISP)	112		260		230	
Unidentified fragments	163		126		55	
TNR	275		386		285	

Table 1. Agiabir: species composition and period-wise distribution of faunal remains. *After Joglekar and A. K. Singh 2017; **After Deshpande-Mukherjee *et al*. 2006; Joglekar *et al*. 2010; ***After Deshpande-Mukherjee *et al*. 2006; Joglekar *et al*. 2010, 2010-2011.

of remains (TNR): 329) attributed to the Chalcolithic, Pre-NBPW with Iron, and NBPW periods. In the following years, P. P. Joglekar *et al.* (2010, 2010-2011) and P. P. Joglekar and A. K. Singh (2017) analyzed the faunal remains collected from later excavation seasons (TNR: 505) to elucidate the site's faunal diversity and utilization patterns through all its cultural phases. The 2010-2011 report specifically elaborated the findings of the Period II (Pre-NBPW) faunal study. At the end of the 2016 excavation season, P. P. Joglekar and A. K. Singh (2017) wrote about the faunal assemblage in the Neolithic contexts of three trenches (14, 16, and 21) dug in that season in greater detail (TNR: 275). Cumulatively, the pre- and post-iron cultures of Agiabir (Periods I-III, TNR: 946, see Table 1) revealed a faunal spectrum of 25 species accounting for the 602 identified specimens (see Table 1). Furthermore, the remaining 344 specimens were designated as unidentified fragments of small (<1 cm), medium (1-5 cm), or large (>5 cm) size exhibiting relatively ancient breakage. Large fragments were numerous compared to the other two sizes.

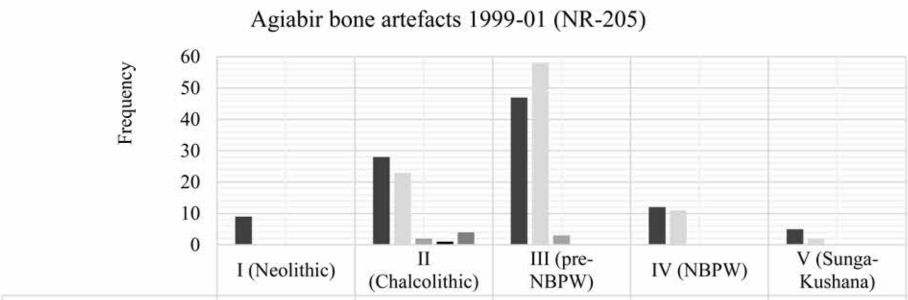
Several similarities in the role and significance of fauna across the various periods of occupation at the site have been observed. Bone preservation was observed to be good, with the overall rate of determination on the higher end (72.2%). With each succeeding period, a greater number of species came to be utilized. Large mammals, almost all known domestic species and, among them, bovids in particular, dominated the assemblages throughout the habitation history of the site, which clearly shows that they were being reared for primary (meat, bone, and marrow) and secondary (milk, wool, hide, traction, and transportation) purposes. Generally, they included cattle, buffalo, sheep, goats, and pigs. Horses and asses were known and probably exploited for secondary purposes by the Pre-NBPW inhabitants. Occasionally, depending on the species, wild animals, such as deer, antelopes, and small game like hares, were either trapped or hunted in the vicinity of the settlement to supplement the food resources. However, only certain body parts were selectively transported to the site for subsequent processing. As the river and forest were near the site, bird-snaring, fishing, and freshwater-mussel-catching added nutrition to the diet. Skeletal parts of both domestic and wild species demonstrated a few taphonomic signatures typical of anthropic treatment for consumption in the form of multiple chop and cut marks, mainly on meat-rich skeletal elements. Some remains yielded evidence of sporadic charring, a result of exposure to fire either naturally or due to cooking activities.

Agiabir bone artifact assemblages

The eight horizontal and vertical digs at the site exposed a rich repertoire of bone artifacts. For those that were retrieved during the 1999-2001 field seasons, the provenance was traced to all cultural periods. These artifacts were analyzed by A. K. Singh (2009). The following section provides a brief review of this past study. Further, a descriptive analysis of the rich bone artifact collection from all the cultural periods, including the Neolithic, assembled during the three seasons of recent excavations at the site (2014-2018), has been attempted. To distinguish between the different raw materials, the reference collections of hard parts of modern animal species and archaeological bone artifacts housed at the archaeozoology laboratory and the archaeology museums at the Deccan College Post Graduate and Research Institute (Pune) and the Department of Ancient Indian History, Culture and Archaeology at Banaras Hindu University (Varanasi) were consulted. The present study is at an initial juncture, and therefore, the observations made are discussed in less detail in the current paper.

Previous studies (1999-2001 assemblages)

In the first corpus of 205 bone artifacts, 175 were from Periods I-III. Typo-technologically, the majority of them were labelled as “points” and “arrowheads” (henceforth AH) by A. K. Singh (see Figure 2). The former type was manufactured primarily from bone and a few (one specimen from Period I, two specimens each from Periods II and III)



	I (Neolithic)	II (Chalcolithic)	III (pre-NBPW)	IV (NBPW)	V (Sunga-Kushana)
■ Points	9	28	47	12	5
■ Tanged AH		23	58	11	2
■ Socketed AH		2	3		
■ Barbed & Socketed AH		1			
■ Barbed & Tanged AH		4			

Figure 2. Agiabir: Period and type-wise distribution of bone artifacts recovered from the 1999-2001 excavations. After A. K. Singh (2009, 52).

from ivory. Points were observed to be shorter and thicker. Based on morphological features, functional edges, and method of handling/hafting, the AHs were categorized as tanged, socketed, barbed and socketed, and barbed and tanged. The tanged AHs were longer and larger than the others with a definite demarcation between the tang and the proximal tapering end. The socketed AHs had a hollow projection at the distal end to attach to a reed or haft. The barbed AHs had lateral tapering projections near the tang or the socket or at the distal end. Similarly, points were divided into single-ended, double-ended with long or short tapering ends, and tanged-and-socketed groups. Generally, a profusion of bone artifact quantities and types was observed in Periods II and III, which yielded 58 and 108 artifacts, respectively. In the next two cultural periods, the numbers reduced to merely 23 and 7 points and tanged AHs respectively. Tanged AHs were found to have a higher representation in Periods II and III, whereas barbed and socketed AHs were comparatively fewer.

Period I or the Neolithic period: Only bone points (NR: 9) were found in this assemblage. They had bold flake scars on the exterior with one or both ends pointed. Some were crude in workmanship with rough bevelling on the body and irregular cross-sections, while others had a fine tip. The ivory point displayed a smooth surface and excellent artistry.

Period II or the Chalcolithic period: A nearly seven-fold increase in the number (NR: 58) and a wider variety of bone artifacts (points and AHs) were evident in this period (see Figure 2). There were just two more AHs (tanged, barbed, and socketed) than points (barbed and socketed). Tanged AHs, made from bone or ivory, were sharp-ended in a few cases. They frequently bore polish or flake scars on their surfaces. The longest one, measuring 24 cm, was found in this assemblage. A punch circlet design was found engraved on the AHs that were not only barbed but also either tanged or socketed. The same design was present on bone points. Some points showed one of the following: rough flake scars that derived from manufacturing, encrustation, discolouration, or usewear marks on the edges.

Period III or the Pre-NBPW period: A further increase, nearly two-fold, was noted in the number (NR: 108) of bone artifacts in this assemblage, but the variety did not change (see Figure 2). The AHs (tanged and socketed), which were more numerous than the points, exhibited a plethora of interesting characteristics. While some had sharp points or well-defined tangs, others had a polished or rough surface. One tanged AH had been made from ivory, and although its exterior was smooth, the tip appeared to bear clear usewear marks and a black tinge. On single- and double-ended points in the assemblage, sometimes the lower portion was sharply cut or showed bold flake scars on the surface.

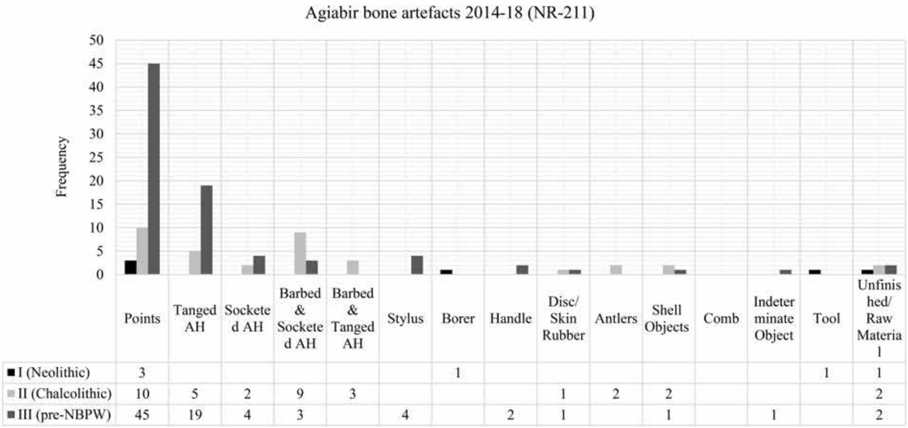
Current study (2014-2018 assemblages)

The sizable collection of 211 artifacts is primarily dominated by bone points (NR: 41) and AHs (NR: 52), as was the case in the previous study (see Figure 3). The same criteria for typological classification as in the previous study have been followed here. This morphology-based categorization agrees with the system followed by Vinayak (2016a and b) in his work on bone artifacts from sites with similar cultural antecedents in the adjoining Upper Ganga Plains. Other types of artifact in the assemblage, which were not diagnosed in the 1999-2001 assemblage, include styli (thin and long, with single- or double-pointed ends and flat cross-sections), borers, handles, disc/skin rubbers, combs, and other tools. Some pieces of bone were tentatively identified as unfinished artifacts that had been discarded during the manufacturing process. Similarly, another set of remains was determined to be debitage or by-products generated during the artifact production process (see Figure 4.1).

Period I or the Neolithic period: Only six artifacts attributed to this culture were recovered. A polished, charred, and partially broken bone point (see Figure 4.2), two fragments identified as unfinished artifacts (roughouts, see Figures 4.3 and 4.4), a double-ended bone point with one end broken (see Figure 4.5), and a bone tool (a borer?) comprised the assemblage of the earliest settlers at the site. One end of the tool was modified to be flattened, U-shaped, and rounded on the edges, while two distinct notches could be discerned along one side. The other end or the butt-end, which was much wider and thicker in comparison, appeared to be rounded and eroded; perhaps it was originally a handhold (see Figure 4.6).

Period II or the Chalcolithic period: Similar to the trends delineated in the previous bone artifact study for Agiabir, a six-fold increase (NR: 36) in the number of artifacts can be highlighted along with greater diversity in the types of artifact that the Chalcolithic inhabitants utilized at the site (see Figure 3). There were nearly twice as many AHs as bone points in this period. The bone points came in two variations: pointed on only one end (unipoint) or both ends (bipoint). The AHs also displayed a variety of forms, with socketed, tanged, barbed and socketed, barbed and tanged distal ends present in the assemblage (see Figure 4.7-10 and 12). The barbed and socketed AHs had punch circlets engraved on them (see Figure 4.11). Except for the bone points and the tanged AH, the other artifacts appeared to have one or both ends damaged. A disc or skin rubber, two antlers, two shell objects, and two pieces of raw material added to the range of artifact typologies.

Period III or the Pre-NBPW with Iron period: From a culture based on lithic and bone artifacts to that of the Chalcolithic period, a society that was familiar with an important metal such as iron, the number of bone artifacts interestingly saw an unexpected increase of two and a half times (NR: 82) when compared to the previous culture as well as slightly greater diversity in artifact typologies (see Figure 3). During the occupation of this site in this period, the inhabitants continued to manufacture and use bone points and AHs in



	Points	Tanged AH	Sockete d AH	Barbed & Sockete d AH	Barbed & Tanged AH	Stylus	Borer	Handle	Disc/ Skin Rubber	Antlers	Shell Objects	Comb	Indeter minate Object	Tool	Unfinis hed/ Raw Materia l
■ I (Neolithic)	3						1							1	1
■ II (Chalcolithic)	10	5	2	9	3				1	2	2				2
■ III (pre-NBPW)	45	19	4	3		4		2	1		1		1		2

Figure 3. Agiabir: Period and shape-wise distribution of bone artifacts from the 2014-2018 excavations.

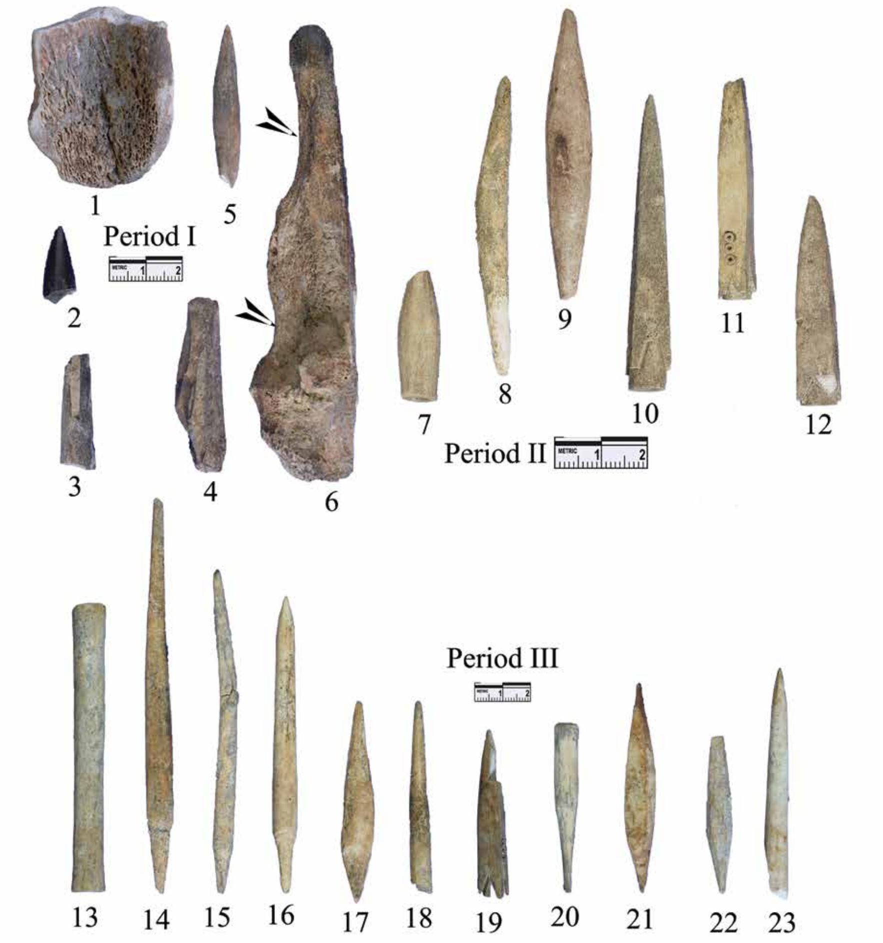


Figure 4. Agiabir: Bone artifacts from the 2014-2018 excavations. Period I (Neolithic): 1-6, Period II (Chalcolithic): 7-12, and Period III (Pre-NBPW with Iron): 13-23.

large numbers (see Figure 4.14-23). While some points had one pointed end, the others were sharp on both ends. The diaphysis of a long bone from a large mammal with its epiphysis cleanly cut off was a rare find in this assemblage (see Figure 4.13). The tangs of some AHs remained intact but appeared eroded and used on the edges. Some AHs exhibited blackened tips. None of the bone points or AHs were charred. A single disc, also called a skin rubber, and a shell object were identified in this cultural period. Two bone handles were a part of this assemblage, as were four styli.

Experimental studies

An actualistic program, designed and conducted by the first author, has been initiated using hard parts of modern animals obtained locally in the city of Varanasi as raw material to reproduce the archaeological points and arrowheads found and documented at Agiabir during the 2014-2018 excavations. This experimental study, still in its initial stages, aims to understand the choices and procedural details that went into the making of the Agiabir bone artifact assemblage. It also aims to examine the site and region-specific variations, if any, that existed and characterized techniques of bone artifact manufacturing employed at the site and in the Middle Ganga Valley as opposed to on the Upper Ganga Plains. It further aims to see if remnants of these techniques and processes can be identified in the archaeofaunal and archaeological record of the site.

Artifacts manufactured from either bone or tooth (ivory), find limited mention in the faunal reports on Agiabir. However, apart from the artifacts themselves, different stages of their production can be discerned from supportive pieces of evidence in the form of isolated epiphyses with clean cut-marks, diaphyseal bone blanks, roughouts, and cut antler fragments. Stone tools, iron implements, and whetstones possibly used for cutting, sharpening, and polishing bone artifacts are also present. For instance, A. Deshpande-Mukherjee *et al.* (2006, 249) noted the presence of bones in the Chalcolithic assemblage that preserved signatures of anthropic modification and use as tools. She pointed to one example, cattle metapodia that had been cut at mid-shaft just above the trochlea after the meat had been processed and possibly shaped into a tool consequently. A scraping tool found in layer 17 of the Pre-NBPW period has been described as having been fashioned out of the distal end of a cattle femur (Joglekar *et al.* 2010, 49).

Through trial and error, this study corroborates the hypothesis that the long bones of large mammals such as cattle or buffalo were a preferred choice of raw material for the production of select artifacts, such as points and AHs. This has been attested to by many researchers (see Vinayak 2016a for a review), who concur that long bones were favoured due to their superior physical and mechanical traits, such as their length, thickness, density, straightness, robustness, and ubiquity. Adult animals were preferred over young ones as the former's bones were fused entirely, had attained the optimum length and density, and could be easily split into longitudinal blanks for further modification (Horwitz *et al.* 2006; MacGregor 1985). The use of antler cannot be wholly negated at Agiabir since fragments have also been positively identified in the archaeofaunal assemblages of all periods (see Figure 5.1-2).

The Neolithic bone tools from Agiabir were not experimentally recreated, but closer scrutiny has revealed how long bones were selectively broken at the mid-point of the diaphysis, with either the proximal or the distal epiphysis retained, probably to serve as digging tools. Two such specimens were found in the Neolithic layers (Period I) of the site.

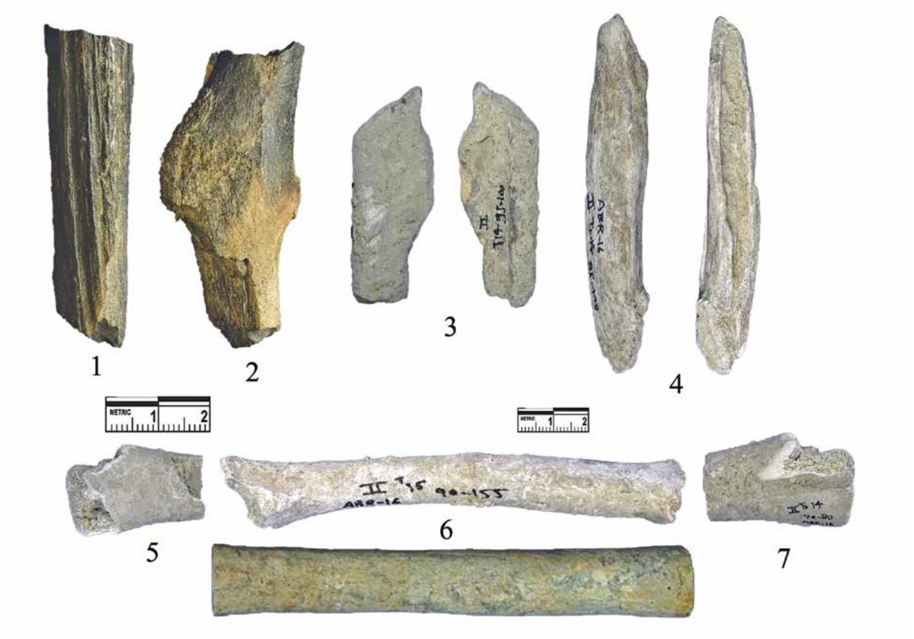


Figure 5. Agiabir: Bone tools and remnants from different stages of the *chaîne opératoire*.

While one is a cattle femur with the distal epiphyseal end and a portion of the diaphysis still intact, the other is a fragment with the scooping/digging diaphyseal end of an unidentified long bone. The presence of several diaphyseal fragments in the assemblage supports their continued use as digging tools or borers even in the succeeding Chalcolithic period or Period II at the site (see Figure 5.3-4). Another technique could have been to remove the epiphyses of long bones for further flaking of the diaphyseal bone blanks to the desired shape. Evidence of this has correspondingly been found both in the Chalcolithic and the Pre-NBPW with Iron assemblages (Periods II and III) of the site (see Figure 5.5-7). These artifacts exhibit some post-depositional impacts in the form of recent fractures and adherent concretion.

Moving forward to other cultures and their respective assemblages at the site, it was decided to reproduce two representative types in the first set of experiments: a point and an AH. For this purpose, 12 dry long bones of cattle and wooden pencil-like shafts without prior boiling and softening were converted or prepared into long thin blanks by the first author. Fresh or green bones were not used as they were greasy and not readily available. The epiphyses were sawed off with a stone scraper or a modern-day metal knife to emulate both pre- and post-iron techniques. Since carbonization is minimal in the archaeological assemblage, pre-firing to strengthen the bone was not done. The bones and wooden shafts were split longitudinally using the stone scraper and the metal knife. All these actions were performed free-hand with the experimenter seated on the floor holding the bone in one hand and the sharp tool in the other. Alternate whittling, wedging, chiselling, shaving, and scraping actions all along the length of the blanks was done until each had attained a cylindrical shape 8-10 cm in length (see Figure 6.1-2). The roughouts thus obtained were processed further with retouches at the tips. For the point, both ends were sharpened. For the AH, the proximal end was sharpened to a point and, a few centimetres from the distal end; a transverse groove was sawn. The distal end from the groove to the edge of the roughout was whittled inward a few millimetres to

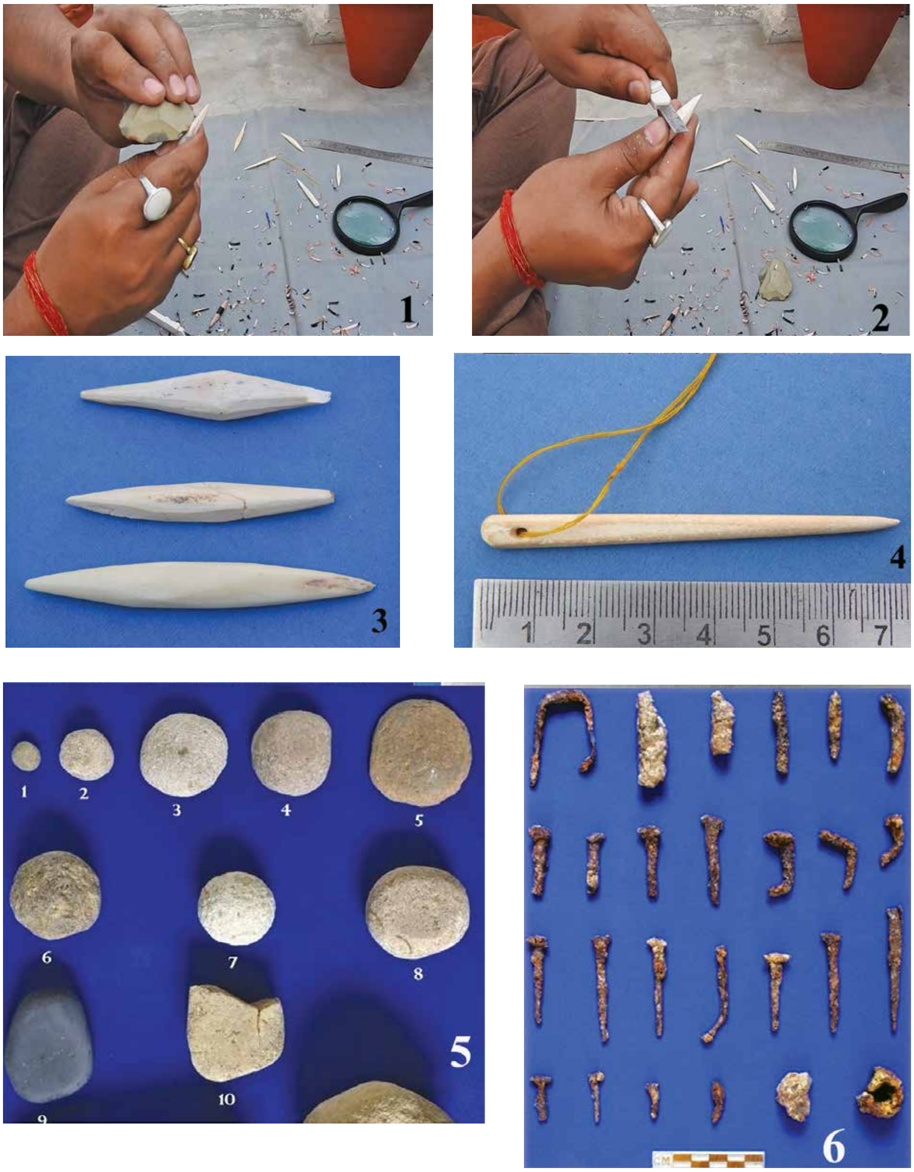


Figure 6. Agiabir: Experimentally produced bone artifacts, archaeological stone (Period II) and iron artifacts (Period III). 1. Experimenter giving a cylindrical shape to a bone blank using a stone scraper. 2. Experimenter retouching the tips of the cylindrical roughout using a metallic knife. 3. An experimentally produced bone point. 4. An experimentally produced needle with a thread passing through its perforation. 5. Stone artifacts from Period II (Chalcolithic) at Agiabir. 6. Iron artifacts from Period III (Pre-NBPW).

create the right-angled shoulder of the tang. The experimental points and AHs were also abraded by rolling and grinding on stone slabs. The finished products appear similar to the archaeological bone artifacts (see Figure 6.3-4). At Agiabir, several whetstones have been recovered from the Chalcolithic and Pre-NBPW periods. These could have been used for polishing the points and AHs. However, with the availability of iron, it is possible that iron artifacts, which are also found at the site from Period III onwards, were used for polishing and sharp chiselling of the bone artifact edges on all sides (see Figure 6.5-6). During the replication process, accidents and errors did occur, which resulted in breakage of the blanks, roughouts, or almost finished products. However, as the experimenter noticed, these could be salvaged and reworked to create shorter points or AHs. In some cases, the broken bits were remade into small bone beads or pendants.

Discussion and interpretations

The data available from Agiabir's faunal and artifact studies, when amalgamated, provide some answers to the questions asked earlier and open a few new ones. Cumulatively, the bone artifact production process is an "extractive-reductive technique" whereby artifacts are fashioned in a step-wise manner by cutting, flaking, and grinding (Emery 2008; LeMoine 2001; Miller 2017; Stone 2011; Vinayak 2016a). At Agiabir, both the production and the diversity of bone artifacts showed a marked increase from the Neolithic period to the Pre-NBPW with Iron period. However, the significance was much greater in the Stone Age than the Metal Age.

By factoring in that they were consumers of meat, as evidenced by archaeofaunal analyses, the Agiabir inhabitants did have access to hard animal parts, such as long bones and antlers, to sustain such production processes over centuries. However, they would have had to ensure access to ivory, a valuable raw material, either locally or through trade, which explains their choice of locations for extended habitation sites near trade routes. Moreover, the selection of raw material for each type of bone artifact was influenced by its properties and availability, manufacturing traditions, specific demands, the craftsmanship of the maker, belief systems, *etc.* (Vinayak 2016a, 3). For this reason, the site was strategically selected for occupation primarily because of its proximity to raw material sources and other important historical cities lying on trade networks. Located 30 km from the Vindhyan mountain ranges and near a regular water source like the River Ganga, the inhabitants had a good supply of both organic (wood, bamboo, bone, *etc.*) and inorganic (stone, metal, *etc.*) means for manufacturing not merely bone but also lithic and metal artifacts in addition to access to other vital requirements, such as navigable routes and fertile land. It is well-established through faunal analyses that animals with a wide range of types and sizes were exploited to satiate the needs of the population. The identification of large mammals like cattle and buffalo, mostly adults, and the presence of large unidentified fragments and diaphyseal fragments extracted from large adult mammals when culled, hunted, or naturally dead, attest to this observation. The earliest settlers were farmers who utilized this raw material to produce and use simpler tools, such as points, borers, and digging tools, which were probably made with the help of other bones and wooden and stone tools using simple techniques.

In the successive Chalcolithic and Pre-NBPW with Iron periods at Agiabir, points and AHs were found in larger quantities and became the chief tools in the toolkit. In the Agiabir artifacts, hafting or the insertion of reed shafts into points and AHs is indicated because of the emphasis on tangs, sockets, and pointed tips. Such composite tools were probably more efficient, as earlier studies have shown (Sharma 1960) for hunting the other species identified in the assemblage, such as deer, antelopes, hares, and birds. Additional applications could have been in warfare, drilling, sketching, inscribing, leather- or skin-working, sewing, weaving, *etc*. The projectile points came with advantages as they were lighter than metal ones, which meant that the ancient people could carry many of them at a time and move swiftly. They could fatally impact targets from a long and safe distance, and their stealth and high velocity enabled deep penetration and the ability to shoot fast-moving targets. Finally, they could be repaired and reused within short durations (Vinayak 2016a). Other artifact types in the assemblage, such as handles, discs, styli, and combs, are yet to be replicated so cannot be further commented on. Elephants have not been identified in the faunal assemblage so far, so it is safe to infer that ivory, in the form of raw material or finished artifacts, was procured from other places. The ivory artifact could also have been discarded, lost, or brought into the settlement as an offering, donation, or gift.

In Period III, however, iron was introduced as an alternative and probably partly advantageous raw material. Societies were gradually undergoing a major transformation from a farm-based rural or village-like configuration to semi-urban spaces with evolving techno-cultural needs. A naturally expected consequence is a simultaneous increase in the number of metal artifacts and diminishing numbers or varieties of bone artifacts. The Agiabir finds tell a different story as the relative number and variety of bone artifacts continued to increase. Among numerous possibilities, it is highly likely that suitable lithic raw materials were not as easily available as they had been before, knowledge about raw material sources was lost, or producers and consumers still did not comprehend the power of metal artifact production and usage, leading to its infrequent use. Iron was not as ubiquitous as bone, and iron artifacts were heavy, too valuable to lose or discard, and not as easy to repair or modify as bone artifacts. In addition to these reasons, there might have been individual and regional preferences in the production of certain types of artifact, leading to the endorsement of bone and antler as primary raw materials (Vinayak 2016a, 87). Therefore, arguably, these bygone craftsmen and consumers alike probably valued bone as highly as other seemingly rarer raw materials like semi-precious stones and metal. But this does not mean that bone technology became stagnant in later societies. Even after the advent of metallurgy, osseous technology was used to manufacture ornaments, tools, and utensils and in areas where the use of metal was still unknown or restricted (Horwitz *et al.* 2006; Schibler 2001, 49; Stone 2011, 6).

In Periods IV-V, some of the iron tools recovered from the site appear to be replicas of their bone counterparts. This shows that even though the raw material changed from Period II to Period IV, the techniques and need to produce similarly shaped and sized artifacts to fulfil the function of their bone counterparts continued in the later periods of Agiabir. The whole of the Gangetic basin transitioned to state formation during these periods, with the supremacy of early historical dynasties established, and iron weaponry played a central role in this process. The newer cultures are marked by rising urban centres, surplus agricultural production, and consolidation of stratified societies (Chakravarti 2010). The decline in bone artifact production and diversity can be explained by the possibility that bones had a degree of “inutility” attached to them or were considered not “modern” enough in comparison to the raw materials, such as ivory or metals used, to manufacture of prestige goods in the new socio-economic and political order (Vinayak 2016a).

Today, the site can provide a partial glimpse into the role and evolution of bone artifacts from the prehistoric period to state formation since it has not been completely exposed and therefore, its antiquities are, at best, a sample of the whole. A majority of the inferences made in this preliminary study are corroborated by similar findings for other sites in the Middle and Upper Ganga Plains, as reviewed earlier. If certain faunal species, artifact types, or remnants of every stage of the manufacturing process are not manifest in Agiabir's archaeological record, it does not imply that they were not there. In other words, an absence of evidence is not necessarily equal to evidence of absence. Excavation techniques, the skills of the researchers, and both pre- and post-depositional taphonomic agents could have impacted their integrity and identification. From this study, new directions for further research have opened up. The *chaîne opératoire* of bone artifacts is certainly a complex process, and phenomena and aspects of it will be taken up in more detail through dedicated lines of inquiry in the future. Consequently, more experiments related to raw material preparation, manufacturing techniques, and usewear, micro-fracture analysis of both archaeological and experimental artifacts, and the use of zooarchaeology by mass spectrometry (ZooMS) of archaeological specimens to identify the animal species used for artifact production are envisaged as the study progresses. Even today, in large parts of India, similar-looking artifacts (points and arrowheads in particular) continue to be made from bamboo, cane, wood, and metal and are used as hair ornaments and knitting needles, for instance. In addition to studying the archaeological artifacts, examining the modern ones experimentally, microscopically, and ethnographically would aid in answering some larger questions, provide insights into the producer-consumer angle, and help reconstruct the socio-economic and cultural past of that site or region.

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Magnifying the differences: Investigating variability in Dorset Paleo-Inuit organic material culture using microscopic analysis

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Abstract

Arctic archaeologists generally accept that Dorset Paleo-Inuit (Tuniit) (*c.* 800 BC-1300 AD) toolkits exhibit high levels of typological uniformity across Arctic Canada and Greenland. This understanding implies that the artifacts were likely produced according to a standardized set of practices that were somehow reinforced over time and shared across the isolated sites and communities inhabiting this vast region. In contrast, recent theoretical developments in the study of technology highlight that material culture traditions are reproduced through localized social practices, and involve both individual and community-based decision-making processes, which would predict a higher level of variability in local manufacture and design features. Our aim in this pilot-study is to test whether Dorset artifacts are, in fact, produced and used in highly standardized ways. We focus on two important tool types crucial to survival in the North: needles and harpoon heads. We sampled assemblages from three Dorset sites located up to 800 km from one other and dating to different Dorset cultural periods. Our results indicate that the sets of tools were made and used in very different ways despite their outward typological similarity. This may reflect the fact that local technological traditions were being learned and practiced differently at each site, though much more work is needed to fully understand the implications of these results in terms of social learning, cultural inheritance, and inter-regional interaction patterns.

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ᐅᑭᐅᖅᑕᖅᑐᒥ ᐃᑦᑕᕐᓂᑕᓕᕆᔨᑦᑐᖅ ᐊᖏᖅᓯᒪᔪᑦ ᑐᐊᓯᑦ ᐃᓅᖅᑳᖅᑐᒥᓃᑦ-ᐃᓄᐃᑦ (ᑐᓃᑦ) (c. 800 BC-1300 AD) ᓴᓇᕐᕈᑏᑦ ᑕᑯᑎᑦᑎᔪᑦ ᖃᓄᐃᑦᑑᓂᖏᑦ ᐊᔾᔨᒌᙱᓐᓂᖏᑦ ᐅᑭᐅᖅᑕᖅᑐᓖᒥ ᑲᓇᑕᒥ ᐊᒻᒪᓗ ᑲᓛᓪᓖᑦ ᓄᓇᖓᓂ. ᑕᒪᓐᓇ ᑐᑭᓯᐊᓇᖅᑐᑦ ᐱᓪᓕᕆᐅᓂᖏᑎᒍᑦ ᐃᑦᑕᕐᓂᑕᐃᑦ ᓱᓇᐃᑦ ᐱᔾᔪᑎᒋᔭᖏᑦ ᒪᓕᑦᑐᒍ ᐋᖅᑭᒃᑕᐅᓯᒪᓂᖏᑦ ᑐᙵᕕᒋᔭᐅᔪᒃᑯᑦ ᐊᑐᖅᑕᐅᔪᑦ ᖃᓄᑭᐊᖅ ᐊᑐᖅᑕᐅᓕᒃᑲᓐᓂᓚᐅᖅᑐᑦ ᑲᔪᓯᓂᑎᒍᑦ

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ᐊᒻᒪᓗ ᓂᖏᖅᑕᐅᓪᓗᑎᒃ ᐅᖓᓯᑦᑐᒥ ᓄᓇᓕᓐᓄᑦ ᓇᔪᖅᕕᒋᔭᐅᔪᓄᑦ ᐊᒻᒪᓗ ᓄᓇᓕᓐᓂ ᓄᓇᖃᖅᑐᑦ ᑕᒫᓂ ᐊᖏᔪᒻᒪᕆᐊᓗᒻᒥ ᓄᓇᒋᔭᒥ. ᖃᐅᔨᒪᓇᖅᑐᖅ ᐊᔾᔨᒌᙱᓐᓂᖓ, ᒫᓐᓇᓵᖅ ᐃᓱᒪᒋᔭᐅᓚᐅᖅᑐᑦ ᓴᖅᑭᑎᑕᐅᔪᑦ ᖃᐅᔨᓴᖅᑎᓪᓗᒋᑦ ᓯᓇᒃᑯᑖᓂᒃ ᖃᐅᔨᓴᕐᓂᒃᑯᑦ ᓴᓇᕐᕈᑎᖏᓐᓂᑦ ᓯᓇᐃᑦ ᐃᓕᖅᑯᓯᒋᔭᐅᔪᒥ ᐊᔾᔨᒋᔭᖓᓂᒃ ᐊᑐᖅᑕᐅᓯᒪᔪᑦ ᐃᓅᖃᑎᒌᓐᓂᒃᑯᑦ, ᐊᒻᒪᓗ ᐃᓚᒋᓪᓗᒋᑦ ᑕᒪᒃᑭᒃ ᐃᒻᒥᒃᑰᖓᔪᒃᑯᑦ- ᐊᒻᒪᓗ ᓄᓇᓕᒥ-ᑐᙵᕝᕕᒃ ᐃᓱᒪᒃᓴᖅᓯᐅᕐᓂᒃᑯᑦ ᐊᑐᖅᑕᐅᔪᒃᑯᑦ, ᑕᒪᓐᓇ ᓂᕆᐅᖕᓇᖅᑐᖅ ᐃᓱᒪᓇᖅᑐᒃᑯᑦ ᐊᔾᔨᒌᙱᓐᓂᖏᑦ ᓄᓇᓕᒥ ᓴᓇᔭᐅᓯᒪᔪᑦ ᐊᒻᒪᓗ ᖃᓄᐃᑦᑑᓂᖏᓐᓄᑦ ᑕᑯᒃᓴᐅᔪᒃᑯᑦ. ᑐᕌᒋᔭᕗᑦ ᑕᒪᓐᓇ ᓯᕗᓪᓕᖅᐹᕆᔭᒃᑯᑦ-ᖃᐅᔨᓴᕐᓂᖅ ᖃᐅᔨᓴᕐᓂᐊᕐᓗᒋᑦ ᑐᓃᑦ ᐃᑦᑕᕐᓂᑕᖏᑦ, ᑕᐃᒪᐅᓪᓚᕆᐅᒻᒪᖔᑦ ᓴᖅᑭᑎᑕᐅᓂᖏᑦ ᐊᒻᒪᓗ ᐋᖅᑭᒃᓯᒪᔭᐅᔪᒃᑯᑦ ᑐᙵᕝᕕᒃᑯᑦ ᐊᑐᖅᑕᐅᓯᒪᒻᒪᖔᑕ ᐊᔾᔨᒌᙱᓐᓂᒃᑯᑦ. ᑐᕌᖅᓯᒪᔪᒍᑦ ᒪᕐᕉᕐᓂᒃ ᐱᒻᒪᕆᐅᔪᓂᒃ ᓴᓇᕐᕈᑎᓂᒃ ᐊᔾᔨᒌᙱᑦᑐᓂᒃ ᐊᒃᓱᕈᕐᓇᖅᑐᒥ ᐊᓐᓇᐅᒪᒐᓱᐊᕐᓂᕐᒧᑦ ᐅᑭᐅᖅᑕᖅᑐᒥ: ᒥᖅᑯᑎᑦ ᐊᒻᒪᓗ ᓴᒃᑯᐃᑦ. ᖃᐅᔨᓴᖅᓯᒪᔪᒍᑦ ᐊᔾᔨᒌᙱᑦᑐᓂᒃ ᐊᔾᔨᒌᕐᓚᒃᑐᓂᒃ ᐱᖓᓱᓂᑦ ᑐᓃᑦ ᓇᔪᖅᕕᒋᔭᖏᑦ 800 ᑭᓚᒦᑕᓂᒃ ᐅᖓᓯᓐᓂᖃᖅᑐᓂᒃ ᓄᓇᒌᑦ ᐊᒻᒪᓗ ᐅᓪᓗᖏᑦ ᐊᔾᔨᒌᙱᑦᑐᑦ ᑐᓃᑦ ᐃᓕᖅᑯᓯᖏᓐᓂᑦ. ᖃᐅᔨᓯᒪᔭᕗᑦ ᐃᓱᒪᓇᖅᑐᑦ ᓴᓇᕐᕉᑦ ᓴᓇᔭᐅᓯᒪᔪᑦ ᐊᒻᒪᓗ ᐊᑐᖅᑕᐅᓯᒪᔪᑦ ᐊᔾᔨᒌᙱᑦᑐᒻᒪᕆᐊᓗᒃᑯᑦ ᖃᓄᐃᒃᑲᓗᐊᖅᑎᓪᓗᒋᑦ ᐊᔾᔨᒌᙱᓐᓂᖏᑦ ᐊᔾᔨᒌᕐᓚᒃᑐᓂᑦ. ᑕᒪᓐᓇ ᐃᓱᒪᓇᖅᑐᖅ ᑕᐃᒪᐅᓪᓚᕆᓐᓂᖏᑦ ᓴᓇᕐᕈᑎᖏᑦ ᐃᓕᖅᑯᓯᒃᑯᑦ ᐃᓕᓐᓂᐊᖅᑕᐅᓚᐅᖅᑐᑦ ᐊᒻᒪᓗ ᐊᑐᖅᑕᐅᓪᓗᑎᒃ ᐊᔾᔨᒌᙱᑦᑐᒃᑯᑦ ᑕᒪᕐᒥᑦ ᐃᒥᒃᑯᑦ ᓇᔪᖅᕕᒋᔭᐅᔪᒥ, ᑭᓯᐊᓂ ᐃᖅᑲᓇᐃᔭᒃᑲᓐᓂᕆᐊᖃᖅᑐᒍᑦ ᑐᑭᓯᐊᔾᔪᑎᒋᓗᒃᑖᕐᓂᐊᕐᓗᒋᑦ ᐃᓱᒪᒋᔭᐅᔪᑦ ᖃᐅᔨᔭᐅᓯᒪᔪᓂᑦ ᐊᑐᕐᓗᒋᑦ ᐃᓅᖃᑎᒌᓐᓂᖏᑦ,ᐃᓕᖅᑯᓯᕆᔭᐅᔪᒃᑯᑦ ᑐᓂᔭᐅᓯᒪᔪᒃᑯᑦ, ᐊᒻᒪᓗ ᐊᑯᓐᓂᖏᑕ-ᓄᓇᖃᖅᑐᑦ ᑕᑯᑦᑕᐅᑎᖃᑎᒌᓐᓂᒃᑯᑦ ᐊᔾᔨᒌᙱᓐᓂᖏᑎᒍᑦ.

Keywords: Dorset, Paleo-Inuit, Arctic, microwear analysis, organic material culture

Introduction

The Dorset culture[1] existed in Arctic Canada and Greenland between approximately 800 and 1300 AD (Appelt, Damkjar, and Friesen 2016; Friesen and Mason 2016; Ryan 2016). Ever since it was first described by anthropologist Diamond Jenness (1925), a suite of features considered "typical" of Dorset technology (such as the apparent absence of drilling technology) have come to define the culture in the minds of archaeologists. It has been generally accepted that Dorset material culture exhibits high levels of typological uniformity across much of the culture's known geographic range and that this uniformity persists across the full Dorset chronological sequence. This implies that all or most Dorset artifact types were made in the same ways, despite the culture's longevity and the often-great distances separating occupied areas. By contrast, ongoing theoretical developments in the study of technology highlight that material culture traditions in small-scale communities are reproduced through localized social practices and involve both individual- and community-based decision-making processes (which would predict a higher level of variability in local manufacture and design features) and that traditions would exhibit change over time (Lemonnier 1993; Jordan 2015). Given these contradictions between current understandings and theoretical predictions, our aim in this paper is to test these assumptions about standardized manufacturing practices. We focus on two tool types crucial to survival in northern coastal regions, needles and harpoons, using materials from three Dorset sites in two widely separated parts of Nunavut, from Early to Late Dorset times. We employ microscopic analysis to assess local variability versus uniformity in manufacturing practices and use.

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[1] Throughout the paper, we employ the term "Dorset" to refer to the later culture phases of the Paleo-Inuit tradition. The term "Paleo-Inuit" is an established academic term (Friesen 2015) also known as "pre-Inuit." Inuit of Nunavut (Nunavummiut) typically employ the Inuktitut term "Tuniit" to refer to the latter Paleo-Inuit peoples who thrived in Arctic Canada and Greenland prior to the arrival of Thule Inuit in the mid-to-late thirteenth century AD. (Raghavan *et al.* (2014) have established a genetic distinction between Dorset and Thule Inuit populations.) Throughout the paper, we employ the term "Dorset" to allow easier comparison with other academic papers investigating this culture group.

Research context: Dorset subsistence, settlement, and technology

The nature of social interaction and the exchange of ideas both within and between different Dorset groups is difficult to reconstruct. Existing knowledge of Dorset culture phases relates predominantly to studies of subsistence and settlement. Though osteoarchaeological remains from Dorset sites are rare (Lynnerup *et al.* 2003) and typically less well-preserved than those from later Thule Inuit sites, zooarchaeological research shows that Dorset hunting patterns focused on marine mammals, such as small phocid seals (*e.g., Pusa hispida*), bearded seals (*Erignathus barbatus*), and Atlantic walrus (*Odobenus rosmarus*), although terrestrial mammals, such as caribou (*Rangifer tarandus*) and musk ox (*Ovibos moschatus*), were also hunted, depending upon location (Murray 1996; Howse 2015; Betts 2016). Excavations and surveys have revealed much about the nature of Dorset settlement patterns, which typically varied according to region, time period, and seasonality. Generally, summer dwellings consisted of skin tents, while in winter, people built more robust structures, including semi-subterranean houses (Maxwell 1985; Ryan 2003; Friesen 2007; Ryan 2016). In terms of social organization, the assumption is that in most regions, Dorset communities would have consisted of a small number of families for most of the year, with the possibility of larger aggregations seasonally in certain areas, depending on the availability of resources (Friesen 2007; Appelt, Damkjar, and Friesen 2016).

Why such high levels of material culture uniformity exist across time and space is an important topic for discussion. Investigations of objects through the *chaîne opératoire* approach highlight the role of skilled practice and focus attention on the multiple steps of artifact manufacture (Martinón-Torres 2002). Most steps involve a degree of technological choice, which highlights the role of human decision-making processes and how particular material traditions are learned and reproduced in small and often isolated communities. Modifications can still be made to an artifact following its "completion," and the technological choices made during manufacture relate specifically to how the artifact will be used, and are thus integral to the intentionality (both practical and symbolic) of the maker. For example, while a tool may be created with the material restrictions of a particular physical task in mind, other requirements relating to the role the tool plays in the wider symbolic system of the society may also be considered by the maker or makers (Lemonnier 1993). In this way, investigating the *chaîne opératoire* of an object is not only limited to examining the steps of manufacture but also promotes the idea that an artifact is a manifestation of social learning based on the technological choices made during its manufacture and use (Jordan 2015).

In the present study, we investigate the *chaîne opératoire* through the microscopic traces created during the manufacture and use of objects (van Gijn 2010). Investigating artifacts at this higher level of detail has many advantages. First, although the observable morphological characteristics of two objects from different regions or time periods may appear similar when observed with the naked eye, microscopic examination could show differences in how the artifacts were produced and used. This may have significant implications for differences in the creative choices and everyday practices of the two groups. Previous studies have incorporated a similar methodology into their framework when investigating organic material culture from sites in the Canadian Arctic (Houmard 2011; Houmard 2018). However, these studies

Figure 1. Map showing the location of the three focus sites in the Foxe Basin (source: Esri).

have mainly been focused on typological and technological developments over time, whereas we also aim to identify regional variation in technological choices employed by contemporary groups.

Materials

We focus our attention in the present study on Foxe Basin and northern Hudson Bay, situated at the centre of the wider Dorset geographic distribution (Figure 1). Although archaeological evidence of the Dorset culture can be found across Arctic Canada and Greenland, our focus area has long been considered the "emergence point" of the culture, particularly in terms of development from the earlier Pre-Dorset culture (Maxwell 1976; McGhee 1976; Nagy 1994; Savelle and Dyke 2014; Ryan 2016).

Our study sites include the Needle Point complex (NgFv-4, -6, -7, -8, -9, -10) on Rowley Island (known in Inuktitut as Salliq) and Kapuivik (NjHa-1) on Jens Munk Island (Kapuiviit)– both in the northern Foxe Basin – and Qulliapik (JlGu-3) on Mansel Island (Pujjunaq) in the northeastern Hudson Bay. There is sufficient geographic and chronological diversity among these locales to examine whether artifacts exhibit any spatiotemporal variability in manufacture and design. The two northern locales (Needle Point and Kapuivik) are approximately 800 km distant from the southern site (Qulliapik). There are also chronological distinctions among the chosen assemblages from each site: The selected Needle Point material dates from the Early to Late Dorset periods, the Kapuivik material from Early to Middle Dorset periods (*c.* 800 BC-500 AD) and the Qulliapik material to the Late Dorset period (*c.* 500-1300 AD) (Table 1).[2] Additionally, the sites are similar in terms of both quaternary geology and ecology.

Since the Needle Point complex of Dorset sites was described by Arthur S. Dyke (Geological Survey of Canada) and James M. Savelle (McGill University) in 2003, several field seasons of survey and excavation have been carried out by McGill researchers Susan Lofthouse in 2004 and 2005 (Lofthouse 2004; Lofthouse 2005) and Sarah M. Hazell in 2005 and 2006 (Hazell 2006; Hazell 2007). The material selected for analysis in the present study comes from the collections held by both researchers: NgFv 6-9 (Lofthouse) and NgFv4 and 10 (Hazell). Together, these contexts span nearly the entire Dorset period, from Early/ Middle to Late Dorset.

The multicomponent site Kapuivik was visited in 1954 and 1957 by Danish archaeologist Jørgen Meldgaard. Since then, the site has been the focus of extensive archaeological investigation. The material for the present study is a selection of the collection excavated in 2016 by a McGill field crew organised by James M. Savelle (Desrosiers 2018). Although Kapuivik has yielded material from a wide range of time periods, the material chosen for this study dates to the Early/Middle Dorset period.

Finally, the Qulliapik site on Mansel Island was investigated by William E. Taylor (National Museum of Canada) and Charles Martijn (Université Laval) in the late 1950s along with Inuit from the community Ivujivik. The Late Dorset material chosen for the present study was recovered in 2017 during the salvage dig of this site by Elsa Cencig and a field crew from the Avataq Cultural Institute (Avataq Cultural Institute 2018).

While there have been many studies concerning the *chaîne opératoire* of Dorset technology, the majority of these have focused on lithic technology (cf. Sørensen 2006; Dionne 2015; Coulson and Andreasen 2020). Similarly, the majority of usewear analysis in the Arctic has also focused mainly on lithic technologies (cf. Monchot *et al.* 2013; Wells, Renouf, and Rast 2014; Paquin 2016; Chabot, Dionne, and Paquin 2017; Park, Milne, and Stenton 2017), and there have been very few focusing on a microscopic analysis of organic materials, not only in the Arctic but also the wider Canadian region (cf. LeMoine 1994; Gates St-Pierre 2007). A analytic comparison with studies focusing on lithic technology has not been included in the present study, as the *chaîne opératoire* of lithic technology is highly distinct from that of organic materials and so is not comparable when conducting

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[2] Date ranges taken from Appelt, Damkjar, and Friesen (2016), Friesen and Mason (2016), and Ryan (2016). The exact site dates for each feature can be found in the site reports.

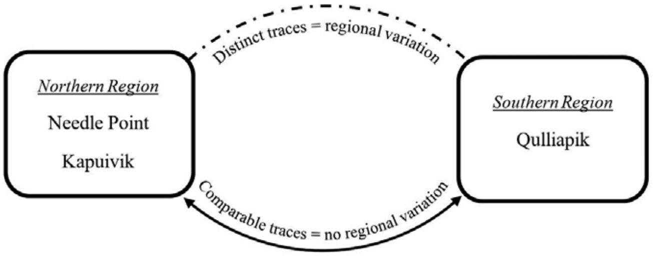
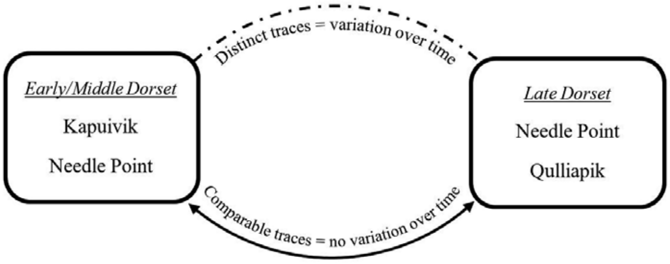
	Qulliapik	**Needle Point**	**Kapuivik**
Needles	22	24	27
Harpoon heads	24	18	18
Time period examined	Late Dorset (*c.* 500-1300 AD)	Early/Middle and Late Dorset (800 BC-1300 AD)	Early/Middle Dorset only (800 BC-500 AD)
Regional variation			
Chronological variation			

Table 1. Overview of the chosen material and associated time periods from the three sites and the hypothesized patterns of regional and chronological variability in the *chaîne opératoire*.

an analysis of tools made from bone, antler, and ivory. Similarly, a comparison of usewear analyses between the two technologies (lithics versus organics) is not relevant for the present study because (a) the traces observed on lithics versus organics are very different, and (b) the uses for which stone tools and bone tools would have been implemented cannot easily be compared. While a cross-craft analysis combining a microscopic investigation into the *chaîne opératoire* of both lithic and organic Dorset materials would be highly beneficial to the discipline, such a broad scope was not possible for the present study, and so we focused on the less-studied organic material.

The most frequently occurring artifact categories present across all three sites are needles and harpoon heads (Table 1) (comprising 73 needles and 43 harpoon heads), which were analyzed for macroscopic and microscopic traces related to manufacture and use (LeMoine 1994). The hypothesized patterns of variability that these traces could demonstrate is highlighted in Table 1.

Needles were – and remain – one of the most essential elements of Arctic Indigenous toolkits. Across much of the pre-modern Arctic, wood was scarce, and so Dorset communities relied on stone, sod, bone, and animal skin when constructing their winter and summer structures (Maxwell 1985; Ryan 2003). Skin would have been used to create portable tents in the summer and water- and windproof roofs in the winter. Additionally, all clothing would have been made from skins, and the ability to properly insulate and waterproof clothing would have been essential. All of this would have been impossible to maintain without the use of needles of varying dimensions capable of piercing hides of a range of thicknesses while also allowing for tight stitches of sinew thread, ease of handling, and portability.

Similarly, harpoon heads were an essential tool in the procurement of food. In addition to terrestrial hunting, the Dorset engaged in maritime-focused subsistence activities, hunting walrus and various seal species (Ryan 2016). This increased focus on maritime hunting was facilitated by the use of toggling harpoon heads designed to rotate 90° within the wound (Maxwell 1985).

Methods

Manufacture

To test for the degree of microscopic similarity of needles and harpoons across the three sites, we first identified a series of morphological traits found on almost every artifact examined. These traits represent manufacturing steps in the *chaîne opératoire*, and each trait reflects a distinct design "decision" on the part of the maker. The identifications were made using the material culture reference collection held at the Leiden University Laboratory for Artifact Analysis. The traits associated with manufacture were identified using an AM7115MZT Dinolite microscope, while an Olympus BX-51 metallographic microscope with an SC50 camera attachment was used to identify the presence of usewear traces.

One of the most fundamental decisions in the manufacturing process of any object is determining its size. We have limited our consideration of size to width and thickness; length is excluded due to the high percentage of broken objects. For harpoon heads, only 19 of the 43 objects are complete, with the remainder broken either at the socket or the blade-slot. Similarly, only 12 of the 73 needles are complete; with the majority including only a shaft and proximal end, suggesting that needles were discarded once the tip – the pointed, distal end – had broken off. Because there are only a limited number of complete needles, the length can therefore not be used as a characteristic to make valid comparisons between site assemblages. However, test measurements of a selection of pieces suggests that the width and thickness of the needles remains consistent across the length of the needle, excluding the very tip of the pointed distal end. Those pieces limited to the distal end (classified as "tip only") are measured at their widest parts; this is considered an approximate representation of the main shaft of the needle and so is comparable to the other needle fragment measurements.

Analyzing the size and shape of the harpoon heads is complicated by the great diversity of harpoon-head types and local variants, some of which are at least partly determined by size (Maxwell 1976a; Houmard 2011). Not accounting for these typologies would arguably invalidate the results of our analysis. Qulliapik includes only two harpoon head types, Dorset Parallel and Dorset Type Ha. Excavations at Needle Point and Kapuivik both produced the Dorset Parallel and Tayara Sliced types. Needle Point also includes an example of Dorset Type J, and Kapuivik includes the Nanook Wasp Waist and Pre-Dorset types. The only harpoon-head type that is present at all sites is the Dorset Parallel;

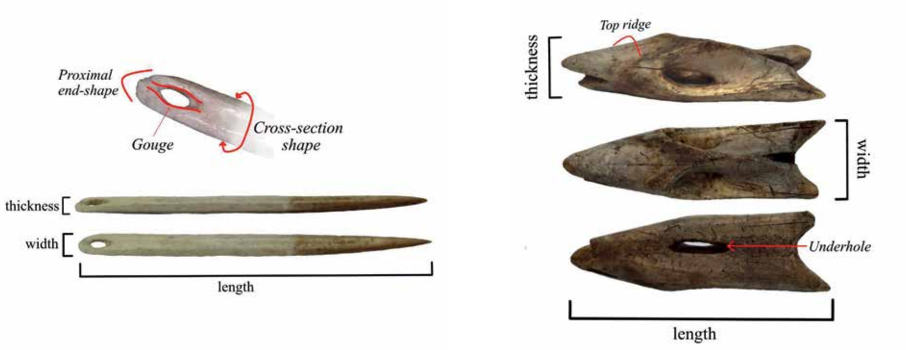


Figure 2. Measurement parameters and morphological traits observed on the needles (left) and harpoon heads (right). The harpoon head pictured here is the Dorset Parallel type.

therefore, the size comparisons have been restricted to this type (see Figure. 2). We also investigated (a) the top-ridge shape (either "curved" or "faceted") and (b) the presence or absence of an underhole (a secondary line-hole on the underside of the object).

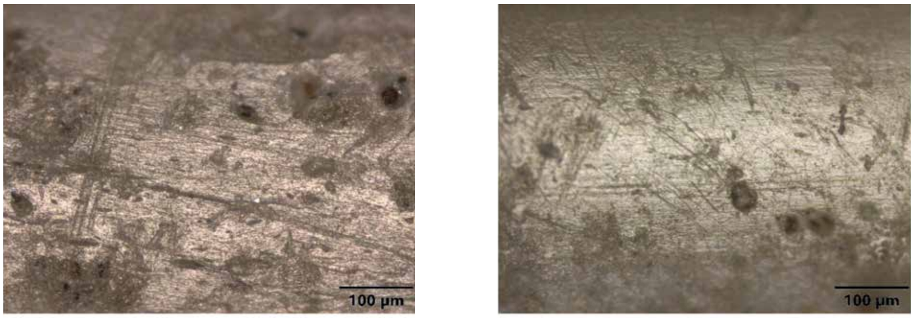
For needles, there are three additional morphological traits to consider: (a) cross-section shape, (b) proximal end-shape, and (c) perforation shape (Houmard 2018) (Figure. 2). As previously mentioned, the perforations on all Dorset objects were created using a gouging action, including the eyes of the needles. We have recorded the gouge length (the extent of the gouge marks on the surface around the perforation) and the gouge angle (whether angled or straight, defined by its position when compared against the needle length).

Usewear

While traits such as size and shape can be used to investigate variations in manufacturing choices while creating tools, the interpretation of microscopic usewear traces can provide insights into the way that the tools were used. For the present study we investigate the variations in polish, striations, and handling traces on needles and harpoon heads.

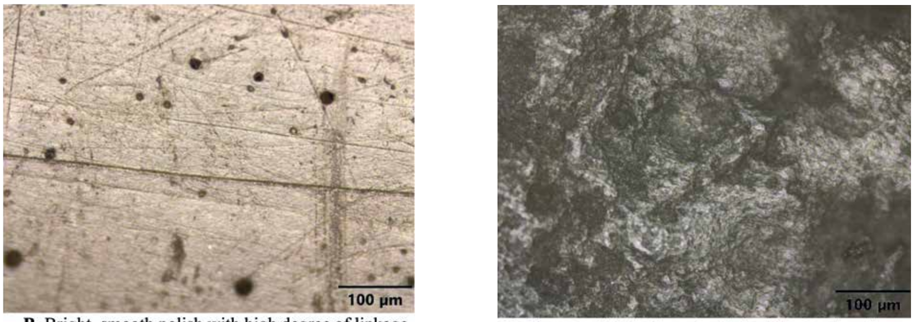
Figure 3 details the different usewear traces observed, which include different polish types, the presence of longitudinal versus circumferential striations, and the presence of handling traces. The polish observed on an artifact is related to the material upon which the artifacts were being used (*e.g.*, types of skin). Polish variability is assessed by examining the brightness (dull, bright, very bright), texture (smooth, rough) and degree of linkage (the extent to which patches of polish visible on an object's surface merge together) (González-Urquijo and Ibáñez-Estévez 2003). Linkage is related to the hardness of the contact material, but also to the degree of wear development. Some of the artifacts examined – especially the needles – have more than one variety of polish along the entire length, which may be evidence of multiple uses (this will be explored in a follow-up study focusing on experimental archaeology). In the present study, we identified only the dominant polish type on each artifact.

Striations are created when contact with an external material creates microscopic scratches on the artifact surface (Gates St-Pierre 2007); such evidence can only be viewed at high magnification. During initial observations of the needles, it was noted that the striations show variability in directionality. No striations were observed on the harpoon heads; this is likely due to the difference in activity associated with the two



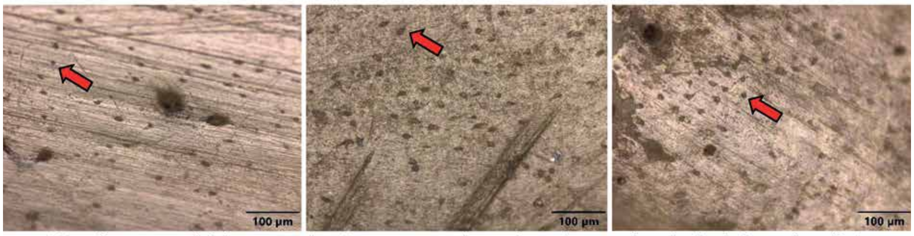
A1. Rough, matte polish with low/medium degree of linkage (NgFv-8 460) (needle).

A2. Rough, matte polish with high degree of linkage (NjHa-1 2260) (needle).

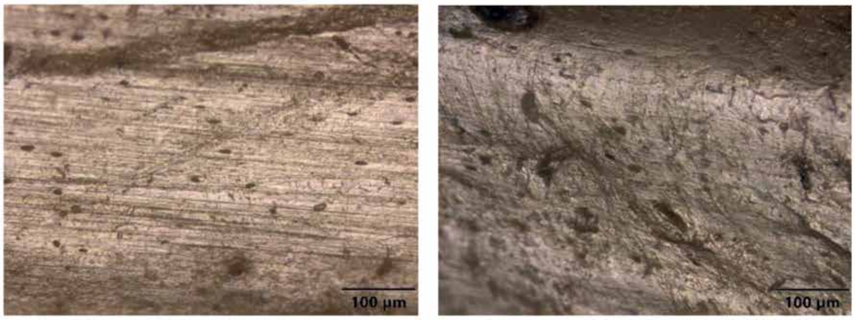


B. Bright, smooth polish with high degree of linkage (NjHa-1 2221) (needle).

C. Greasy, slightly domed polish with a low/medium degree of linkage (NgFv-4 912) (harpoon head).



Handling traces (with arrows showing one example per image) on archaeological pieces (needles) (left to right: NgFv-7 48, NjHa-1 2164, JlGu-3 711).



Examples of longitudinal (left NgFv-7 48) and circumferential striations (right NgFv-6 57) (needles).

Figure 3. Examples of the different usewear traces considered in the present analysis, including different polish types (upper), the presence of longitudinal versus circumferential striations (middle), and the presence of handling traces (lower).

artifact types. While needles are used more often and in a repetitive motion, harpoon heads are used in short, intense bursts of activity, likely followed by extended periods of non-use in storage. In general, there is very little interpretable usewear present on the harpoon heads, and experiments by the first author have shown that very little usewear is created on a harpoon head used the same number of times as a needle (Siebrecht and Pomstra 2020).

Experimental research has shown that the handling of organic objects – especially bone tools – results in small pinpricks referred to as handling traces (Maigrot 2003; van Gijn 2006). It is still unclear how these traces develop. Previous studies investigating the formation of handling traces have also noted the creation of polish during handling (D'Errico 1993). However, because in the present study we are unable to reliably differentiate between polish associated with human handling and that associated with the various types of skin we intend to experiment with, we believe that the presence of the pinprick-like traces is a more reliable sign of human handling. Examples of these tiny pinpricks are shown in Figure 3; they are not to be confused with the larger pockmarks representing osteons or Volkmann canals.

Results

Manufacturing traces on needles

For all needles, the thickness is generally smaller than the width (Figure 4). This correlates with the assumed manufacturing technique of the groove-and-split method,[3] whereby a thinner preform allows a quicker and easier cut. The needles from the southern site of Qulliapik are generally larger in terms of both width and thickness than needles from the northern locales of Needle Point and Kapuivik. Although there is variation between the two northern locales, there is a higher degree of similarity between them when compared with Qulliapik. Although this may imply that there is indeed a regional distinction between the northern and southern sites, it is also necessary to consider the different chronologies of the assemblages.

As seen in Table 1, all the selected material from Qulliapik dates to the Late Dorset period, while the material from Needle Point includes dates from the Early/Middle Dorset period to the Late Dorset period, and the assemblage from Kapuivik includes only Early/Middle Dorset material. The same characteristics must therefore be examined in consideration of the associated time period. For the Late Dorset artifacts, there is a strong similarity between the needles from Qulliapik and those from Needle Point both in terms of width and thickness, though the median for Qulliapik remains slightly larger in both measurements. The same is true when comparing the two Early/Middle Dorset collections; the needles from Kapuivik are slightly thicker and wider than those from Needle Point. (The data may be biased slightly by two irregularly-shaped outliers.) Therefore, when considering the variation in needle measurements over time period – without considering their geographic location – Late-Dorset needles are generally slightly thicker than Early/Middle-Dorset needles, although the width remains roughly the same.

When comparing the cross-section and (proximal) end-shapes, the needles from Needle Point and Kapuivik have more similarities with one another than either

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[3] The "groove-and-split" method involves creating a groove in a piece of bone with, for example, a stone tool. Once this groove has reached an appropriate depth, a small stone wedge is used to split the material completely.

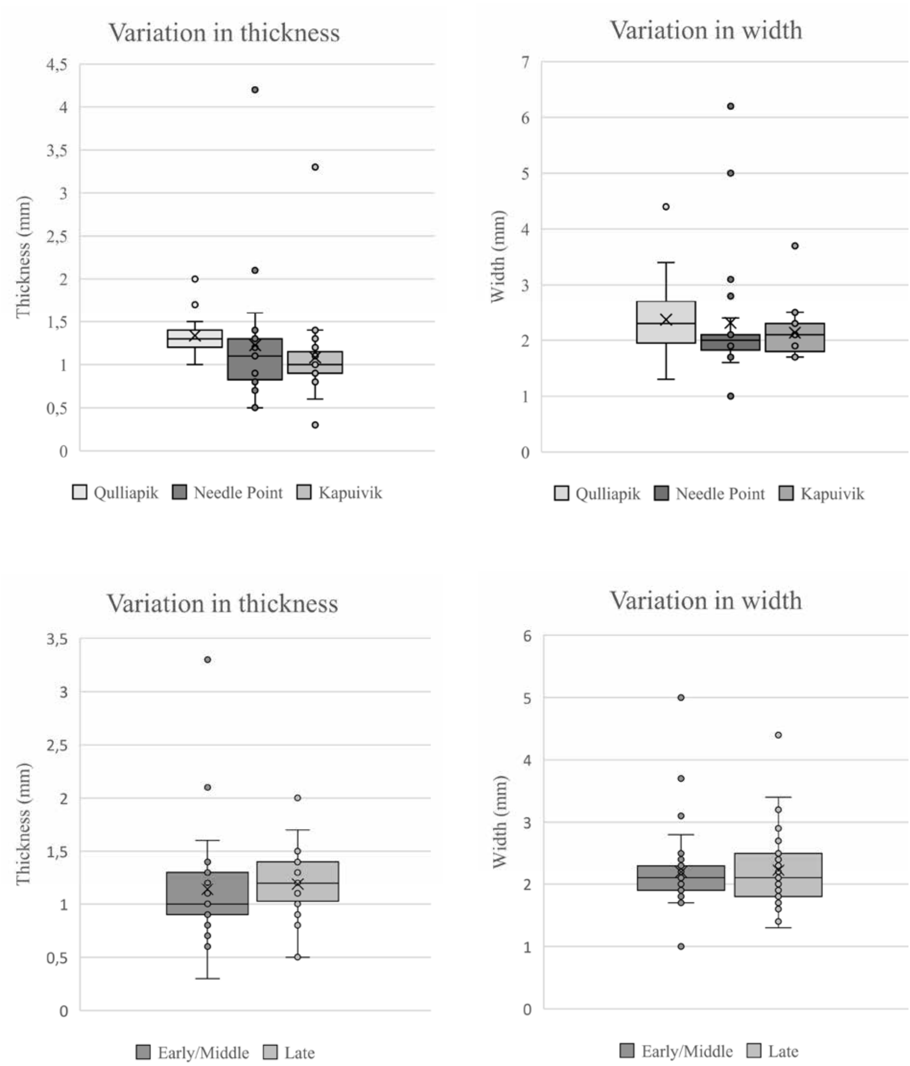

Figure 4. Comparisons of needle thickness (left) and width (right), according to site (upper) and time period (lower).

assemblage has with Qulliapik (Figure 5). The greatest percentage of needles from Qulliapik are quadrangular, whereas at both northern locales, the most common shape is oval. Additionally, both Needle Point and Kapuivik include needles with a diamond-shaped cross-section, which is not present in any of the needles from Qulliapik. The only cross-section shape that remains consistent across all sites is the lens shape.

A large percentage of the end-shapes from all sites are unidentifiable, as many needles include only the shaft or the distal tip. In general, both Needle Point and Kapuivik have a higher percentage of pieces with a pointed end-shape, with some curved ends, while Qulliapik includes a higher percentage of needles with a curved end-shape and some flat ends. Therefore, this manufacturing trait is more similar between the two northern locales than between the northern and southern sites.

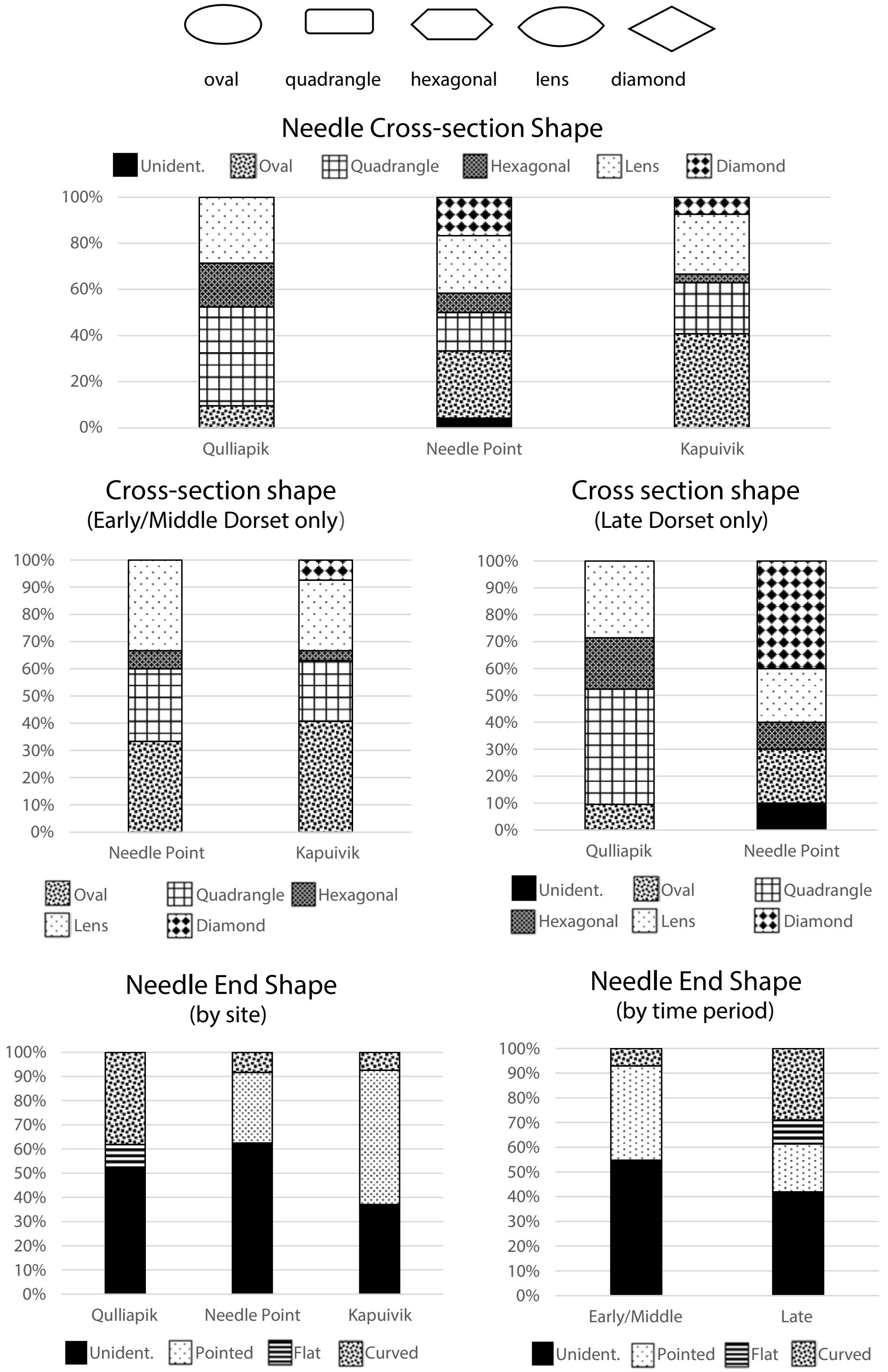

Figure 5. Comparisons of the percentage of needle cross-section shapes across all sites (upper) and time periods (middle) and the percentage of needle (proximal) end-shape (lower) across all sites (left) and time periods (right). ("Unident." = unidentifiable)

Site	Gouge angle (% of site total)			Gouge length (% of site total)		
	Unident.	Straight	Angled	Unident.	Long	Short
Qulliapik	62	29	9	62	19	19
Needle Point	71	29	0	71	21	8
Kapuivik	26	56	18	26	52	22

Table 2. Comparisons of needle gouge angle (left) and length (right) according to site ("Unident." = unidentifiable.)

When considering variations in needle shape between time periods, the two Early/Middle Dorset assemblages from Needle Point and Kapuivik show a high degree of similarity. The main differences are the inclusion of diamond-shaped cross-sections at Kapuivik but not at Needle Point, as well as a higher percentage of pointed end-shapes at Kapuivik. The Late Dorset collections from Qulliapik and Needle Point differ more, especially in the proximal end-shape. The majority of Late-Dorset needles from both sites have a curved end-shape, but Qulliapik also includes objects with flat ends, and Needle Point has some with pointed ends. When considering the percentages of different cross-section shapes and end-shapes at the two sites, this contrast between regions becomes even clearer.

Although there are some variations across time periods – with a more defined relationship between end-shape (compared with cross-section shape) at Early/Middle and Late Dorset sites – the needle shapes appear to be generally comparable within regions. Notably, when considering the cross-section shape, the two northern locales show a much greater similarity in needle shape than does either site with Qulliapik, even when considering the differences in chronology.

Comparing the length of the gouge marks around the perforations suggests a stronger degree of similarity between the two northern locales than between either Kapuivik or Needle Point with Qulliapik (Table 2). Approximately half of the gouge lengths from Qulliapik are long, whereas the two northern locales have a significantly lower percentage of long gouges. However, comparing the gouge angle suggests a different pattern whereby the strongest similarity is between Needle Point and Qulliapik, although there is also some similarity between Kapuivik and Qulliapik, which are the only two sites to have needles with angled gouge marks. However, these relationships do not correlate with either a regional or temporal relationship, and could simply be due to the limited variability that is possible when creating a perforation (there are only so many ways to gouge a hole). With both the gouge length and gouge angle, no variability was observed when comparing between time periods, thus suggesting that local regional factors have greater influence on this trait of manufacture, if at all.

Manufacturing traces on harpoon heads

Comparisons between the width and thickness of the harpoon heads suggests that time had a stronger influence on this particular trait of manufacture (Figure 6). When comparing by site, we see that even without taking chronology into account, Needle Point and Qulliapik have objects with similar dimensions, though there is some variation in that the Needle Point pieces are generally thicker than the two Qulliapik objects. However, when comparing

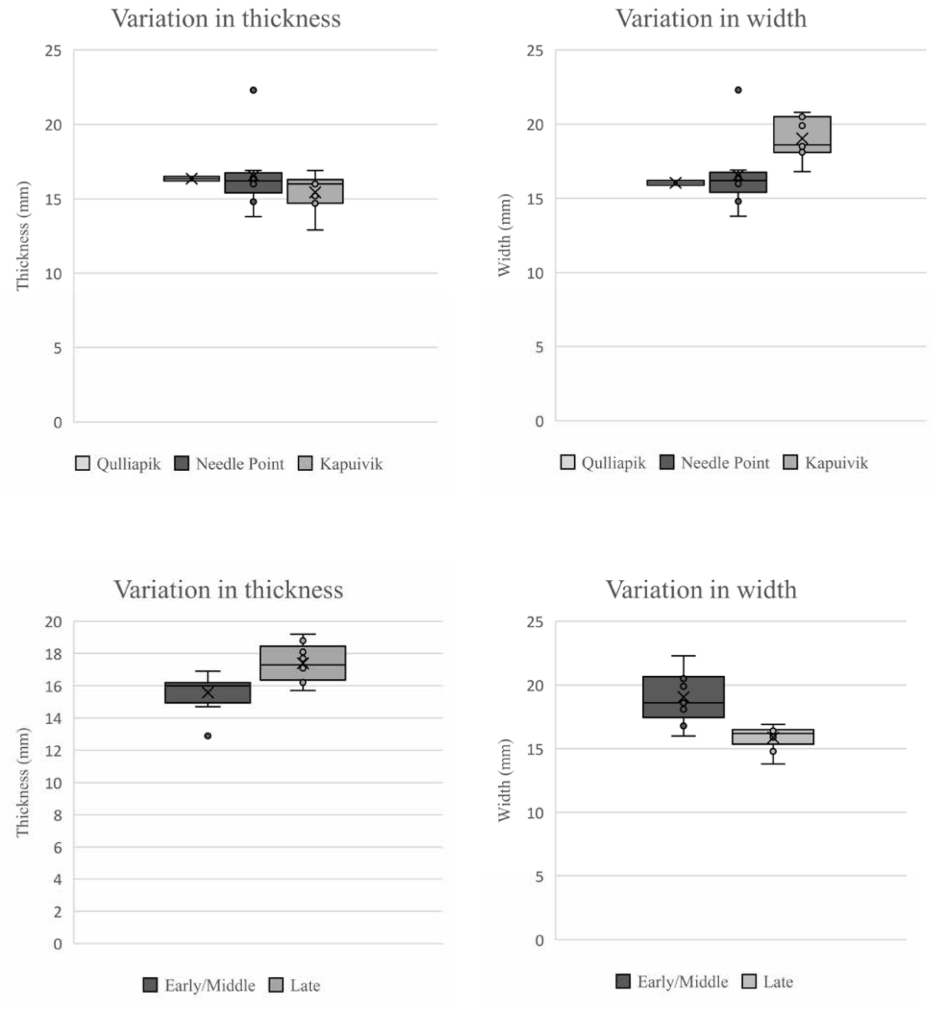

Figure 6. Comparisons of Dorset Parallel harpoon-head thickness (left) and width (right) according to site (upper) and time period (lower).

the two time periods, it becomes clear that Late Dorset pieces are thicker, while Early/Middle Dorset pieces are wider, which suggests a possible change in size over time.

All the harpoon heads from the Qulliapik assemblage have faceted top-ridges. This contrasts with the two northern locales, where the majority of the objects have curved top ridges. Even when considering the influence of time period, the shape of the top ridge appears to be regionally determined.

The presence of an underhole cannot accurately be compared across all three sites because, due to issues of preservation, it was not possible to identify the presence or absence of this trait on the Dorset Parallel harpoon heads from Qulliapik. However, when comparing the Early/Middle and Late Dorset assemblages from Needle Point and Kapuivik, the underhole is absent from all objects from the later period. Although there may be insufficient data in the present study to validate this result, it does support the suggestion by Houmard that the creation of underholes in harpoon heads is a distinctly Early/Middle Dorset manufacturing choice (Houmard *pers. comm.*).

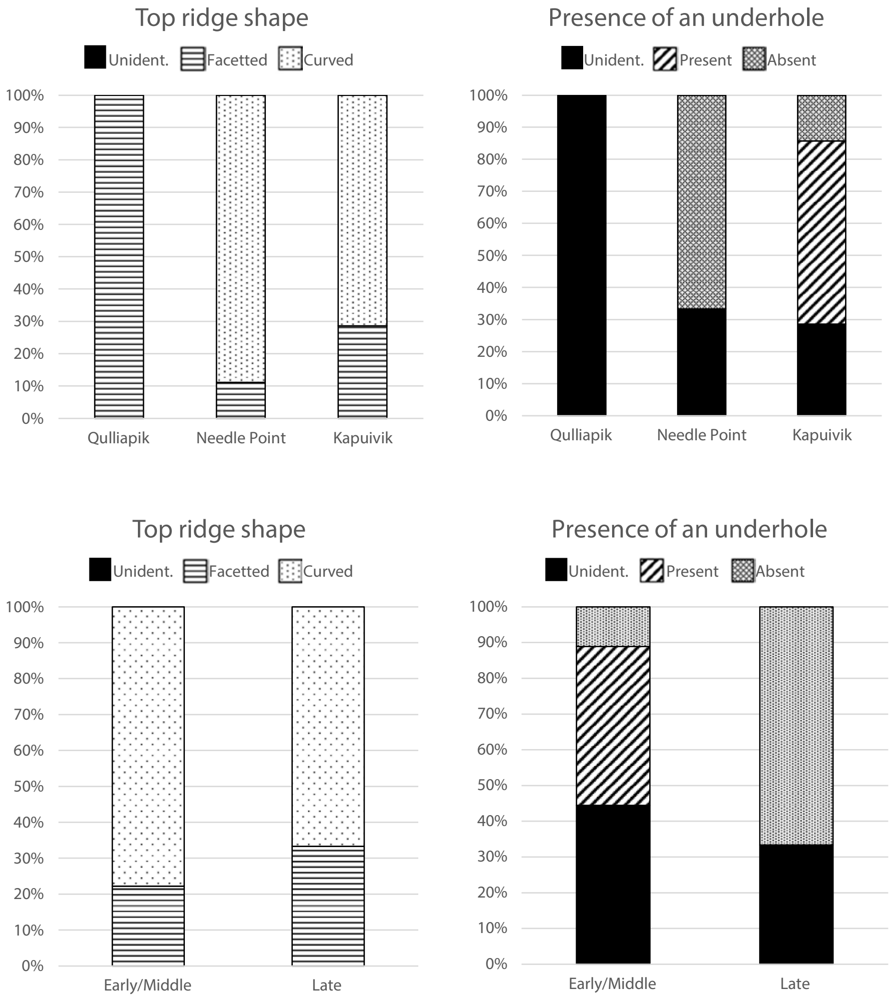

Figure 7. Comparisons of top-ridge shape (left) and the presence of an underhole (right) in Dorset Parallel harpoon heads according to site (upper) and time period (lower). ("Unident." = unidentifiable.)

Usewear traces on needles and harpoon heads

Table 3 presents the results of the usewear analysis, showing the percentages of the different usewear traces observed on the needles and harpoon heads from all three sites. As previously mentioned, the aim of the analysis in the present study is to identify whether there is any variation in the type of usewear present on objects between the different regions and time periods. The reasons behind such variation will be the subject of an upcoming experimental study, which will then provide the necessary data to allow interpretation of the different usewear traces observed (for example, experiments to investigate the possibility of distinguishing between the type of polish and striations created through contact with terrestrial versus maritime mammal skin, the effect of contact with storage vessels on the preservation of needle usewear traces, *etc.*).

The results of the comparative analysis shows that the polish on the needles from Needle Point and Kapuivik is more comparable than that between Qulliapik and either of the two northern assemblages. Qulliapik has a higher percentage of objects with A1 polish and no pieces with the brighter B polish, which is present on a relatively high percentage of the needles from the two northern locales. Polish variation therefore seems to be associated less with change over time than with regional location.

Striations included "longitudinal" (those running lengthwise along the needle body) and "circumferential" (those curving around perpendicular to the length of the needle body) varieties (Figure 3). Compared with the harpoon heads, the needles demonstrate significant variation in the observed striation morphology. However, the reasons for this variation remain unclear. Compared with other usewear traces, the analysis of the striations does not reveal a clear distinction in terms of chronology or region for either the longitudinal or the circumferential striations. There is a slightly greater degree of similarity between Kapuivik and Needle Point compared to Qulliapik, as the ratio of pieces with longitudinal striations is higher at the northern locales than at the southern site. This regional relationship remains strong even when comparing the presence or absence of striations on needles from the different time periods at the northern and southern sites.

The relative percentages of needles from Needle Point and Kapuivik with and without handling traces are more similar to one another than to those from Qulliapik (Figure 6).[4] However, a comparison according to chronology suggests that perhaps temporal variation has more of an influence than geography. A reasonable explanation for this relationship requires further investigation.

The same criteria are used to distinguish polish types on harpoon heads as on needles. There is more similarity between the polish types on harpoon heads from the two northern locales than on those from either northern site and the southern site. Qulliapik has only a small percentage of pieces with A1 polish, with the majority demonstrating the C type. By contrast, both Needle Point and Kapuivik have a higher percentage of pieces with A1 polish than with C polish. Notably, the two northern locales also include a small number of pieces with the brighter B-type polish. Regional location, rather than time period, seems to have a stronger influence on the type of polish exhibited on harpoon heads from the analyzed assemblages.

The percentage of harpoon heads with handling traces is higher for the Late Dorset period than for the Early/Middle Dorset period. Further investigation is required to determine how long a piece must be handled before handling traces appear and the resulting relationship between the handling of an object and the concentration of handling traces. Although other studies have investigated the formation of handling traces (D'Errico 1993; Maigrot 2003), further specialized exploration is still necessary. Additionally, considering the extent to which a needle must be handled – even during manufacture – it seems unlikely that an object would have no handling traces at all; despite the generally excellent preservation of northern latitudes, taphonomic factors may be impacting the analysis. It is also important to consider how modern handling and treatment by archaeologists might negatively impact the preservation of traces on organic materials.

The combined results of the complete analysis are presented in Table 4, which provides a general overview of variability in traits pertaining to the manufacture and use of the needles and harpoon heads. Clearly there is a much higher level of variation in these traits

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[4] Those pieces classified as unidentifiable were considered too badly preserved to accurately identify whether handling traces were indeed present on the surface. Those pieces that are designated as having no handling traces were sufficiently preserved to enable their identification; however, they did not exhibit any handling traces on their surface.

Usewear traces		Site comparison			Chronological comparison	
		Qulliapik	*Needle Point*	*Kapuivik*	*Early/Middle*	*Late*
Needles (% of pieces)	Polish	Unident.: 14 % A1: 57 % A2: 29 % B: 0 % C: 0 %	Unident.: 12 % A1: 21 % A2: 42 % B: 25 % C: 0 %	Unident.: 11 % A1: 26 % A2: 41 % B: 19 % C: 3 %	Unident.: 7 % A1: 24 % A2: 45 % B: 22% C: 2 %	Unident.: 19 % A1: 45 % A2: 29 % B: 7 % C: 0 %
	Striations present	Unident.: 10 % Longitudinal: 81 % Circumferential: 48 %	Unident.: 13 % Longitudinal: 75 % Circumferential: 29 %	Unident.: 4 % Longitudinal: 93 % Circumferential: 44 %	Unident.: 10 % Longitudinal: 83 % Circumferential: 38 %	Unident.: 6 % Longitudinal: 84 % Circumferential: 42 %
	Handling traces	Unident.: 10 % Present: 52 % Absent: 38 %	Unident.: 8 % Present: 75 % Absent: 17 %	Unident.: 4% Present: 81% Absent: 15%	Unident.: 7 % Present: 74 % Absent: 19 %	Unident.: 6 % Present: 68 % Absent: 26 %
Harpoon Heads (% of pieces)	Polish	Unident.: 29 % A1: 14 % A2: 0 % B: 0 % C: 57 %	Unident.: 17 % A1: 33 % A2: 0 % B: 17 % C: 33 %	Unident.: 0 % A1: 39 % A2: 0 % B: 22 % C: 39 %	Unident.: 4 % A1: 37 % A2: 0 % B: 22 % C: 37 %	Unident.: 25 % A1: 25 % A2: 0 % B: 6 % C: 44 %
	Handling traces	Unident.: 43 % Present: 14 % Absent: 43 %	Unident.: 28 % Present: 22 % Absent: 50 %	Unident.: 0 % Present: 17 % Absent: 83 %	Unident.: 7 % Present: 15 % Absent: 78 %	Unident.: 38 % Present: 24 % Absent: 38 %

Table 3. An overview of the results from the usewear analysis of both the needles and the harpoon heads ("Unident." = unidentifiable), including regional and chronological comparisons.

Artifact category	Manufacture traces	Trend observed	Use traces	Trend observed
Needles	Size	Variations over both region and time	Polish	Regional variation
	Cross-section shape	Regional variation	Striations	Similarities over both region and time period
	Proximal end-shape	Mainly regional variation	Handling traces	Variation over time period, with some regional differences
	Perforation	Possibly random		
Harpoon heads	Size	Mainly variation over time period	Polish	Regional variation
	Top-ridge shape	Regional variation		
	Underhole presence	Possible variation over time period (data limits)	Handling traces	Temporal variation

Table 4. Summary of the main spatiotemporal trends in the dataset.

than would have been predicted by a purely superficial typological approach, and so we can refute the long-held assumption that Dorset tools were made and used in the same way across larger areas. Interpreting and explaining these patterns of variability is more challenging, and we offer some suggestions below.

Discussion and conclusion

In this study, we aimed to develop a new perspective on the nature of technological practice among Dorset groups. The unique Dorset material culture has long been used to define this tradition in relation to earlier Paleo-Inuit and later Thule-Inuit cultures as well as to draw conclusions about the extent of cultural contacts between them, especially the poorly-understood interactions between Late Dorset communities and early Thule Inuit peoples. As a result, Dorset material culture was defined in terms of superficial typological criteria that emphasized similarity and downplayed internal variability. Recent theoretical perspectives on technological practice highlight the fact that material culture traditions are acquired and reproduced via situated social practices and that the production and subsequent use of any artifact is subject to a wide array of copying errors and deliberate cultural choices, which have the capacity to inject high levels of variability and change into technological traditions (Shennan 2008; Hosfield 2009). This may especially be true of small and relatively isolated groups of hunter-gatherer-fishers, such as the Dorset. These theoretical frameworks led us to question the assumptions underlying the general consensus that Dorset material culture was highly standardized over large geographic areas.

Using the *chaîne opératoire* approach to undertake a detailed microscopic analysis of the manufacturing and usewear traits in needles and harpoons recovered from three Dorset locales, we are able to demonstrate higher degrees of variability than could have been predicted by a purely typological approach. This raises a number of important new questions about what generated these patterns, including the manner in which the two technological traditions – needles and harpoon heads – were acquired, practiced, and shared, both regionally and over time. Accounting for these patterns of variability on the basis of the current dataset is challenging. Clearly, the most compelling possible explanations potentially relate to dynamic developments in local learning and social practice, regional interaction patterns (including the trade or exchange of objects, partners, skills, and ideas), and their impacts on long-term cultural inheritance. However, drawing firm conclusions would be speculative at this early stage. Although traces of manufacture and use can be observed and described, they will only lead to interpretations, not identifications (van Gijn 2014; Bradfield 2016). Any interpretations made here, or in any study investigating the *chaîne opératoire*, should always be open for re-interpretation in future studies (Coulson and Andreasen 2020). Further research is needed to test these ideas more explicitly, using more targeted case-studies, as well as larger datasets drawn from more sites, periods, and artifact categories.

Our primary conclusions are that (a) Dorset material culture was produced and used in subtly different ways, even within the same superficial typological categories; (b) a microscopic approach to manufacturing trace and usewear analysis, combined with theoretical concepts from the anthropology of technology, is an effective approach to investigating and documenting this diversity and (c) a much larger project scale and dataset of research is still required to properly document and fully explain these patterns. Clearly, our appreciation of Dorset technology and material culture has reached a new threshold, and much important work remains to be done before we fully understand the deeper social significance of its production and use.

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Antler as raw material among hunter-gatherer groups from the Pampean Region (Argentina)

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Abstract

Deer are an important economic resource worldwide. In prehistoric societies, they were always exploited when locally available, and antler was the preferred organic raw material used to make different types of artifacts. Hunter-gatherers who inhabited the Pampean region were no exception. However, during the Holocene, this wide sector of the Southern Cone showed high material variability. In particular, bone technology was not developed in the same manner throughout the landscape. Bone tools were common and complex in the Low Paraná wetland and scarce and simple in the rest of the region. The aims of this paper are to evaluate the importance of antler on a regional scale and to assess the spatial and chronological records of its use as well as the physical and morphological properties of the assemblages. Our results confirm that, while antler was exploited in most Pampean sectors, a higher degree of development is shown on the Low Paraná wetland. In the other sectors, antlers are usually used without modification. Nonetheless, this information should be further considered in light of the natural marks on both deer species that inhabited the area: Pampas deer (*Ozotoceros bezoarticus*) and marsh deer (*Blastocerus dichotomus*).

Resumen

Los cérvidos constituyen un importante recurso económico a nivel mundial. En las sociedades prehistóricas son explotados siempre que se encuentran disponibles localmente, y allí el asta es el material orgánico preferido para la manufactura de diferentes tipos de artefactos. Los cazadores-recolectores que habitaron la Región Pampena no fueron una excepción. Durante el Holoceno, sin embargo, este amplio sector del Cono Sur muestra una amplia variabilidad material. Particularmente, la tecnología ósea no se desarrolló de la misma manera a lo largo del espacio. Mientras que los artefactos óseos son abundantes

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y complejos en el humedal del río Paraná inferior, en el resto de la región, son escasos y muestran mayor simplicidad en sus diseños. Este trabajo tiene como objetivos evaluar la importancia del asta en escala regional, su distribución cronológica y las propiedades morfológicas de los conjuntos. Los resultados obtenidos confirman que el asta fue utilizada en la mayoría de los sectores pampeanos, con un mayor desarrollo en el humedal del Paraná inferior mientras que en los restantes sectores las astas son utilizadas sin modificación antrópica. A futuro, la información obtenida deberá ser contrastada a la luz de las marcas naturales de las dos especies disponibles en el área: venado de las pampas (*Ozotoceros bezoarticus*) y ciervo de los pantanos (*Blastoceros dichotomus*).

Keywords: bone tools, deer antlers, natural marks, Ozotoceros bezoarticus, Blastocerus dichotomus

Introduction

Deer antler has been one of the organic raw materials preferred by different societies through time due to its mechanical properties. Although antler use has been proposed for the Lower and Middle Palaeolithic (*e.g.*, Münzel and Conard 2004; Stout *et al.* 2014; Villa and d'Errico 2001), systematic exploitation occurred in the Upper Palaeolithic, particularly during the Magdalenian period. The manufacture of a wide variety of tools including points, harpoons, and spear-throwers is related to the demographic and geographic expansion of modern humans (*e.g.*, Knecht 2000; Langlais *et al.* 2012; Langley, Pétillon, and Christensen 2016). In the Americas, Paleoindian sites show signs of antler use, mainly in the manufacture of the so-called rods (see Moore and Schmidt 2009 for a synthesis). Indeed, Guthrie (1983) argues that as humans spread across the continent, they found that their preferred caribou antler was scarce in the south and replaced it with stone, resulting in the Clovis complex. In the Archaic period, widespread morphological types made of antler include flakers, atlatl weights, hooks, projectile points, and harpoon points (Moore and Schmidt 2009 and references cited therein). Where deer were locally available, they became an important economic resource for prehistoric people not only because of their nutritional value but also because of their importance as sources of raw material: bones and antlers were regularly used, as seen in different archaeological contexts (*e.g.*, Averbouh 2000; Baron and Diakowski 2018; Buc 2012; Gates St-Pierre, Boisvert, and Chapdelaine, 2016; LeMoine 1991; Wild 2020).

The Pampean region is no exception. The aim of this paper is to test the importance of antler to the hunter-gatherers that inhabited this area during the Late Holocene. For that purpose, we consider the spatial and chronological record of archaeological sites where technical signs of antler exploitation have been found. We evaluate the morphological structure of the assemblages (cf. Buc 2012) on a regional scale that includes different sectors where bone technology was variably developed (Acosta, Buc, and Loponte 2020).

Background

The Pampean region extends from -30° to -39° S and from -50° and -60° W (Figure 1). In the Argentinean territory, it comprises almost the entire Buenos Aires province, the northern part of La Pampa, the southern parts of the Entre Ríos and Santa Fe provinces, and the southwestern part of Córdoba. Originally, the region was dominated by the temperate grassland biome. It is mainly a plain grassland interrupted by small sectors

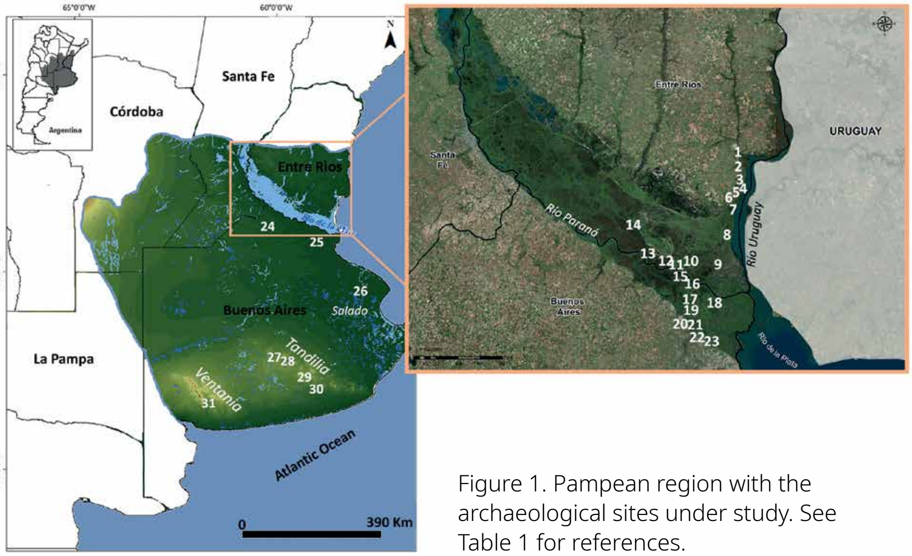

Figure 1. Pampean region with the archaeological sites under study. See Table 1 for references.

with depressions and undulations. From this plain, the Ventania (120 m.a.s.l.) and Tandilia (500 m.a.s.l.) mountain systems emerge as rocky formations in the Buenos Aires province. In the northeastern sector, the delta and islands of the Paraná ecological unit develop along the last portions of the Paraná and Uruguay river basins and the estuary of Río de la Plata to the San Borombón bay in Buenos Aires (Burkart *et al.* 1999). This is the only sector of the region that has subtropical conditions (Cabrera and Zardini 1978).

Most archaeological sites with antler records are located in the Paraná basin (Buc 2012). In a lower proportion, antler has been identified in the nearby plains of the Rolling Pampa, the Salado depression and the mountain/intermountain region (see Acosta, Buc, and Loponte 2020; Álvarez 2014, 2018; M. I. González 2005; Mazzanti and Valverde 2001).

Human occupation in the Pampean region dates from *c.* 11,000 BC (Politis *et al.* 2016). Local researchers have suggested that in the Late Holocene, human groups experienced a series of changes that led to the formation of complex hunter-gatherer organizations. This process was mainly characterized by an increase in population, the adoption of new technologies (such as pottery and the bow and arrow), residential stability, and occupational redundancy, which are linked to territorial behaviour, delimited mortuary spaces, diet diversification, the development of new modes of resource exploitation that incremented the resource return rate, and exchange systems that included exotic goods that enhanced intra- and intergroup interaction (Barrientos 1997; M. I. González 2005; Loponte, Acosta, and Musali 2006; Martínez 1999; Mazzanti 2006; Paleo and Perez Meroni 2005-2006; Politis and Madrid 2001). In this wide region, the aforementioned process was not homogeneous because of the high archaeological variability among different groups and areas. For example, early sites from the Middle Holocene have been found in the mountain range sector (Politis *et al.* 2016). Humans occupied the Low Paraná and Uruguay wetlands as late as nearly 1500 BC, lithic raw material was not locally available, and marsh deer (*Blastocerus dichotomus*) and Pampas deer (*Ozotoceros bezoarticus*) were the main animals exploited (Acosta 2005; Loponte 2008). In the other Pampean regions, lithic raw material was extensively exploited, and guanaco (*Lama guanicoe*) was the main faunal resource (Álvarez 2018; Mazzanti and Quintana 2001). In the same vein, bone technology showed great variability in the Low

Paraná wetland, being complex with different morphological groups, whereas it was simpler and featured limited tool types in the other sectors (Acosta, Buc, and Loponte 2020). Consequently, we expect that the use of antler as raw material should follow a similar path.

Antler as raw material: General considerations, mechanical properties, and natural marks

The structural properties of antler and its importance as raw material for past societies has been addressed in various papers (*e.g.*, Averbouh 2000; Guthrie 1983; MacGregor and Currey 1983; Margaris 2009). Antlers grow from the skull on a bony protuberance termed the pedicle and their diameter grows as the animal ages (Chapman 1975). Except reindeer (*Rangifer tarandus*), antlers are distinctive of males, who use them as weapons in their rivalry with other males (Barrette and Vandal 1990; Ungerfeld *et al.* 2008b); this process is related to sexual selection and therefore, to reproductive cycles (*e.g.*, Chapman 1975; Clutton-Brock 1987; Demarais and Strickland 2011; Piovezan *et al.* 2010). The mechanical and design properties of antlers are considered an inheritable selective advantage (Demarais and Strickland 2011; Picavet and Balligand 2016). Their status and development are conditioned by factors such as climate, precipitation, the individual's nutritional state and age, and the population size (Chapman 1975; Demarais and Strickland 2011; Karns and Ditchkoff 2012; Landete-Castillejos *et al.* 2019). Although there could be variations between temperate and tropical regions, deer usually shed their antlers once per year, after the rut period (Chapman 1975; Price, Allen, and Faucheux 2005). During the Late Holocene, two deer species inhabited the Pampean region: Pampas deer and marsh deer. The brown brocket deer (*Mazama guazoubira*) is recorded in traditional literature from the area, although its distribution is on the northern portion of the Paraná wetland. Loponte *et al.* (2019) performed an exhaustive analysis of actual samples of this species and could not identify it on archaeological sites from the southern portion of the Paraná wetland.

Regional research shows that Pampas deer and marsh deer were exploited for alimentary and technological purposes (*e.g.*, Acosta 2005; Álvarez 2018; Buc 2012; Day Pilaría, Merino, and Gambaro 2013; M. I. González 2005; Loponte 2008; Martínez and Gutiérrez 2004). However, there were notable differences in their use in different sectors of the Pampean region (Acosta, Buc, and Loponte 2020). Both species were variably spatially distributed according to their ecological requirements. The marsh deer is the largest neotropical deer. Its historical distribution was from the Amazonas river in Brazil to Rio de la Plata in Argentina, including southern Uruguay and the Paraná delta (Figure 2a) (Piovezan *et al.* 2010; Weber and S. Gonzalez 2003). Its height varies between 110 and 127 cm, and its weight is between 80 and 150 kg (Pinder and Grosse 1991; Piovezan *et al.* 2010). The marsh deer lives in the plains inundated by large rivers and coastal swamps (Pinder 1994). Archaeological data suggest that during the Late Holocene, marsh deer were mainly located on the Paraná delta, although they were also found in the coastal margin of Rio de Plata and probably reached the Bahía of Samborombón (cf. Loponte 2004) and the Salado depression (Aldazabal, Eugenio, and Silveira 2017; M. I. González 2005). Marsh deer develop antlers annually (Piovezan *et al.* 2010) and average 8 to 12 tines on both beams (D'Alessio *et al.* 2012). The beam and the anterior tines are similar in size, and both are commonly forked. Anterior tines branch from the straight shaft and the beam at nearly a right angle, as tines do not form helical curves (Gustafson 2015). Antlers are big, reaching 60 cm in length and width (Pinder and Grosse 1991). Complete development takes four to

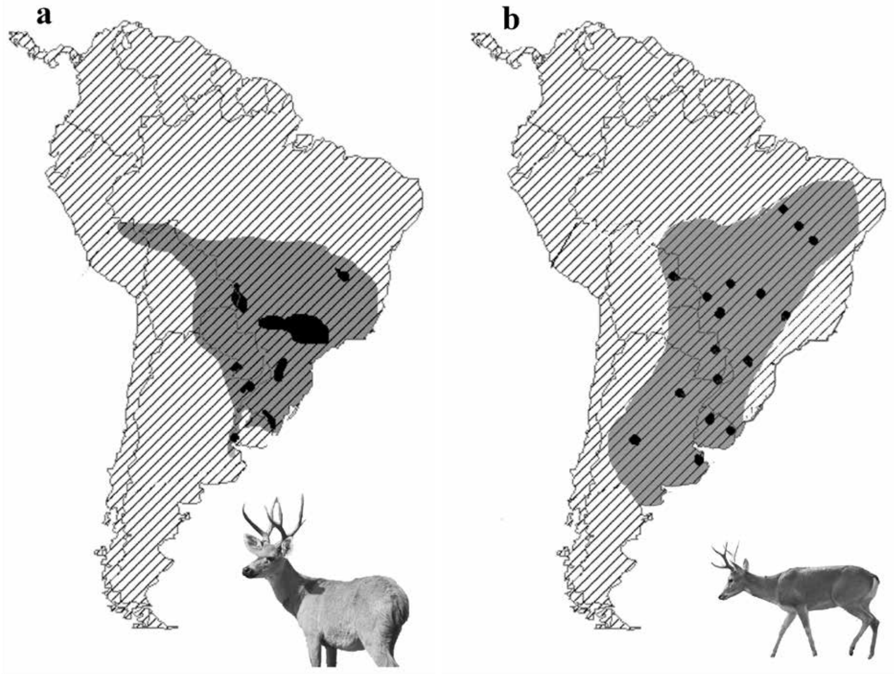

Figure 2. Spatial distribution of a) marsh deer and b) Pampas deer. The gray area marks the historical distribution, and the black dots are actual locations of both species. Taken and modified from Weber and Gonzalez (2003).

five months, and shedding occurs between September and October, in the beginning of spring (Piovezan *et al.* 2010).

The Pampas deer is a smaller deer that was originally distributed across the open grasslands of South America at latitudes between 5° and 4° S (Figure 2b) (Jackson and Langguth 1987; Weber and S. González 2003). Its height is between 65 and 75 cm, and its weight is between 20 and 35 kg (S. González *et al.* 2010; Jackson 1987; Weber and S. González 2003). Although it inhabited open and well-drained grasslands, the Pampas deer also penetrates fairly inundated open environments (*e.g.*, Parera and Moreno 2000; Reis Lacerda 2008). The antlers of Pampas deer have, on average, six tines, which develop in three to four months. They have their widely separated bases sloped posterodorsally 60° above the parietal surface and have open, doubly dichotomous branches that are moderately to transversally flattened and lack helical rotation (Gustafson 2015). The antlers are similar to those of marsh deer but smaller, reaching approximately 25 cm (Ungerfeld *et al.* 2008a). Shedding occurs between August and September (Jackson 1987; Ungerfeld *et al.* 2008b). The two deer species are difficult to distinguish by morphological or external skeletal aspects, particularly when dealing with archaeological artifacts, especially points. Young marsh deer specimens are very similar to adult Pampas deer specimens in general, and this does not exclude antlers.

Although antler is one of the hard animal raw materials, its histological structure and the proportion of mineral and collagen confer particular properties that differ from those of other bone elements (Currey 1979; Currey *et al.* 2009). The histological sequence is several times higher than that of other mineralized tissues (Goss 1983; Price, Allen, and Faucheux 2005), with records of 14 kg in six months, reaching 2 to 4 cm per day (Chapman 1975; Goss 1983). In comparison with bone, antler has a low mineral fraction (apatite) and, conversely, a higher collagen content (Currey 1979). Because of this, its stiffness is half that of standard cortical bone in mammals, including humans (Chapman 1975; Currey *et al.* 2009). Therefore, antler is a very resistant material that can absorb a great deal of energy before fracturing: antlers are designed to resist the stress that males face during mating (Chapman 1975; Currey *et al.* 2009; Karns and Ditchkoff 2012). The most-mineralized portions of antlers are the outer burr and tine tips (Landete-Castillejos *et al.* 2019; Miller *et al.* 1985). Conversely, the main beams on antlers from adult males show more trabecular bone, which makes them more resistant to impact forces (Chapman 1975; Landete-Castillejos *et al.* 2019). Both properties must have been considered when antlers were selected as raw materials to make artifacts. On the basis of the published records, antlers were used for making harpoon heads (both detachable and fixed), other types of point, and knapping tools involved in the production of lithic artifacts worldwide (*e.g.*, Bello *et al.* 2016; Knecht 2000; Rigaud *et al.* 2013). Perforated antlers (traditionally known as "pierced batons") are also frequent; their real use is still under discussion, but due to their high fracture rates, they were probably used in a stressful activity (see Glory 1965 and Lucas *et al.* 2019 for a synthesis).

Pampean Sector	**Archaeological Site (Refer to Figure 1)**	**Lab Code, ^{14}C Date, Standard Deviation**	**Calibrated Date (Years BC/AD)**	**Sample**	**Reference**
Mountain/ Intermountain Sector	Empalme Querandíes 1 (27)*	3000-2000 years BP	1050–50 BC	Several samples	Messineo et al. 2013
	Calera (28)*	3000-1500 years BP	1050 BC - 450 AD	Several samples	Álvarez 2018
	Cueva Tixi (31)*	AA-12129 4865 ± 65 ^{14}C BP	3763-3377 calBC	Charcoal	Mazzanti and Valverde 2001
		AA-15809 715 ± 45 ^{14}C BP	1272-1395 calAD	Charcoal	
		AA-12127 170 ± 60 ^{14}C BP	1668 calAD	Charcoal	
	Paso Otero 4 (30)*	7700-4600 years BP	5750-2650 BC	Several samples	Álvarez 2018
	El Picadero (29)	AA-94613 718±42 ^{14}C BP	1274-1392 calAD	Pampas deer	Colombo 2013
		AA-94614 634±41 ^{14}C BP	1299-1417 calAD	Pampas deer	
Rolling Pampa	Hunter (24)	Beta-284161 1990±40 ^{14}C BP	55 calBC-194 calAD	Guanaco	Tchilinguirian, Loponte, and Acosta 2011-2014
	Cañada de Rocha (25)	Beta-220693 540±40 ^{14}C BP	1391-1459 calAD	Guanaco	Toledo 2010
		Beta 220695 560±40 ^{14}C BP	1390-1451 calAD	Guanaco	Toledo 2010
		AA-108389 542±24 ^{14}C BP	1439-1611 calAD	Guanaco	Buc and Loponte 2016
Salado Depression	La Guillerma 5 (26)*	1400-370 years BP	550-1580 AD	Several samples	Escosteguy, Salemme and González 2017
		AA-108389 623±41 ^{14}C BP	1301-1427 calAD	Screeming hairy (*Chatophractus*)	
Low Paraná and Uruguay Wetlands	Cerro Lutz (8)	AA-103643 1116±45 ^{14}C BP	880-1043 calAD	Human	Buc and Loponte 2016
		AA-77310 976±42 ^{14}C BP	1024-1190 calAD	Human	
		AA-103648 953±47 ^{14}C BP	1029-1214 calAD	Queen palm (*Syagrus romanzoffiana*)	
		AA-77311 795±42 ^{14}C BP	1206-1379 calAD	Human	
		AA-77312 916±42 ^{14}C BP	1044-1231 calAD	Domestic dog (*Canis familiaris*)	
		LP-1711 730±70 ^{14}C BP	1218-1403 calAD	Human	
	Túmulo 1 Brazo Gutiérrez (9)	AA-72635 752±41 ^{14}C BP	1227-1387 calAD	Human	Bernal 2008
	Túmulo 1 Brazo Largo (10)	AA-93217 656±42 ^{14}C BP	1293-1406 calAD	Human	Bonomo, Politis and Gianotti 2011

Table 1. (continued on right page) Archaeological sites analyzed. Dates were calibrated using OxCal 4.3 (Bronk Ramsey 2009) and the calibration curve for the southern hemisphere, SHCal13 (Hogg *et al.* 2013). * Sites studied by other authors with several dates are considered as temporal ranges.

Pampean Sector	Archaeological Site (Refer to Figure 1)	Lab Code, ^{14}C Date, Standard Deviation	Calibrated Date (Years BC/AD)	Sample	Reference
Low Paraná and Uruguay Wetlands	Brazo Largo (10)	No date			Torres 1911
	Cementerio 1 Paraná Guazú (11)	No date			Torres 1911
	Escuela 31 (12)	AA-103651 1764±46 ^{14}C BP	219-415 calAD	Marsh deer	Buc and Loponte 2016
		AA-103650 1732±50 ^{14}C BP	228-475 calAD	Marsh deer	
		AA-103649 1712±47 ^{14}C BP	246-518 calAD	Marsh deer	
		AA-103644 1807±47 ^{14}C BP	130-382 calAD	Human	
	Isla Lechiguanas 1 IV (13)	AA-97461 2267±34 ^{14}C BP	385-205 calBC	Marsh deer	Loponte, Acosta, and Mucciolo 2012
		AA-97467 2296±34 ^{14}C BP	399-209 calBC	Marsh deer	
	Isla Lechiguanas 1 II (13)	AA-97462 408±30 ^{14}C BP	1451-1626 calAD	Marsh deer	
	La Argentina (14)	AA-103642 979±44 ^{14}C BP	1022-1192 calAD	Human	Buc and Loponte 2016
		AA-97463 1645±34 ^{14}C BP	380-541 calAD	Marsh deer	Loponte and Corriale 2012
		LP-3057 1480±70 ^{14}C BP	428-688 calAD	Human	Del Papa et al. 2016
		LP3036 1810±70 ^{14}C BP	111-416 calAD	Human	Del Papa et al. 2016
	Túmulo 2 Paraná Guazú (15)	AA-72633 846±41 ^{14}C BP	1162-1283 calAD	Human	Bernal 2008
	Túmulo 1 Paraná Guazú/El Cerrillo (16)	AA-93215 576±42 ^{14}C BP	1319-1448 calAD	Human	Bonomo, Politis, and Gianotti 2011
	Túmulo 1 Río Carabelas (17)	No date			Torres 1911
	Paraná Guazú-Mini (18)	No date			Bonomo, Capdepont, and Matarrese 2009
	Paraná Mini (18)	No date			Bonomo, Capdepont, and Matarrese 2009
	Arroyo Los Tigres (19)	No date			Bonomo, Capdepont, and Matarrese 2009
	Arroyo La Garza (19)	No date			Bonomo, Capdepont, and Matarrese 2009
	Túmulo de Campana 1 (20)	AA-100007 1754±49 ^{14}C BP	216-426 calAD	Human	Loponte, Acosta, and Corriale 2016
	Anahí (21)	Beta-147108 1020±70 ^{14}C BP	966-1215 calAD	Coypu (*Myocastor coypus*)	Loponte 2008
	Las Vizcacheras (21)	Beta-148237 1090±40 ^{14}C BP	946-1046 calAD	Guanaco	Loponte 2008
		LP-1401 1070±60 ^{14}C BP	946-1153 calAD	Queen palm	Loponte 2008
	Rio Luján (22)	AA-97458 1692±46 ^{14}C BP	251-530 calAD	Marsh deer	Acosta, Loponte, and Tchilinguirian 2013
	Punta Canal (22)	LP-1293 900±80 ^{14}C BP	1026-1283 calAD	Marsh deer	Buc and Loponte 2016
	Garín (22)	LP-240 1060±60 ^{14}C BP	893-940 calAD	Coypu	Loponte 2008
	El Cazador 3 (22)	AA-103656 1091±43 ^{14}C BP	891-1046 calAD	Guanaco	Acosta, Buc, and Davrieux 2015
		AA-103657 1063±46 ^{14}C BP	966-1150 calAD	Guanaco	Acosta, Buc, and Davrieux 2015
		AA-97464 1031±36 ^{14}C BP	994-1072 calAD	Human	Mazza and Loponte 2012
		AA-97470 921±43 ^{14}C BP	1038-1229 calAD	Marsh deer	Loponte and Corriale 2012
	Rancho Largo (22)	AA-97459 1010±45 ^{14}C BP	995-1163 calAD	Coypu	Buc and Loponte 2016
	Arroyo Sarandí (22)	UGA-10788 1290 ± 40 ^{14}C BP	681-881 calAD	Human	Loponte 2008
		AA-103654 760 ± 37 ^{14}C BP	1226-1384 calAD	Coypu	Bonomo, Politis, and Gianotti 2011
	La Bellaca 1 (23)	LP-1288 1100 ± 70 ^{14}C BP	1023-1271 calAD	Mammal bone	Loponte 2008
	La Bellaca 2 (23)	LP-1263 680 ± 80 ^{14}C BP	1378-1633 calAD	Marsh deer	Loponte 2008

Pampean Sector	**Archaeological Site (Refer to Figure 1)**	**Lab Code, ^{14}C Date, Standard Deviation**	**Calibrated Date (Years BC/AD)**	**Sample**	**Reference**
Low Paraná and Uruguay Wetlands (continued)	El Espinillo (23)	AA-103655 1048 ± 38 ^{14}C BP	986-1150 calAD	Coypu	Buc and Loponte 2016
		AA-103652 1073 ± 38 ^{14}C BP	898-1145 calAD	Marsh deer	
		AA-103653 1046 ± 35 ^{14}C BP	987-1149 calAD	Ampullariidae	
	Guazunambí (23)	Beta-147109 940 ± 60 ^{14}C BP	1024-1231 calAD	Marsh deer	Loponte 2008
	San Luis Costa - Túmulo 1 (1)	No date			Castro and Del Papa 2015
	Tumulo 2 Cerro Sur de Machado (2)	LP-2838 840 ± 50 ^{14}C BP	1151-1295 calAD	Human	Castro and Del Papa 2015
	Túmulo de Lucuix (3)			No date	Castro 2017
	Sambaquí de Puerto Landa (4)	LP-2828 630 ± 50 ^{14}C BP	1296-1427 calAD	Human	Castro and Del Papa 2015
	El Aserradero Viejo (5)	No date			Castro 2017
	Las Conchillas (6)	No date			Castro 2017
	Cerro de los Pampas (7)	No date			Castro 2017

Table 1. continued.

Materials and methods

Modified antlers have been recorded at 43 archaeological sites used by hunter-gatherers in the Pampean region. Most of them (n=35) are located in the Paraná and Uruguay wetlands (see Table 1; Buc 2012; Buc and Coronel 2013; Castro 2017; Lothrop 1932; Torres 1911), two in the Rolling Pampa (Acosta, Buc, and Loponte 2020), one in the Salado depression (Escosteguy, Salemme, and González 2017), and five in the region of the Tandilia and Ventania mountain ranges (Álvarez 2018; Colombo 2013; Mazzanti and Valverde 2001) (Figure 1; Table 1).

In this assemblage, we mainly included sites excavated by our research team, but also included samples published by other authors (see Table 2). Moreover, the Torres and Castro Collections housed at the Museo de Ciencias Naturales de La Plata (MCNLP, La Plata) and the Río Luján sample stored at the Museo Municipal de Ciencias Naturales Carlos Ameghino (Mercedes) were directly analyzed. The MCNLP assemblages were treated as samples, not as archaeological sites, because some of them only carry spatial references (*“Paraná Guazú-mini,” “Paraná mini,” “Brazo Largo”*). The Túmulo 1 del Paraná Guazú sample recovered by Torres and housed at the MCNLP is from the archaeological site named El Cerrillo by Lothrop (1932), which was studied using the official records of the National Museum of the American Indian (NMAI, Washington DC) along with the Arroyo Sarandí sample. We keep these assemblages separate due to the nature of the collected data. Although Bonomo (2013) analyzed the Lothrop NMAI bone tools collection directly, it was not complete, according to the Museum’s records.

The deer species is specified when it could be differentiated but, for most items, it cannot be determined because of the similarities already mentioned. When we did not have direct access to the sample, we took the published determination as valid, except for Lothrop’s data, where we identified them as “Cervidae” due to their informal

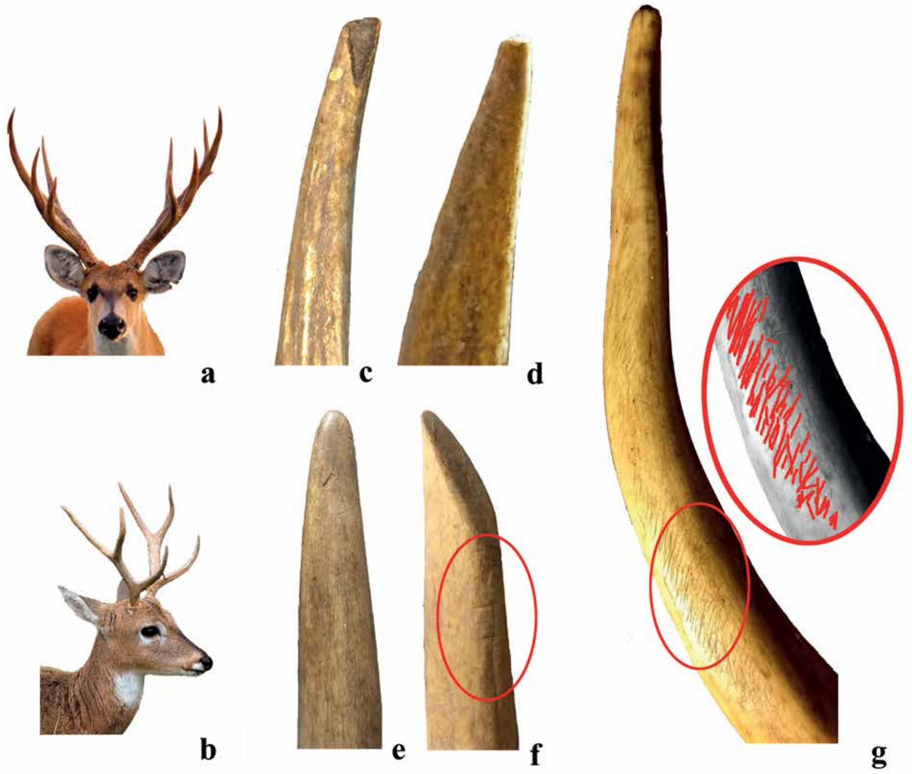

Figure 3. Antlers of a) marsh deer and b) Pampas deer. Natural marks recorded on actual samples: c) bevelled fracture, d) transverse fracture, e) polish at the apical end, f) bevelled polish with transversal marks (circle), g) natural striations, h) microscopic cut marks (light microscope 50x), i) microscopic natural marks (light microscope 50x) (after Buc, Acosta, and Loponte 2019).

identification. Both deer are very different in size from brown brocket deer, which are much smaller and have thinner antlers.

After taxonomic identification, the artifactual type or morphological group was determined using a local database as a reference (Buc 2012). Direct records, published images, or published identifications were taken into account. The broad category of "points" includes determinations made by different authors (*e.g.*, "awls"). Natural antlers without modification were included as well as antlers with sawing and other anthropic marks.

It is well known that natural antlers show marks that can mimic anthropic or intentional modifications as striations, polishes, and fractures (Jin and Shipman 2010; Olsen 1989). In a previous paper on Pampas deer and marsh deer antlers, natural traces were recorded on 45% of the studied samples (Buc, Acosta, and Loponte 2019). Fractures are usually bevelled (simple or double fractures), but there are also transverse fractures that could mimic blunt points (Figure 3cd). Polish is seen as very bright apical rounding; it can present on simple or double bevelled points at the short or long ends (Figure 3ef). Striations are almost exclusively placed on the external and lateral faces of beams, usually on their apical ends or medial sectors. Most striations are short, variable in depth, and transversely or diagonally placed (Figure 3g). With the naked eye, differences could be established

		Analyzed Specimens										Taxonomical identification				
Sector	**Archaeological site**	**Antlers with saw marks**	**Antlers with other anthropic marks**	**Natural antlers**	**Points**	**Blunt points**	**Harpoon heads**	**Harpoon pre-forms**	**Bevelled tools**	**Perforated antlers**	**Total**	**Cervidae**	***B. dichotomus***	***O. bezoarticus***	***Mazama* sp.**	**Reference**
Mountain / intermountain sector	Empalme Querandíes 1		9								9			9		Álvarez 2018
	Calera		20								20			20		Álvarez 2018
	Cueva Tixi early componenet				2	1					3			3		Mazzanti and Valverde 2001
	Cueva Tixi late component				1	1					2			2		Mazzanti and Valverde 2001
	Paso Otero 4		1								1			1		Álvarez 2018
	El Picadero			2							2			2		Colombo 2013
Rolling Pampa	Hunter			2		1			1		4			4		Acosta, Buc, and Loponte 2019
	Cañada de Rocha			1							1			1		Ameghino 1918 (1880)
Salado depression	La Guillerma 5								1		1	1				Escosteguy, Salemme, and González 2017
Low Paraná and Uruguay wetlands	San Luis Costa – Túmulo 1				1						1	1				Castro 2017
	Tumulo 2 Cerro Sur de Machado				1						1	1				Castro 2017
	Túmulo de Lucuix				1						1	1				Castro 2017
	Sambaquí de Puerto Landa				2		5	3		1	11	9	1		1	Castro 2017
	El Aserradero Viejo			1							1	1				Castro 2017
	Las Conchillas			1							1	1				Castro 2017
	Cerro de los Pampas				6		3	1	2	1	13	12	1			Castro 2017
	Cerro Lutz	2	2	3	6		1				14	14				This paper
	Túmulo 1 Brazo Gutiérrez				1						1	1				Torres 1911
	Túmulo 1 Brazo Largo				6		2	1			9	9				Buc and Coronel 2013
	Brazo Largo	14		9			6	5		1	35	35				This paper
	Cementerio 1 Paraná Guazú	1									1	1				Torres 1911
	Escuela 31	9		4	1				9		23	23				This paper

Table 2 (continued on following page). Antler records from the Pampean region. Analyzed sample. MNE: minimum number of elements.

		Analyzed Specimens										Taxonomical identification				
Sector	**Archaeological site**	**Antlers with saw marks**	**Antlers with other anthropic marks**	**Natural antlers**	**Points**	**Blunt points**	**Harpoon heads**	**Harpoon pre-forms**	**Bevelled tools**	**Perforated antlers**	**Total**	**Cervidae**	***B. dichotomus***	***O. bezoarticus***	***Mazama* sp.**	**Reference**
Low Paraná and Uruguay wetlands (continued)	Isla Lechiguanas 1 non-ceramic	3			2		1		3		9	9				This paper
	Isla Lechiguanas 1 ceramic period	1					1	1			3	3				This paper
	La Argentina	1		2	1				1		5	4	1			This paper
	Túmulo 2 Paraná Guazú	1					1				2	1	1			Buc and Coronel 2013
	Túmulo 1 Paraná Guazú*	4		1			2				7	5	2			Buc and Coronel 2013
	El Cerrillo	85	8	4			7			3	107	107				NMAI Official Records
	Túmulo 1 Río Carabelas				5						5	5				Torres 1911
	Paraná Guazú-Mini						2			1	3	2	1			Buc and Coronel 2013
	Paraná Mini	2		2							4	4				Buc and Coronel 2013
	Arroyo Los Tigres			5							5	5				This paper
	Arroyo La Garza			2							2	2				This paper
	Túmulo de Campana 1	1		1			1				3	3				This paper
	Anahí	4			8		1				13	12		1		This paper
	Las Vizcacheras				2						2	2				This paper
	Rio Luján	2					2			1	5	3	2			This paper
	Punta Canal	2		1	3		2				8	8				This paper
	Garín	2		4	3		1				10	8	2			This paper
	El Cazador 3	6	1	14	17		12	2		1	53	52	1			This paper
	Rancho Largo	2					1				3	3				This paper
	Arroyo Sarandí	14		1	3		10			3	31	31				NMAI Official Records
	La Bellaca 1	1		3	3		1				8	7	1			This paper
	La Bellaca 2	5	3	3	8		9	5			33	30	3			This paper
	El Espinillo				4		2			1	7	7				This paper
	Guazunambí				1						1	1				This paper
	TOTAL	162	44	66	88	3	73	18	17	13	484	424	16	43	1	

Table 2. continued.

only in the case of anthropic striations, which are regular, have V-shaped cross-sections, and usually have internal striations (cf. Buc 2012). Usually, they are associated with clear macro traces, such as sawing or cut marks. A preliminary examination conducted by light microscopy showed that natural striations are shallow and sinuous (Figure 3i), while anthropic marks are deep and straight with a V profile (Figure 3h). However, a systematic microscopic database of natural features is currently under development. After these results, data on modified antlers should be considered with caution when they have not been identified after a systematic analysis of the sample (see for example Álvarez 2018; Buc, Acosta, and Loponte 2019).

Results

The results are summarized in Table 2. In the mountain ranges sector, the antlers belong to Pampas deer, the local species that naturally inhabited this sector. Bone tools made of antler have been recorded only at the Cueva Tixi archaeological site. The Middle Holocene artifacts have been described by Mazzanti and Valverde (2001) as a blunt point and two burnt points with polished areas. However, according to our database of natural marks on antler, a detailed examination using natural samples for comparison is needed to conclude that they are real tools. The Late Holocene sample from Cueva Tixi includes a blunt point that "shows longitudinal and transverse striations in the distal and medial sectors as well as some scars in the apical sector" (Mazzanti and Valverde 2001, 169; own translation). But the second artefact (no. 23) is defined as an "awl," which, according to the morphological identification made by the authors, shows "transverse incision and longitudinal scraping" (Mazzanti and Valverde 2001, 169), which are clearly anthropic. At the Calera and Empalme Querandíes 1 archaeological sites, both dated between 1150 and 50 years BC, antlers with anthropic modifications have been recorded. Álvarez (2018) used published references for natural marks as a frame to analyze the antler tines and pedicles recovered at these sites. Based on their abraded surfaces and negative flakes, the author concludes that the bases were usually used as soft hammers (Figure 4b). The same features were recorded by Álvarez on the antler recovered at Paso Otero 4, a Middle Holocene archaeological site (Álvarez 2018). At El Picadero, a Late Holocene archaeological site related to lithic production, a Pampas deer antler (Figure 4c) was recorded that, according to Colombo (2013) would have been linked to the extraction of raw material from bedrock.

In the Rolling Pampa, five antler elements were recorded; all were made on Pampas deer, the local species. One of them was recorded by Ameghino (1918 [1880]) at the Cañada de Rocha archaeological site; it is a fragment of a naturally shed skull cap (Figure 4a). The author mentioned the existence of serrated natural antlers, but he specified that no bone tool based on this raw material was identified. Four other antler elements came from the Hunter archaeological site. Two completely polished tines could have been described as tools, but, on the basis of natural marks (Buc, Acosta, and Loponte 2019), we cannot assume they were modified by use. The two remaining antler tines do show anthropic usewear: in one case, the tine was intentionally segmented by sawing, although the evidence for anthropic usewear on the bevelled apical sector is uncertain (Figure 4d; see Buc, Acosta, and Loponte 2019), and in the other case, on a naturally shed antler, the apical marks could be related to compressive activities on hard materials (as flakers; cf. Nami and Scheinsohn 1997) (Figure 4d, 5c).

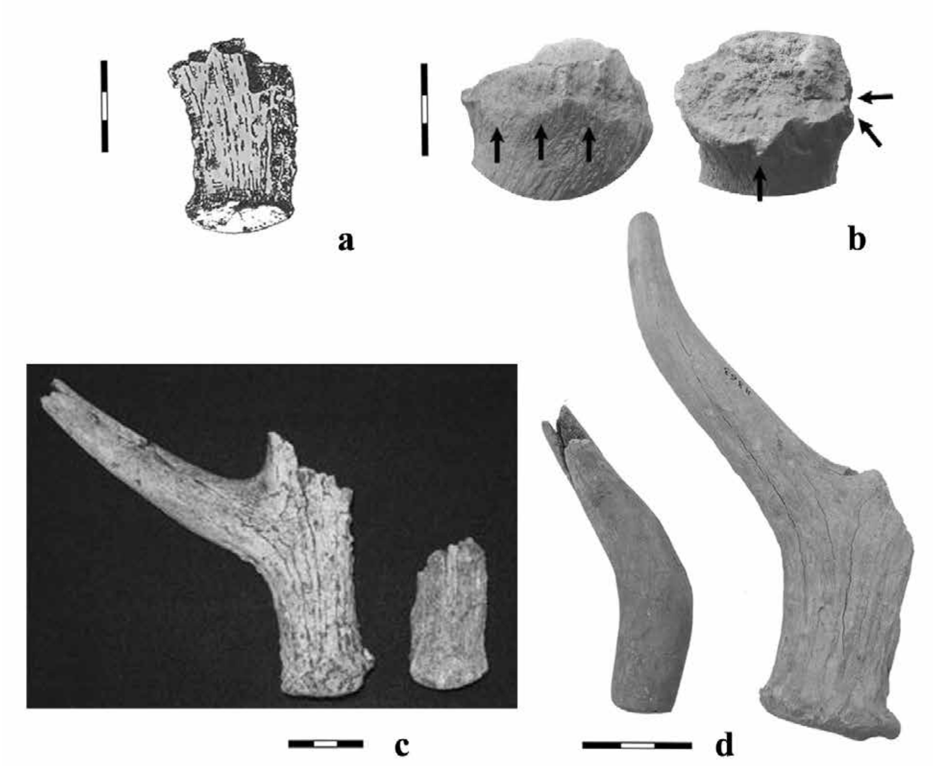

Figure 4. Antlers recovered at: a) Rolling Pampa (from Ameghino 1918 (1880), lam. XV); b) Mountain range sector: Empalme Querandíes 1 (modified from Álvarez 2018, Figure 8); c) Mountain range sector: El Picadero (modified from Colombo 2013, Figure 101); d) Rolling Pampa: Hunter (from Buc, Acosta and Loponte 2019, Figure 4).

From the Salado depression, only one antler fragment (no species identified) has been recovered. It is a 21.9 mm apical burnt fragment that is bevelled and polished. According to Escosteguy, Salemme, and González (2017, 75), this last feature is the result of the use, but more information is needed to be conclusive about its anthropic origin.

The Low Paraná wetland contributes the highest numbers of antler elements. We counted 441 items in 37 assemblages. Marsh deer was identified in 16 cases, Pampas deer in only one case and, in one extra case, brown brocket deer was identified by Castro (2017). The ample majority of the sample was assigned to the Cervidae family. Almost half of the sample consists of natural antlers that are completely unmodified and unsegmented: there are 56 items in an assemblage of tines and pedicles, two naturally shed antlers (Figure 5a, c) and three pedicles with neocranium (Figure 5e-g) without anthropic modification. A total of 162 antlers or tines were segmented by sawing; these are firmly associated with anthropic activities whether or not they were effectively used; from this assemblage, we only recorded one naturally shed antler that has its beams cut off (A5; Figure 5b). The serrated antlers included in this group could be manufactured waste or raw materials stocked for production of artifacts. In some cases, we could identify preforms, but they are included in the cultural assemblage (see below). In a previous paper (Buc, Acosta, and Loponte 2019), we analyzed samples from 14 archaeological sites in the Low Paraná wetland. In this case, although there was a considerable number of antler elements

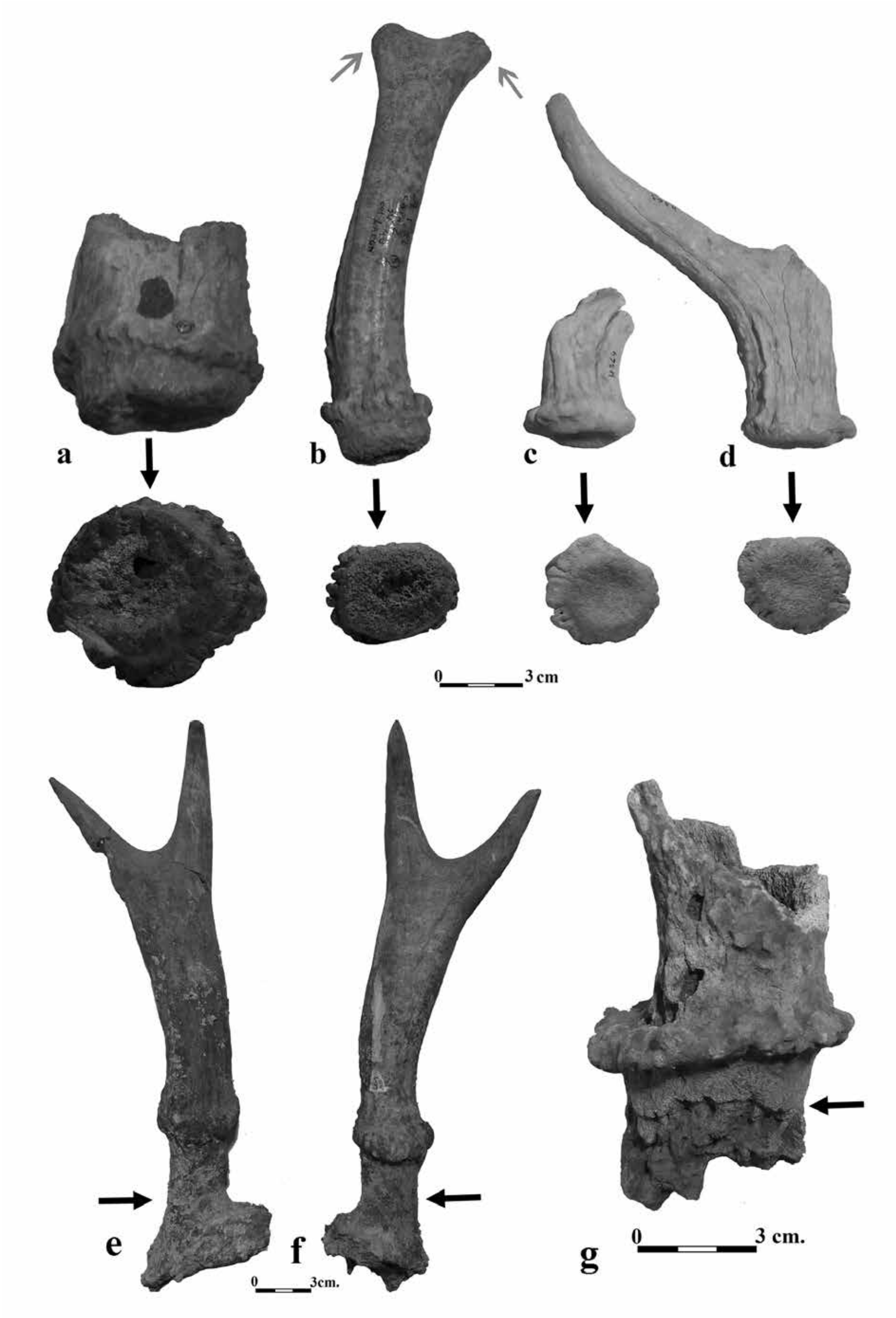

Figure 5. a-c) Naturally shed antlers from the Garín, Anahí, and Hunter archaeological sites with the grey arrows showing serrated beams; e-f) antlers with pedicles and neocranium from the La Bellaca 1 and La Argentina archaeological sites.

Figure 6. Main morphological groups made on antler: a) bevelled point, b) bipoint (double point), c) harpoon head, d) perforated antler.

with saw marks, the use of their apical ends, which showed bevelled or blunt fractures, polished areas, and striations similar to natural records, remained uncertain. The group of non-manufactured antlers with clear anthropic marks suggesting use is small, containing 14 items, most of them defined by their decoration.

The assemblage that includes the other half of the antlers is composed of 204 bone artefacts. Most of them are formal bone tools, but we also found pre-forms (n=18). The most representative morphological group is that of the harpoons (Figure 6c), with 73 items. In the Paraná wetland harpoons are exclusively made on antler tines (Buc 2012). Secondly, we found a “points” group that is composed of diverse apical ends (Figure 6b). The group of convex and bevelled points comprises almost 20 items (Figure 6a). In both morphological groups, antler is one of the main raw materials used. Finally, there are also perforated antlers (n=13; Figure 6d). Usually, they are divergent branches with a central perforation, but there are also divergent branches with both tines serrated that could have been pre-forms (see Figure 5b).

Discussion

On a regional scale, clear differences in antler representation among the different areas of the Pampean region can be noted. The Low Paraná wetland is the sector with the greatest number of tools made of bone in general, and it also has the greatest diversity of said tools (Acosta, Buc, and Loponte 2019). This is also the case for antler. Although deer antlers are represented in almost all archaeological samples, they are rarely used without modification, with the main type recorded in other Pampean sectors. In all cases, bone tools are less frequent, even though there are differences in the archaeological record of the area. While the Rolling Pampa has been analyzed the least, and one can argue for a sample bias, the mountain range area is one of the traditional sectors studied in the archaeology of the Pampa region due to its a rich lithic record; early finds have been decisive in discussing

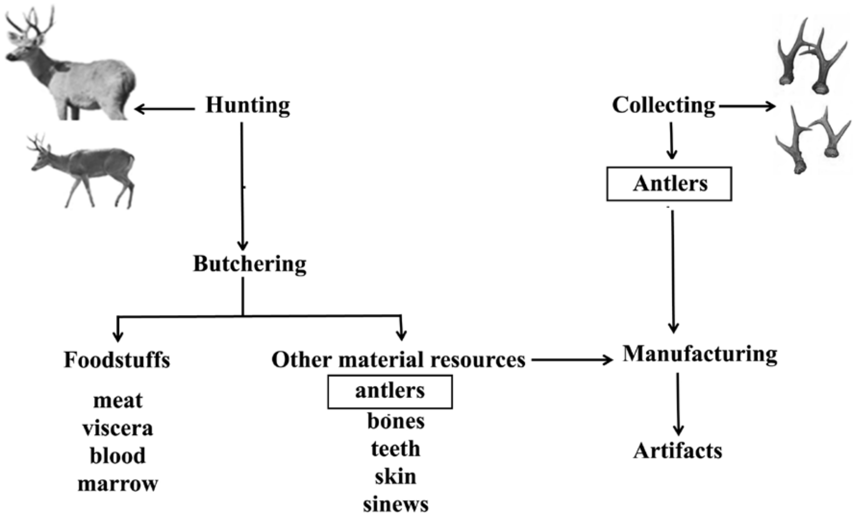

Figure 7. Hypothetical sequence of antler procurement.

the peopling of the Americas (*e.g.*, Politis *et al.* 2016). However, bone tools are quite scarce in this sector and tools made on antler are even more so. The Salado depression is the area with the most bone tools aside from the Paraná wetland, although there is only one antler specimen. The distribution of bone tools made on antler is related to the Paraná basin, not the Pampean region, following the general tendency of bone technology (Buc 2012).

In the Low Paraná wetland and in the Salado depression, Pampas deer and marsh deer could have been exploited for antler procurement. This situation, along with the high degree of modification seen in the Low Paraná wetland, impedes greater precision in the species identification. However, considering the spatial distribution and eto-ecological properties of both taxa, it is highly probable that marsh deer could have been the main species exploited in the island sector. In contrast, in the areas near the Pampean plains, both taxa could have been exploited in a more balanced form as seen in the faunal record (*e.g.*, Acosta 2005; Loponte 2008). In a recent osteometric study, on the basis of the analysis of Pampas deer remains from archaeological sites in the Low Paraná wetland, Loponte *et al.* (2019) confirm that male Pampas deer were the preferred prey. Therefore, Pampas deer antlers could have entered the campsite with hunted individuals. However, at archaeological sites from the Low Paraná wetland and other Pampean sectors, pedicles with neocranium fragments along with naturally shed antlers were found (see examples in Figure 5). Therefore, both procurement strategies (hunting and collecting) could have been involved in antler procurement.

The mechanical properties of antler are exceptional because their elastic modulus gives them high resistance to stress (Guthrie 1983; Currey 1979; Currey *et al.* 2009), which makes them suited for manufacturing maintainable and reliable tools (Bleed 1986). Their naturally pointed apex makes it easy to transform them into different kinds of points; moreover, the high content of spongy tissue (Currey 1979) lets them be hollowed out easily when they are wet (cf. Buc 2012). In the case of the Low Paraná wetland, this implied simply sawing tines and, occasionally, regularizing the surface with a coarse-grained material, and in the case of hollow points and harpoons, the inner cortical bone was removed (Buc 2012). Antlers were also used in some types of tools whose use we cannot confirm, such as bevelled tools and perforated antlers. Bevelled tools were only found at archaeological sites in the northern portion of the Low Paraná wetland. It is highly probable that they were related to a specific activity, and they may have been used as wedges in wood production (cf. Cinq-Mars and Le Blanc 2008; Scheinsohn 1997), a case where resistance is critical. The use of perforated antlers is unclear and the subject of a worldwide debate, although systematic work suggests they were artefacts that were part of a complex system and exposed to high stress (Glory 1965; Lucas *et al.* 2019; Rigaud 2001, 2004).

Moreover, antler's exceptional mechanical properties could explain the presence of points with or without signs of use and with no manufacturing traces in the Pampean Region in general. Antlers could have been collected from the landscape or removed from prey as raw material (Figure 7). This situation would have enlarged the frequency and natural availability of antlers, conditioning their exploitation strategies. Naturally shed antlers have been identified (Figure 5), but they cannot be related to seasonal markers as they can be collected from the landscape at any time of year (Wild 2020). There is no consensus on the quality of naturally shed antlers as different from unshed ones (see for example Capelli *et al.* 2017; Currey *et al.* 2009; Vitezović 2017); it is mostly determined by nutritional and ecological variables (*e.g.,* Landete-Castillejos *et al.* 2019). In the Paraná wetland, the operational sequence would have occurred at the residential bases due to the high numbers of antlers with saw marks and the pre-forms recovered. In this sector, antler tines were the main raw material used, and they were obtained through sawing.

Concluding remarks

The results of the analyzed sample confirm that antler was differentially used among hunter-gatherer groups in the Pampean Region. It was obtained either through hunting or by being collected from the landscape; its nutritional value is null, while its mechanical properties are formidable. In the sectors where bone technology was highly developed, such as the Low Paraná wetland, antler was the main raw material transformed into different types of tool. Conversely, in other sectors of the region, where bone technology followed an expedient strategy, antlers were kept as raw material, used in their natural form, or transformed into informal artifacts. Considering the natural marks recorded for the Pampean deer species suggests that the use of tines should be reconsidered by systematic analysis in several cases.

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Osseous artifacts from the Maros-culture necropolis at Ostojićevo (northern Serbia)

Selena Vitezović

Abstract

The Bronze Age Maros culture, widespread in the southern parts of the Carpathian basin, is characterized by the rich and diverse material culture recovered from settlements and necropoles. Some of the burials of the Maros culture contained rich funerary equipment that encompassed ceramic vessels, bronze weapons, bronze and gold jewellery, as well as ornaments made from osseous raw materials. One of the necropoles that yielded interesting finds of bone ornaments was discovered at the site of Ostojićevo, situated in the Banat region in northeastern Serbia. This necropolis contained graves belonging to the Early and Middle Bronze Age; out of 285 graves, 77 were attributed to the Maros culture. Osseous ornaments recovered from these graves were made from diverse raw materials, bones, teeth, and mollusc shells. The typological repertoire includes pendants, beads, decorative pins, and applications. Their typological and technological traits as well traces of use are analyzed, highlighting their overall importance and symbolic role for Maros culture communities.

Rezime

Bronzanodopska kultura Maroš bila je rasprostranjena u južnim oblastima Karpatskog basena, i karakteriše je bogata i raznovrsna materijalna kultura, otkrivena u naseljima i na nekropolama. Pojedini grobovi maroške kulture sadržali su bogati pogrebni invenar, koji je obuhvatao keramičke posude, bronzano oružje, bronzani i zlatni nakit, kao i ukrase izrađene od koštanih sirovina. Jedna od nekropola sa koje potiču zanimljivi nalazi koštanog nakita otkrivena je na lokalitetu Ostojićevo, koji se nalazi u Banatu u severoistočnoj Srbiji. Na ovoj nekropoli otkriveno je ukupno 285 grobova iz ranog i srednjeg bronzanog doba, od čega 77 grobova pripada nosiocima maroške kulture. Koštani ornamenti pronađeni u ovim grobovima izrađeni su od različitih sirovina – od kostiju, zuba i ljuštura mekušaca. Tipološki repertoar obuhvata priveske, perle, ukrasne igle i aplikacije. Analizirane su njihove tipološke i tehnološke odlike, kao i tragovi upotrebe, koji pokazuju značaj i simboličku ulogu ovih ukrasa u okvrima zajednica maroške kulture.

Keywords: Bronze Age, osseous raw materials, personal ornaments, beads

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The archaeological background: The Bronze Age Maros culture

The Bronze Age culture labelled Maros (Moriš) was a widespread phenomenon in the southern Carpathian basin among the valleys of the Tisza (Tisa) and Maros (Moriš or Mureş) rivers in present-day southeastern Hungary, northwestern Serbia, and southwestern Romania (Tasić 1974; Garašanin 1983; O'Shea 1996). The culture is usually labeled "Maros" or "Moriš," but the terms "Periamos" or "Mokrin culture" may be encountered in the earlier literature (Garašanin 1983, 476).

Research on this culture began over 100 years ago, and numerous sites are known today, including flat and tell settlement sites and necropoles (Garašanin 1983; O'Shea 1996; and references therein). Among them, we may outline the tell settlements of Pecica-Şanţul Mare (O'Shea e*t al.* 2005; O'Shea *et al.* 2006; O'Shea *et al.* 2011) and Perjámos-Sánchalom (Periam) in Romania and Klárafalva-Hajdova in Hungary (O'Shea 1996) as well as the flat settlements Ószentiván-Nagyhalom in Hungary (O'Shea 1996) and Popin Paor in Serbia (Girić 1987). Necropoles have been more extensively researched and include sites such as Szöreg (with 229 burials), Batanya (79), and Pitvaros (42) in Hungary (Tasić 1974; O'Shea 1996), and Mokrin (Girić 1971) and Ostojićevo-Stari Vinogradi in Serbia (Milašinović 2008; 2009). Mokrin, situated 12 km from present-day Kikinda, can be singled out as one of the most important sites. This is the largest Maros culture cemetery, with 312 graves uncovered. It was extensively excavated in the 1960s using then-current recovery techniques and, importantly, thoroughly analyzed and published by the excavator (Girić 1971). The analysis of the excavated archaeological and anthropological remains continues today with the application of novel methodological approaches and techniques (*e.g.,* Žegarac *et al.* 2019).

Absolute dates obtained from the necropolis in Mokrin place it in the period between the 21st and 19th centuries BC, while the site of Klárafalva is dated to the period between the 23rd and 16th centuries BC (Forenbaher 1993; O'Shea 1996, 37; and references therein).[1] In the past few decades, new analyses have been done, and new dates have been obtained for the Bronze Age in the Carpathian basin; therefore the chronology is constantly being revised (see Szabó 2017 for a full discussion of the problem).

The Maros culture communities practiced agriculture and herded domestic animals – cattle (*Bos taurus*), sheep (*Ovis aries*), goats (*Capra hircus*), pigs (*Sus scrofa*), horses (*Equus*), and dogs (*Canis familiaris*)–while wild species had a minor role. Cattle, sheep, and goats were exploited for both primary (for meat, but also for skin and bones) and secondary products (milk, wool, and traction) (Greenfield 2001). Metallurgy played an important role in the economy; metal became more common in comparison with previous periods, and metal artifacts increased in frequency towards the end of the Early Bronze Age. It is interesting, however, that majority were weapons and ornaments, while utilitarian items were less frequent (Garašanin 1983; O'Shea 1996).

The European Bronze Age is generally perceived as the time when important changes in social structures occurred and social stratification emerged (Dani *et al.* 2016, 219). The rich and diverse burial rites and funerary equipment recovered from

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[1] Uncalibrated (BP) dates obtained from the necropolis at Mokrin are following: 3690 ± 30 (GrN-14179), 3655 ± 30 (GrN-14178), 3650 ± 50 (GrN-7977), 3650 ± 35 (GrN-14180), 3595 ± 35 (GrN-14181) and 3500 ± 35(GrN-8809) (Forenbaher 1993, t. 1, 244; also listed in O'Shea 1996, 37; Szabó 2017, t. 1, 112). Extensive lists of available dates for the Bronze Age in the Carpathian basin are provided in Forenbaher 1993; O'Shea 1996, 37, table 3.1; Szabó 2017 – please see them for further discussion.

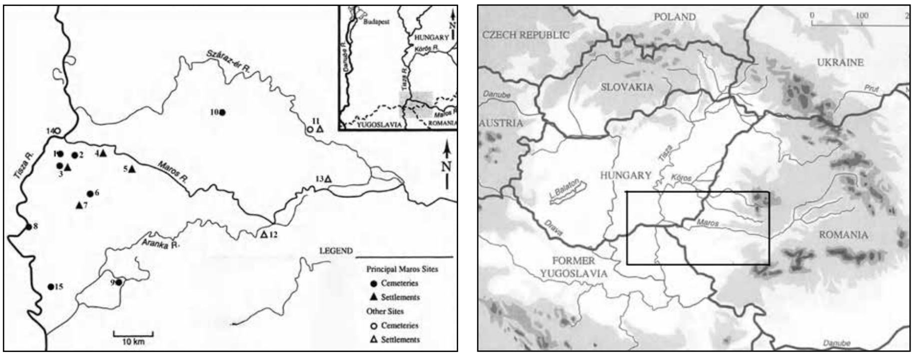

Figure 1. Map of the Maros culture: 1. Szöreg, 2. Deszk A, F, 3. Ósentiván, 4. Klárafalva-Hajdova, 5. Kiszombor-Új Élet, 6. Óbeba, 7. Rabe, 8. Novi Kneževac, 9. Mokrin, 10. Pitvaros, 11. Battonya, 12. Perjámos, 13. Pécska, 14. Tápé, and 15. Ostojićevo (adapted after O'Shea 1996; Milašinović 2009).

Maros culture cemeteries were the basis for the studies of social stratification in this period in the southern Carpathian basin. Numerous researchers were interested in this topic (*e.g.*, Soroceanu 1975; Primas 1977). The most comprehensive analysis of the society was carried out by J. O'Shea (O'Shea 1996), and later studies relied on his methodological and theoretical framework (Milašinović 2008; 2009). O'Shea included the data from all the studies of cemeteries of the Maros group available at the time – Mokrin, Szöreg, Deszk A, Deszk F, Ószentiván, and Óbéba. He distinguished a "normative" burial mode (flexed inhumation, facing east), which represents the standard form that a community member could expect on death, and a series of differentiated modes. He argued that some of them, such as weapons and certain head ornaments, may be signs of hereditary social office, while other items, notably body ornaments, are seen as representing "associative" wealth, that is, wealth derived from membership of a particular household by the person possessing it (O'Shea 1996; cf. also Harding 2004).

The site of Ostojićevo-Stari Vinogradi

The site of Ostojićevo-Stari Vinogradi is situated in the Banat region in northeastern Serbia, 24 km northwest of present-day Kikinda (Figure 1). The site itself is located on the left bank of a now-dry meander of the Tisza river. Along with the nearby Mokrin, it is one of the largest Bronze Age cemeteries discovered in Serbia, and one of the most important cemeteries of the Maros culture. The site was first noted in 1954 and excavated in the period between 1981 and 1991 by the National Museum of Kikinda (Girić 1959; Milašinović 2008; 2009). The excavated area exposed 3886 m^2 in 136 trenches, where 285 graves dating to the Early and Middle Bronze Age were discovered. Seventy-seven graves were attributed to the Maros culture; it was possible to clearly discern these burials by differences in depth and a clear hiatus in the stratigraphy (Milašinović 2009). Unlike Mokrin, the examination of archaeological and anthropological remains from this site was only partially completed (Milašinović 2008; Vučetić 2018), and further analyses are to ensue.

Ornaments from osseous raw materials from Ostojićevo

A rich funerary inventory is one of the hallmarks of the Maros culture, and the attention of researchers often focused on analyzing archaeological evidence obtained from the cemeteries. As mentioned above, studies have mainly been concentrated on social relations and social hierarchy, as evidenced by the differences in burial rites and funerary equipment; metal objects especially have received more attention. However, personal ornaments made from osseous raw materials also provide some insight into social relations and symbolic worldviews of the Maros-culture communities.

Ornaments made from osseous raw materials were discovered in 20 of the 77 graves from the necropolis at Ostojićevo attributed to the Maros culture (Table 1). These ornaments were analyzed from technological and typological viewpoints. They were examined with a hand lens and a microscope with magnification up to 60x. Analytical criteria for the technological and functional interpretation of manufacture and usewear traces were established based on the previous work of numerous authors (Bonnardin 2008; 2009; Christidou 2008; d'Errico 1993; Legrand and Sidéra 2006; Newcomer 1974; Peltier 1986; Semenov 1976).

Raw materials

The osseous raw materials used include bones, teeth, and mollusc shells.

The bones were mainly those of medium or small mammals, predominantly sheep/goats, followed by cattle and pigs. The teeth were predominantly canines from domestic dogs, with occasional use of the canines of red deer (*Cervus elaphus*), cattle incisors, and teeth from pigs; one specimen was a horse tooth. Almost exclusively, skeletal elements from domestic animals were used; they were most likely obtained locally. Ornaments made from antler were not noted at Ostojićevo, although red deer antlers were otherwise used for everyday tools at the Maros-culture settlement of Pecica-Şanţul Mare (Nicodemus, Lemke 2016).

The mollusc shells include valves of *Glycymeris*, shells of *Dentalium*, *Columbella*, and fragments of shells that could not be identified, mainly due to heavy erosion of the surfaces and fragmentation. At least some of them were obtained via some sort of exchange; there is a possibility, though, that some of them were in fact fossil shells obtained almost locally (directly or through a local exchange network).[2]

Typological repertoire

Artifacts were classified following the typological scheme outlined by H. Camps-Fabrer and colleagues in *Fiches typologiques* (Camps-Fabrer 1991) and the scheme proposed by S. Bonnardin (Bonnardin 2008; 2009, 57-67) adapted to the particular assemblage of the Maros culture.[3] Such classification includes the following main types: pendants, beads, decorative pins, and applications. Subtypes and variants were defined using the morphological criteria and raw material.

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[2] The criteria for distinguishing fossil from fresh molluscs follow Dimitrijević, Tripković 2006; cf. also Dimitrijević *et al.* 2010 and Dimitrijević 2014 for the availability of fossil *Dentalium* shells in the Danube valley. However, the small sample size and poor preservation at Ostojićevo do not allow firm conclusions regarding the origins of the molluscs.

[3] See the typological scheme proposed for Mokrin in Vitezović 2017 and the more detailed beads only in Vitezović *in press.*

Grave no.	Osseous artifacts
35	Perforated teeth of *Canis familiaris* (n=1)
79	Perforated teeth of *Canis familiaris* (n=26) Decorative pins (n=2)
107	Triangular application (n=1) Beads made from long bones (n=6) Perforated teeth (total=28) of *Canis familiaris* (n=20) of *Bos* (n=4) of *Cervus elaphus* (n=3) of *Equus* (n=1)
114	Beads made from *Dentalium* (n=3) Beads made from long bones (n=2)
120	Beads made from *Dentalium* (n=5) Beads made from long bones (n=28) Beads made from other molluscs (n=2) Applications made from *Bivalvia, Glycymeris,* and undetermined (n=5)
126	Decorative pins (n=2)
128	Beads made from long bones (n=5) Perforated teeth (total=9) of *Canis familiaris* (n=3) of *Bos* (n=4) of *Sus scrofa* (n=2)
141	Decorative pins (n=2) Semi-globular application (n=1)
147	Triangular application (n=1) Discoid application (n=1) Fragmented tooth of *Sus scrofa*, unidentified artifact (n=1)
166	Decorative needle (n=1)
184	Decorative pins (n=2)
186	Beads made from *Dentalium* (n=2)
190	Elongated pendant (n=1) Discoid application (n=1)
226	Bead made from *Dentalium* (n=1)
227	Fragmented tooth of *Sus scrofa,* unidentified artifact (n=1)
229	Perforated tooth of *Canis familiaris* (n=1)
230	Beads made from *Dentalium* (n=3) Beads made from *Columbella* (n=2) Applications made from *Bivalvia, Glycymeris,* and undetermined (n=3)
250	Beads made from *Dentalium* (n=3) Fragment of *Unio* shell (it is not certain whether it is an artifact)
280	Beads made from *Columbella* (n=7)
283	Beads made from *Columbella* (n=1)

Table 1. List of Maros culture graves from Ostojićevo and osseous ornaments discovered within them.

Pendants

Pendants are decorative objects that are suspended or attached by their upper part while their lower part is free; they have at one end (in the upper part) a perforation or, rarely, a groove used for suspension (Taborin 1991).

Two subtypes of pendants can be distinguished in the material from Ostojićevo, A (perforated animal teeth) and B (shell valves with perforations) (type A is after Bonnardin 2009 – *coquillage et dents simplement percées*); additionally, one unique pendant from bone was discovered.

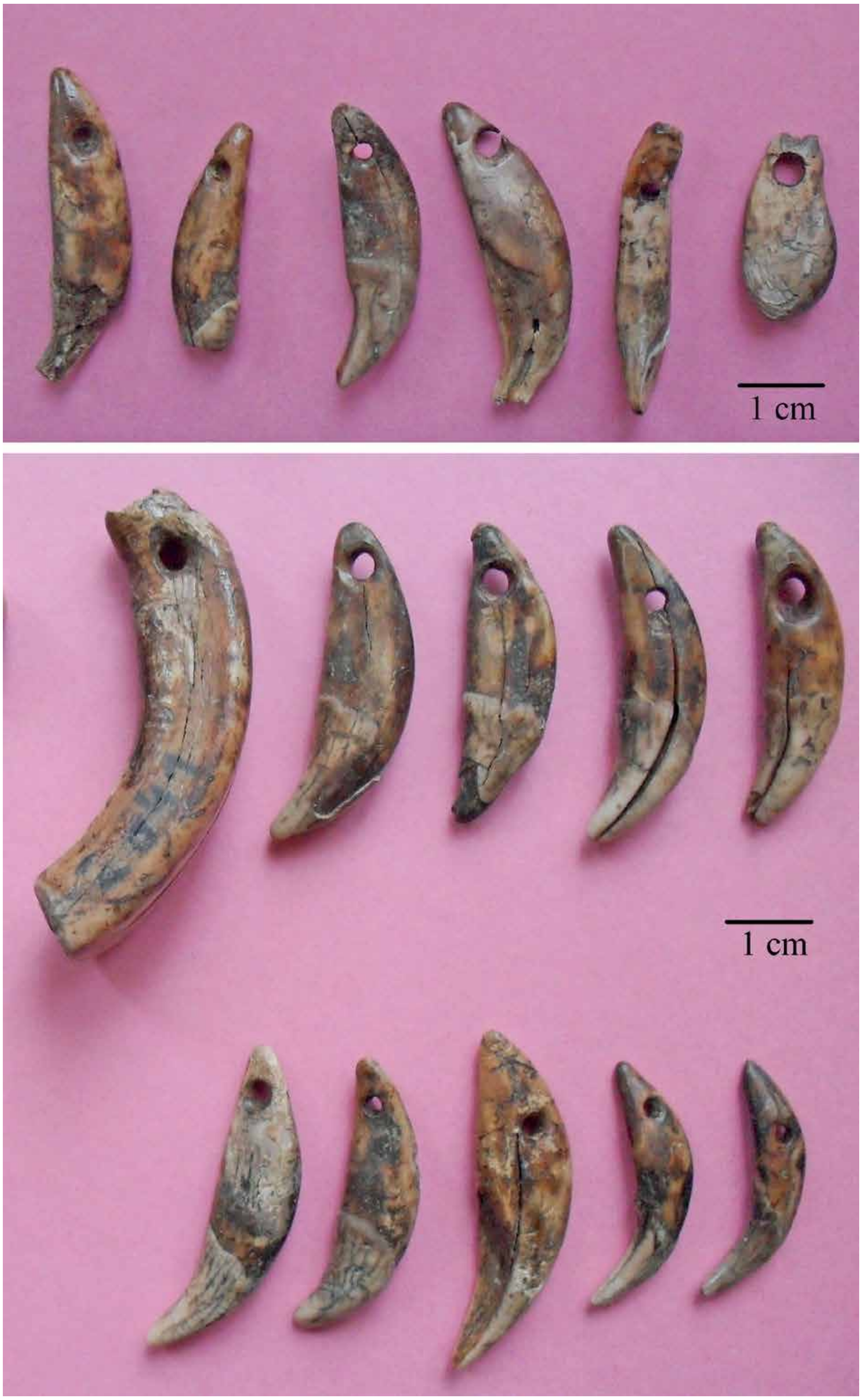

Figure 2. Some of the perforated teeth from grave no. 107, including red deer teeth (upper row, last one) and an *Equus* tooth (second row, first to the left).

Perforated animal teeth are the most common ornament among the osseous raw materials at Ostojićevo (Figure 2). They were produced simply by drilling a perforation at the root, usually from both sides. Regular concentric lines from drilling are still visible inside some of them. On some of the teeth, the surface was slightly scraped before drilling was initiated. The diameter of these perforations is 2-3 mm. The quantities of perforated teeth vary considerably (Table 1); while some burials contain just one perforated tooth (for example, grave no. 35), in others they are quite numerous: 26 teeth were recovered from grave no. 79 and 20 from grave no. 107 (Figure 2).

The traces of use on the perforated teeth from Ostojićevo consist of intensive polish and wear in the area of the perforation; usually, the upper part of the perforation has more prominent polish and wear, which is consistent with suspension (Figure 3). Occasionally, the perforations are deformed from use or even broken. It is interesting to note that the intensity of usewear differs considerably on the different specimens, even those from the same burial. While some of the pendants are completely worn down, others were barely used. This shows that these ornaments were worn during the life of the buried individual and at the same time implies something else: that the composite ornaments containing these teeth were enriched and/or repaired over time by adding new pieces and/or replacing the broken ones. It is possible that some were even inherited.

Canine teeth from *Canidae* were prevalent and probably all from dogs. Teeth from other species are rare. In addition to dog teeth, grave no. 107 contained four cattle teeth, two red deer teeth, and one horse tooth (Figure 2). Among nine teeth found in grave no. 128, three were from dogs, four from cattle, and two from pigs. It is not clear, however, whether the various species had different meanings or simply a substitute for the otherwise preferred dog teeth. Perforated teeth were also frequent at Mokrin, and there the predominant species was also dog (Vitezović 2017, 70). One perforated dog tooth was found at the Maros culture settlement at Pecica-Şanţul Mare (Nicodemus and Lemke 2016).

Perforated animal teeth are generally a common and widespread type of personal ornament and have been widely used since the Palaeolithic (Cattelain 2012). They remained in use in the metal ages and are commonly encountered at other Bronze Age sites in the region. Diverse species are represented, but the relatively frequent presence of dog teeth is conspicuous, suggesting that a certain symbolic meaning attributed to dog teeth was common for many Bronze Age communities. For example, at the Monteoru culture site of Năeni-Zănoaga Cetatea 2 in Romania, perforated canines from domestic dogs were noted together with a cattle incisor and a red deer canine (Mărgărit *et al.* 2011, 17-18; Figure 4). Pendants from dog and wild boar (*Sus scrofa*) teeth were discovered at the Early and early Middle Bronze Age site of Tiszaug-Kéménytető in Hungary (Choyke and Bartosiewicz 2000; Figure 4), while at the Middle Bronze Age site of Jászdózsa-Kápolnahalom, perforated teeth from domestic dogs, pigs, horses and different wild animals were found (Choyke and Bartosiewicz 2009).

The second subtype of pendants are single valves of *Bivalvia* shells with a perforation at the apex (Figure 4). Only the *Glycymeris* shells were identified with certainty (some of the shells were too fragmented). They were not frequent; five were discovered in grave no. 120 and three in grave no. 230 (Table 1). These shells are generally poorly preserved, with eroded surfaces, and fragmented; furthermore, the perforations have intensive traces of wear. Therefore, it is not possible to reconstruct with certainty the method of

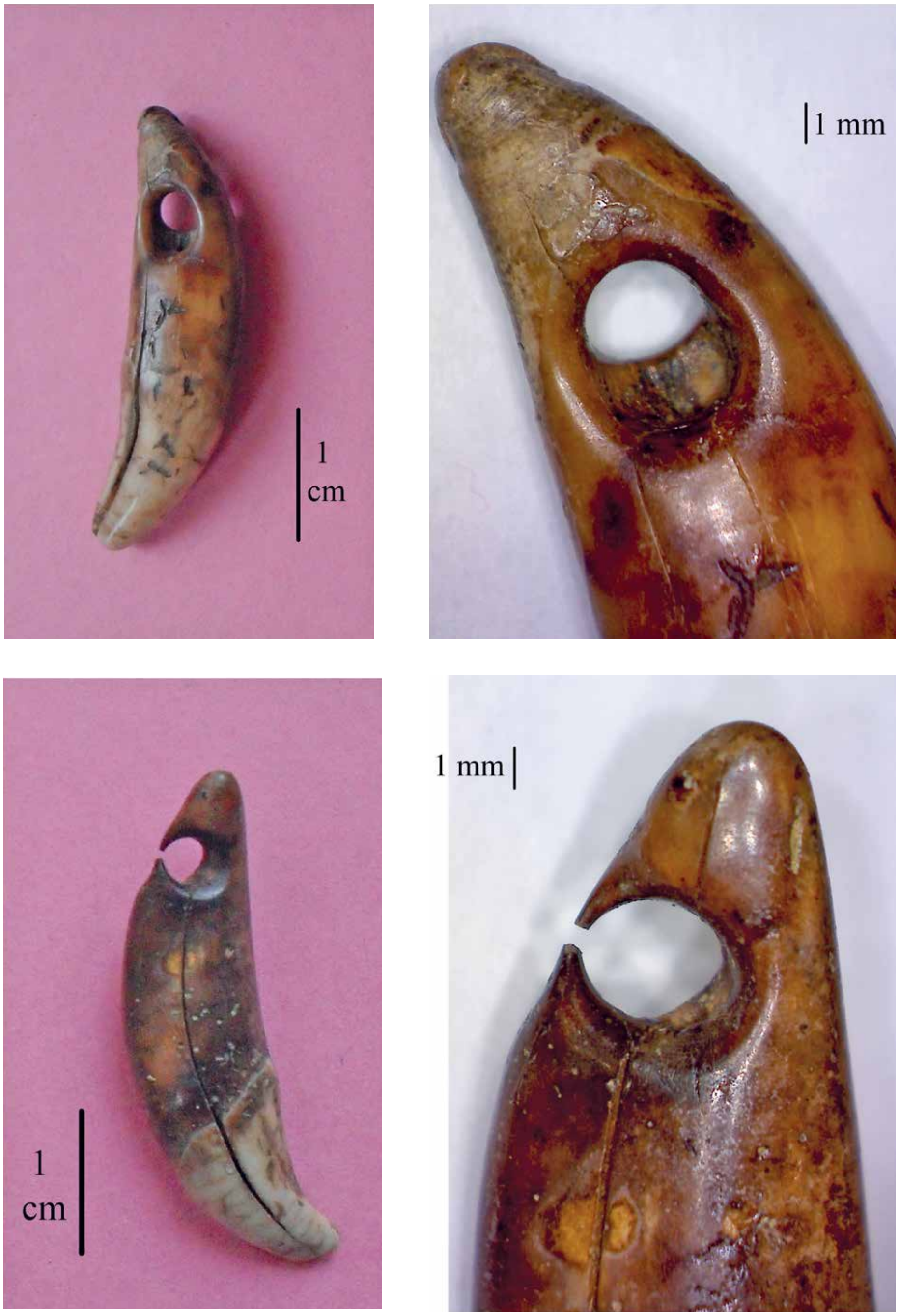

Figure 3. Perforated teeth from grave no. 107: upper row – anterior side of one of the teeth and details of the traces of manufacture and use on the perforation; lower row – posterior side of the tooth with the perforation broken from use and details of the traces of manufacture and use.

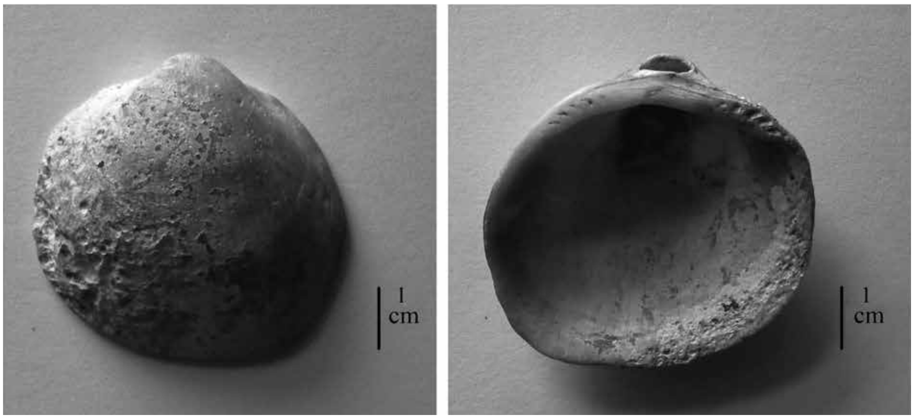

Figure 4. Pendant made from *Glycymeris* shell, grave no. 120, anterior and posterior sides.

manufacture. It is possible that the shell surface was first abraded and then pierced. The usewear consists of polish, and sometimes the perforation is not regular but deformed.

One quite unusual pendant made from a complete lateral metatarsal bone of *Sus scrofa* was discovered in grave no. 190. It was not modified except for a perforation on the upper part, made by drilling, and worn and polished from use. Exact analogies for such an object are unknown at present. It is interesting to note, however, the presence of drilled hare and dog metapodial bones at the Middle Bronze Age site of Százhalombatta-Földvár in Hungary (Choyke *et al.* 2003).

Beads

Smaller objects of different shapes and sizes, with central, usually vertical perforations positioned in such a way that they could be lined up on a string, are classified as beads (Barge-Mahieu 1991). Three subtypes of beads were distinguished at the necropolis at Mokrin (Vitezović *in press*), and two of these subtypes are present at Ostojićevo: A, elongated cylindrical or barrel shaped beads, and C, irregular beads, while the remaining subtype (B, discoid beads), was not noted.[4]

The most common subtype consists of elongated tubular beads (*perle tubulaire*, type B2 after Bonnardin 2009) (Figure 5). These are cylindrical or barrel-shaped, and two variants, made from different raw materials, may be distinguished: beads from minimally modified *Dentalium* shells (variant A1) and beads produced from bones (variant A2).

Dentalium beads were quite simple, produced from minimally modified shells – the ends of the shell were just broken or cut off in order to use the widest, mesial segment, or perhaps already broken shell segments were simply collected and used. Their outer surfaces are often weathered and eroded, hence it is not possible to determine whether they were fossil or fresh.[5] They are up to 25 mm long and usually 7 mm wide. *Dentalium* beads were not frequent at Ostojićevo; for example, in burial no. 120, five such beads

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[4] Discoid beads were labelled as subtype B beads in the Mokrin assemblage (Vitezović *in press);* that is why subtypes A and C are listed here.

[5] For the availability of fossil *Dentalium* shells in the Danube valley in Serbia and their use by Neolithic communities, see Dimitrijević *et al.* 2010 and Dimitrijević 2014.

Figure 5. Elongated cylindrical beads made from bone, grave no. 120.

were discovered, and in burial no. 186, only two were found (Table 1). *Dentalium* beads were found at the Mokrin necropolis as well (Vitezović 2017, 67; *in press*), and this type of ornament was present throughout prehistory, in the Mesolithic, the Neolithic, and the metal ages (*e.g.,* Taborin 2004; Dimitrijević 2014).

The second variant consists of beads made from smaller long bones, probably all metapodial bones from smaller ungulates (mainly or even exclusively sheep/goats) (Figure 5). They were produced by transverse division of the bone diaphysis: after the epiphyses were removed, a transversal groove was made. After that, the bone was cut through by sawing, and sometimes we may notice traces of the sawing near the edge. Finally, either the bone was completely cut through or a small portion was broken or snapped off. The cross-section of the cut is therefore either completely smooth and straight, or somewhat irregular or ragged, or has a small piece of excess bone (from the piece from which it was cut off). Manufacturing traces are not well preserved due to taphonomic weathering and usewear traces; therefore, it is not possible to determine which tools were used, but it seems that chipped stone tools, not metal ones, were used.[6]

Depending on the part of the bone that was used, the shape of these beads was more or less cylindrical or slightly barrel-shaped, *i.e.,* the outer surface was straight or slightly biconical. There is no clear border between cylindrical- and barrel-shaped beads; the differences are gradual rather than sharp, and this is why they were grouped together. This difference is not only barely noticeable, which makes it difficult to assign them to either shape, but also has no significance, since the beads share other technological traits and these final variations in shape were not intentional.

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[6] The criteria for distinguishing chipped stone from metal tool marks follow Christidou 2008 and Semenov 1976.

One bead, from grave no. 120, stands out. It has a groove in its mesial part, which makes its shape resemble the number 8 (Figure 5). It was produced in the same manner as the remaining beads; this groove is simply the trace of an unfinished groove for transverse cutting. A similar method of making a decoration on beads, by marking a groove on the mesial part, has also been noted at Mokrin (Vitezović *in press*).

The dimensions of these beads vary slightly, suggesting there was no pre-determined template for them. Their length ranges from 8 mm to 13 mm, which means that from a single metapodial bone, several beads could have been produced. The traces of use that can be observed on these beads are polish and shine, the result of contact with soft materials, such as clothes.[7] These beads could have been arranged on a string as part of a composite necklace or bracelet, sewn to clothes (dress, cloak, belt, …), *etc*.

Bone beads were more frequent in Ostojićevo burials than those made from mollusc shells. The richest grave was no. 120, where 28 beads were recovered. These beads are in every aspect similar to those recovered from Mokrin; the only exception is that at Mokrin, a few more of the beads with grooves were found (Vitezović *in press*). Similar beads have been encountered at other Bronze Age necropoles in the southern Carpathian basin and in central Europe, *e.g.*, at the Early Bronze Age site of Kichary Nowe in southeastern Poland (Winnicka 2016), at the Middle Bronze Age site of Jászdózsa-Kápolnahalom in Hungary (Csányi and Tárnoki 1992, 194, cat. 264), or the Late Bronze Age site of Mačkovac in eastern Croatia (Kalafatić *et al.* 2016).

Other beads found at Ostojićevo belong to the subtype of irregular beads produced from almost entire shells of *Columbella* snails. *Columbellae*, mainly and probably exclusively *Columbella rustica*, were used with minimal modification. In the central part of the shell they have perforations, usually of irregular circular shape, made by piercing. The perforated surface is often worn from use.

Columbella beads were rare – they were noted in only three graves; seven beads in grave no. 208, two in grave no. 230, and just one in grave no. 283 (Table 1). Graves containing *Columbella* beads at Mokrin also contained other objects considered luxurious – for example, in grave no. 12, one *Columbella* bead was discovered along with several ornamental items made from gold (Girić 1971, 100; Vitezović *in press*).

Columbella shells were used for producing beads throughout prehistory (*e.g.*, Taborin 2004). It is interesting to note that one such bead was discovered at the Maros culture settlement of Pecica-Şanţul Mare in Romania (Nicodemus, Lemke 2016, Figure 2b), showing these items were worn daily and were not restricted to funeral equipment.

A few more objects made from shell segments may be classified as irregular beads. One is made from an unidentified *Gastropoda* shell with heavily eroded surfaces, and the remaining two are from irregular segments of shells (one being the innermost segment of *Gastropoda*). These were probably recycled ornaments from broken pieces of other shell ornaments.

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[7] Criteria for analyses of usewear traces follow Bonnardin 2008 and 2009; also d'Errico 1993 and Semenov 1976.

Figure 6. Decorative pins with perforations from grave no. 184.

Decorative pins

Decorative pins are elongated objects with elaborated heads on the basal part and pointed distal ends (Camps-Fabrer 1991).

The pins recovered at Ostojićevo were made from metapodial bones of small ruminants (*Ovis/Capra*), except for one, which was made from a pig fibula (Figure 6). The metapodial bones were longitudinally split, and the proximal segments, with a very small portion of the epiphysis retained at the basal part, were modified into pointed objects. Their cross-section is smaller than semi-circular, *i.e.*, a segment that was less than one longitudinal half of the bone was used. On some of them, traces from scraping with a chipped stone tool are preserved along the side edges and sometimes on both ventral and dorsal surfaces. Handling polish is preserved on some of them. Their overall preservation, however, is not very good, and some are fragmented.

These pins usually have small perforation, with diameter 2-3 mm, made near the base (only those from grave no. 126 are not perforated). They were probably perforated with the same tool used for drilling teeth. These perforations are often polished and slightly deformed from use. Typologically and technologically they are identical to those recovered from the necropolis at Mokrin (Vitezović 2017, 72-73). The only exception is the pointed object made from fibula of *Sus scrofa*, from grave no. 166. Its basal part is fragmented, and it has a fine, pointed end, but the concretions on its surface cover any possible traces of manufacture or use.

The pins at Ostojićevo were generally found in pairs,[8] although this is not a strict rule for all of the Maros culture necropoles (O'Shea 1996, 190). These pins were most likely used for fastening clothes. They were almost exclusively found in female graves, and they are considered markers of the high social status of the buried individual (O'Shea 1996, 189; Milašinović 2009, 67).

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[8] The only exception is grave no. 166, but this pin differs from the others by its raw material.

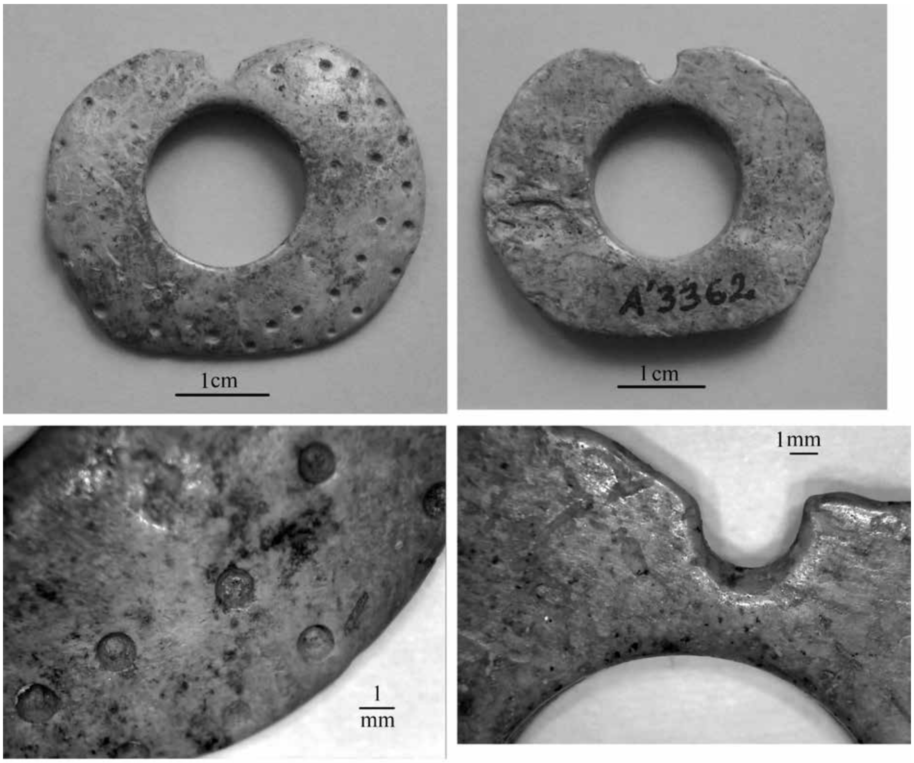

Figure 7. Discoid application from grave no. 147: Anterior and posterior sides and details of the dotted decoration and broken perforation.

Perforated pointed artifacts made from long bones were common at other Bronze Age sites in the Carpathian basin, although it is possible that they had other functions as well. They are noted at the sites of Jászdózsa-Kápolnahalom (Csányi and Tárnoki 1992, 195, cat. 283), Túrkeve-Terehalom (Csányi and Tárnoki 1992, 195, cat. 284), and Tiszaug-Kéménytető in Hungary (Choyke and Bartosiewicz 2000, Figure 4/1), as well as at Năeni-Zănoaga Cetatea 2 in Romania (Mărgărit *et al.* 2011).

Applications

This type of ornament encompasses diverse forms of items used as some sort of application, most likely attached to clothes. They are rather unique in shape and not as numerous as, for example, the beads or the pendants. Two applications have more-or-less triangular shapes, two have discoid shapes, and one possible application is semi-globular in shape.

Triangular applications were found in graves no. 107 and 147. Both are made from hyoid bones of *Bos*. The one from grave no. 147 has lateral ends cut off. At the apex of the triangle, there is one broken perforation with another immediately below it, worn from use, that was probably made after the first one broke. This new perforation, with R=3 mm, is also worn from use, and the traces of usewear polish are visible all over the artifact. The other application, from grave no. 107, is fragmented, but we may assume it resembled the first one.

The discoid applications, discovered in graves nos. 147 (Figure 7) and 190, were produced from segments of large long bones from a large mammal. The blanks were cut from the diaphysis and then modified into discoid shape with central large perforations. Traces of manufacture are not preserved, but they were probably finalized by abrasion. The edges are polished and worn from use. They have relatively large perforations in the center.

The application from grave no. 147 is also ornamented. It has small dots on its outer side made by superficial drilling. They run around the circumference of the application, organized into two rows. This application also had one smaller perforation at the side that was made by drilling, broken from use, and intensively polished. The entire artifact has intensive traces of polish from manipulation and contact with soft organic materials.

Morphologically similar to those is one discoid-shaped application made from red deer antler from Mokrin, grave no. 245 (Vitezović 2017, 74).

Another osseous artifact that may have been used as application was discovered in the grave no. 141. It was more-or-less semi-globular in shape and made from the head of the femur of a large mammal. This bone segment was transversally divided in two; the used half was also cut on the outer side to make both surfaces flat, *i.e.*, it has a truncated semi-globular shape. Handling polish can be noted on it. It is possible, however, that it was a functional object (a spindle whorl) and not an ornament.

Discussion

Although the Maros culture is known for its developed metallurgy and rich bronze and gold jewellery, osseous raw materials were still widely in use for the production of personal ornaments. In fact, they kept their importance, aesthetic, and symbolic role. Some of the symbolic value lies in the raw material itself – in its origin and/or physical and mechanical properties.

In case of perforated teeth, we may note the careful selection of species and type of teeth (predominantly canines, teeth that usually stand out by their shape), as well as the prolonged use and instances of repair of these pendants. Perforated teeth were mainly found in female graves, and perhaps their symbolic meaning included display of status and/or belonging to a group. A preference for dog teeth is apparent, perhaps because their elongated, slightly crescent-like shape was aesthetically attractive, but this may also be linked with a meaning attributed to them (a display of prestige, status, and/or symbolic value attributed to dogs). Whether dogs as a species had specific symbolic meaning is difficult to say at this point, although the preference for dog teeth not only among Maros culture communities but also within some other Bronze Age cultures[9] suggests the possibility that indeed a certain symbolic meaning and value was attributed to dogs.[10]

Antler was not noted in the assemblage from Ostojićevo, and at Mokrin it occurs rarely (Vitezović 2017). In contrast, it was frequent in the assemblage from the settlement of Pecica-Şanţul Mare (Nicodemus and Lemke 2016); it is difficult to assess whether it was considered inadequate for ornaments or more valuable for production of tools.

As for the distribution of the certain types of raw material in different graves, some patterns emerge, but are inconclusive (Tables 2 and 3). Some graves (*e.g.*, nos. 107, 120, and 128) are richer and have larger quantities and greater diversity of ornaments. Graves

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[9] As mentioned above, dog teeth are encountered at, among others, at the Monteoru culture site of Năeni-Zănoaga Cetatea 2 in Romania (Mărgărit *et al.* 2011, 17-18), at the Early and early Middle Bronze Age site of Tiszaug-Kéménytető in Hungary (Choyke and Bartosiewicz 2000, fig. 4), and at the Middle Bronze Age site of Jászdózsa-Kápolnahalom (Choyke and Bartosiewicz 2009).

[10] Although the value and meaning may not be identical among all these communities.

Type of ornament	Grave no.
Perforated teeth	35, 79, 107, 128, 229
Pins	79, 126, 141 , 166, 184
Bone beads	107, 114, 120, 128
Dentalium beads	114, 120, 186, 226, 230, 250
Columbella beads	230, 280, 283
Glycymeris and other shell ornaments	120, 230
Bone applications and pendants of various shapes	107, 141, 147, 190

Table 2. Distribution of groups of ornaments within the Maros culture graves from Ostojićevo.

no. 107 and 120 particularly stand out. Grave no. 107 contained one triangular application, six bone beads, and 28 perforated teeth from different species, including the only red deer and horse teeth in the Ostojićevo necropolis. Grave 120 contained beads from diverse raw materials: bone, *Dentalium*, undetermined molluscs, and applications from molluscs. Thus, it is the richest grave with mollusc ornaments (a total of five *Dentalium* beads and seven other mollusc beads and applications).

Certain groups of ornaments can be singled out. In some graves, perforated teeth are the only or the predominant type of ornament (graves no. 35, 79, 107, and 128). Either pins are the only type of osseous ornament placed in the grave (graves no. 126, 166, and 184) or the other ornaments are not particularly rich or diverse (graves no. 79 and 141). Mollusc shells are the only or the predominant raw material for ornaments in some of the graves (graves no. 120, 186, 226, 230, 250, 280, and 283). Mollusc shells generally seem to have been more valued as raw materials; the majority of these ornaments also show prolonged use and instances of repair, even recycling. Furthermore, they occur in smaller quantities than, for example, bone beads. Additionally, it seems (judging from data obtained from the Mokrin necropolis, see Vitezović 2017 for details and references therein) that beads from *Columbellae* may be related to richer graves, which raises the possibility that ornaments made from mollusc shells may be related to the display of wealth and/or prestige.

Further analyses of other findings from graves, as well as comparative analyses of the age, sex, health status, *etc.* of the individuals will provide information regarding the symbolic meaning of this distribution.

It is interesting to note the occurrence of skeuomorphism or interchangeable raw materials, that is, the occurrence of one variant made from different raw materials. Beads were also produced from white or whitish stones, and a few pendants were made from whitish stones that resembled perforated teeth in shape. Furthermore, beads made from shell and bone may have the same or a similar shape, as in the case of the two variants of subtype A, elongated cylindrical beads. It is possible that this was a replacement for the more highly valued mollusc shells, or perhaps the white color was important. The importance of white color has already been suggested for other ornaments in prehistory (cf. Luik 2007; Antonović *et al.* 2017), and it is possible that the physical and mechanical properties of osseous materials, such as white color, overall shine, and smooth surfaces and durability, contributed to the value of these ornaments.

Long use of these ornaments and instances of recycling suggests another thing – the possibility that some of them were inherited. This would imply that osseous ornaments were used to display not only prestigious status but also belonging to a certain group (family or other).

Grave no.	Perforated teeth	Pins	Bone beads	***Dentalium* beads**	***Columbella* beads**	***Glycymeris* and other shell ornaments**	Bone applications of various shapes
35	x						
79	x	x					
107	x		x				x
114			x	x			
120			x	x		x	
126		x					
128	x		x				
141		x					x
147							x
166		x					
184		x					
186				x			
190							x
226				x			
227							x
229	x						
230				x	x	x	
250				x			
280					x		
283					x		

Table 3. Presence of certain groups of ornaments within the Maros culture graves at Ostojićevo. The fragmented tooth from grave no. 227 and the *Unio* shell from grave no. 250 are not included in Tables 2 and 3 since these artifacts are fragmented and their type cannot be determined.

Further bioarchaeological analyses of the individuals buried with osseous decorative items at Ostojićevo may shed some more light on the possible meaning and value of these ornaments.

The majority of these ornaments (all types of bead, perforated teeth, and *Glycymeris* applications) do not differ in raw material selection or other techno-typological traits from those recovered at Mokrin (Vitezović 2017, *in press*) and have strong parallels at other Maros culture necropoles (O'Shea 1996 and references therein), suggesting that these ornaments had some common fashion and/or common symbolic meaning and value among Maros culture communities.

Ornaments made from locally available raw materials were most probably also produced locally. Osseous industries at Maros culture sites are known only from the settlement site of Pecica-Şanţul Mare in Romania (Nicodemus and Lemke 2016), and although the comparison between the assemblages from the necropolis and the settlement poses numerous obstacles, some common traits may be recognized. One concerns technology of production – the use of chipped stone tools such as burins, drills, *etc*., and the other concerns the presence of the same or similar techno-types – *Columbella* beads, perforated valves of *Bivalvia* shell (in case of Pecica, *Cardium*), and perforated dog teeth.

Conclusion

Ornaments made from animal hard tissue remained in use even after the introduction and spread of metals. In fact, although they are often considered “cheaper substitutes,” they did not lose their value. Osseous raw materials, probably valued for their origin (from living animals) and physical and mechanical properties (hardness, color, and surface smoothness) throughout prehistory, were used for a long time as personal ornaments and remained in use for these purposes in the Bronze Age as well. These ornaments were valued by the members of communities of the Maros culture; they had certain symbolic roles and were used to display status and/or prestige.

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An antler workshop in a Germanic settlement in Nitra, Slovakia

Gertrúda Březinová and Erik Hrnčiarik

Abstract

In 1996 and 1999-2000, the Institute of Archaeology of the Slovak Academy of Sciences conducted a rescue excavation at Nitra-Chrenová that produced as many as 220 fragments of worked osseous material. The worked half-finished products were clearly used for making various parts of composite combs. A detailed analysis of them provided several technological details that can shed light on antler working and the production of single-sided composite combs. These finds from Nitra-Chrenová clearly attest to the existence of a specialized workshop for the production of composite combs.

Abstrakt

V rokoch 1996 a 1999-2000 realizoval AÚ SAV záchranný archeologický výskum v Nitre – Chrenovej, počas ktorého a podarilo objaviť až 220 fragmentov opracovaného osteologického materiálu. Ich podrobnou analýzou sa zistilo, že sa jedná o polotovary, ktoré nesú jasné stopy po opracovaní a pochádzajú z viacerých častí kompozitných hrebeňov. V predloženom príspevku sme sa teda spolu s autorkou rozhodli detailne rozanalyzovať túto skupinu nálezov. Analýza nálezov opracovanej parohoviny z Nitry, potvrdila existenciu špecializovanej dielne na výrobu trojvrstvových hrebeňov.

Keywords: osseous technology, craft, single-sided combs, half-finished products

Introduction

The first Germanic tribes of the Suebian Quadi arrived in the area of present-day Slovakia shortly after the beginning of our era (first-fourth century AD). They settled mainly in southwestern Slovakia, where Nitra, part of Chrenová, is located. The area north of them continued to be inhabited by the La Tène population of the Púchov culture, the Cotini (*c.* 300 BC-180 AD), while the remnants of the Celto-Dacian population continued to live in southeastern Slovakia. Towards the end of the Early Roman period, and particularly in its later phase, the Quadi population spread also northwards and eastwards. In northern and

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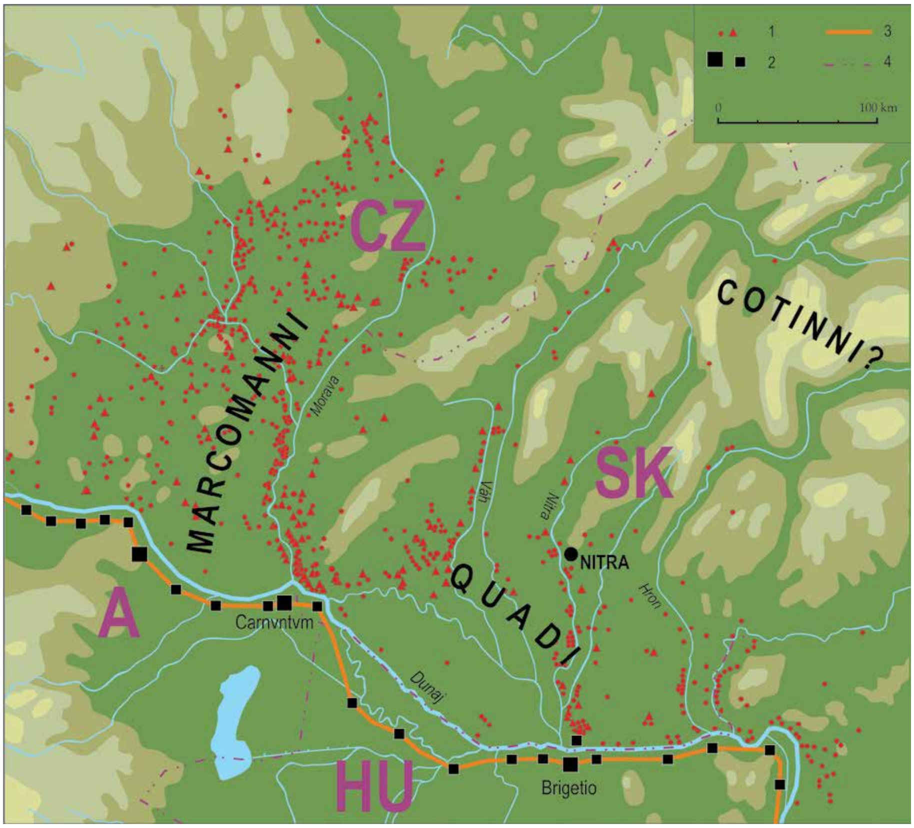

Figure 1. The Roman frontier in northern Pannonia: 1. Germanic settlements and graves, 2. Roman frontier installations, 3. frontier road, and 4. contemporary state borders (Authors: P. Červeň and J. Rajtár from Archeologický ústav SAV Nitra).

northeastern Slovakia, the Púchov culture was replaced by the North-Carpathian group, while the southeast was settled by Vandal tribes (Figure 1) (Varsik 2011b, 133-51).

In 1996 and 1999-2000, the Institute of Archaeology of the Slovak Academy of Sciences conducted a rescue excavation at the Germanic site of Nitra-Chrenová, which produced as many as 220 fragments of worked osseous material. G. Březinová, who excavated the site, interpreted a feature at Nitra-Chernová as a bone and antler working workshop (Březinová 2003a, 34-35). Here, we present the analysis of these finds.[1]

Nitra-Chrenová

The site Nitra-Chrenová is situated on a slightly sloping part of the left-bank terrace of the River Nitra at 147-150 m.a.s.l.. The terrain slopes towards the south, with a difference in altitude of about four to five meters. Earlier excavations (1969, 1981, 1983, 1984) proved that the site was occupied by different cultures (Březinová 2003b, 11). Past surveys revealed a Neolithic settlement of the so-called Želiezovce group, a Germanic settlement from the Roman period, and a medieval settlement (ninth-tenth century AD). Gardens and

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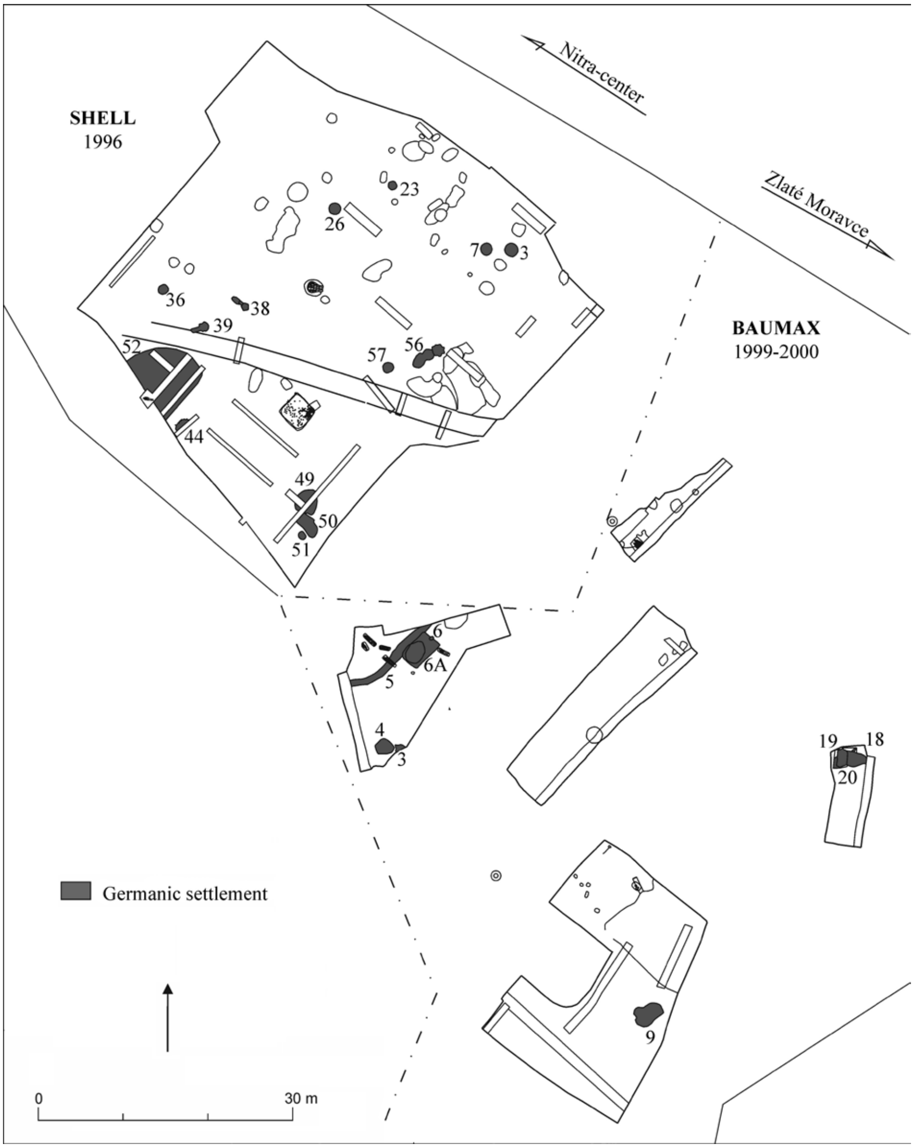

Figure 2. Germanic settlement Nitra-Chrenová (Image: P. Červeň).

various temporary structures built in the 1980s and 1990s have had a destructive impact on the remains of the archaeological structures. Archaeological investigations of the site did not start until the construction of large commercial buildings was planned in this location. The excavation was conducted in two phases. The *Shell* location was investigated in 1996 (Březinová 2003a, 19-38), while the area under *Baumax* was investigated in 1999-2000 (Březinová and Benediková 2003, 39-64) (Figure 2). The outcome of the rescue excavations was strongly affected by weather conditions, particularly in 1999-2000, when the excavation took place in the winter months.

In 1996, the *Shell* site, an area of 6000 m^2, was investigated, and 66 settlement structures and four inhumation graves were documented. The excavation was carried out on ground cleared of humus, and the topsoil layer with packed earth was 40-100 cm thick.

The site of the *Baumax* was investigated in 1999-2000. The construction of the hall for this shopping center endangered an area of 25,300 m^2. The choice of the excavation area, five larger units and eight narrow sections in former gardens with a total area of 2500 m^2 was determined by the effort to primarily investigate the area where the hall and access roads were planned. The choice was partly limited by the terrain. A large part of the endangered area could not be investigated because it had been disturbed or completely destroyed by earlier building activities. The buildings and greenhouse ruins covered an area of 12,122 m^2.

The excavation unearthed part of a prehistoric settlement, structures from the Roman period, the Migration period, and the Middle Ages, and graves from a medieval cemetery. In total, 19 structures from the Roman and Migration periods were investigated on the site. The structures unearthed in 1996 were three pottery kilns (38, 39, and 56), an exploitation pit (52), three storage pits (23, 26, and 57), and three more pits that may have been used for production (49, 50 and 51). In 1999, two huts (pit-houses 6 and 9) and seven other structures of unknown function were investigated. Their fill consisted mostly of domestic and imported pottery (Kuzmová 2003, 65-67), animal bones, archaeobotanical remains, tiny artifacts such as fragments of glass and brooches, and iron and bronze fragments of unknown function. The excavated archaeological artifacts date most of the structures from the end of the second to the beginning of the third century. A few of the investigated structures (6, 9, and 20) date from the end of the third to the beginning of the fourth century AD. The location of the settlement on one of the branches of the Amber Road (from the Baltic coast to the head of the Adriatic Sea – Aquileia; in Slovakia via Považie, from the Nitra region to the province of Pannonia – Brigetio), and numerous finds of Roman imports (Hrnčiarik 2013) in the Germanic environment indicate that the inhabitants of the settlement, of which only a small part survived and was investigated, had intensive contacts with the Roman province of Pannonia.

All the animal bones, both worked and unworked, were subjected to an archaeozoological analysis by M. Fabiš in 2003. The studied collection (1112 pieces) contains mostly bones of domestic animals (96.2% NISP) such as cattle (*Bos taurus*), pig (*Sus scrofa f. domestica*), small ruminants (sheep: *Ovis aries*, goat: *Capra hircus*), hen (*Gallus*), and horse (*Equus caballus*). The bones of wild animals (5.8% NISP) are represented by species that lived in this area since the Neolithic: wild boar (*Sus scrofa*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), European ground squirrels (*Spermophilus citellus*) and European pond turtles (*Emys orbicularis*) (Fabiš 2003, 99-132).

Worked osseous material

Among the preserved osseous material, we identified 220 items that bore traces of deliberate bone- and antler-working. Despite a previous archaeozoological analysis (Fabis 2003, 99-132), a re-examination of all the archaeological material by the authors of this document revealed 18 new pieces that had not yet been identified as deliberately processed antlers. Items with butchering marks caused by cutting meat off the bone were excluded. The identified worked items account for only 19 percent of the total number of excavated bone and antler items (Figures 3-4). Moreover, with the exception of one artifact made from bone, all other modified pieces were made of antler (219 pieces).

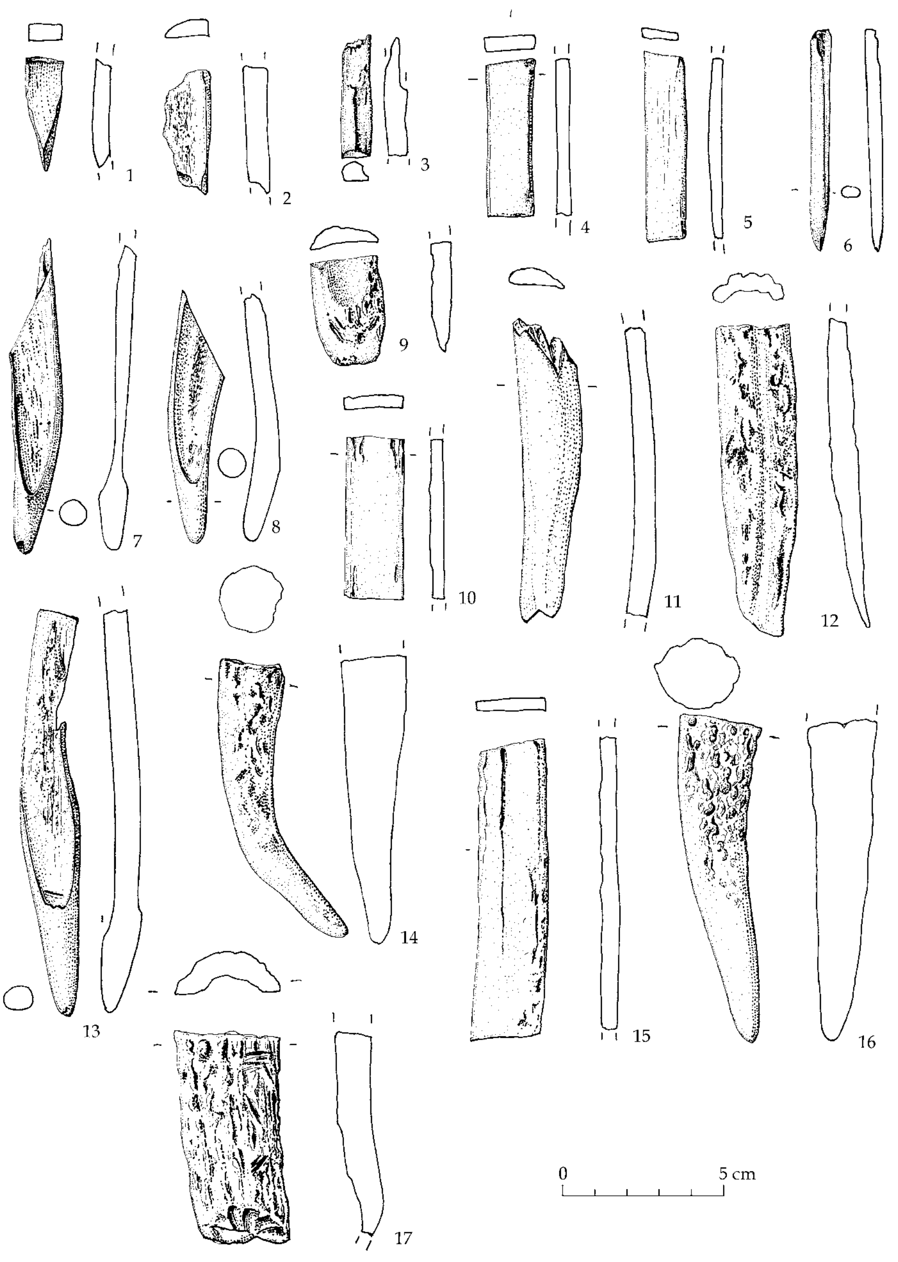

Figure 3. Half-finished products found in different places in Nitra-Chrenová.

With the exception of one artifact, the bones from this site – mostly long bones – did not bear traces of working. The only bone item from the studied site was a single-sided bradawl that was pointed at one end and made from a cattle long bone (Figure 3.6). The bone tool from our site was discovered in the upper layer of the exploitation pit.

The antler items discovered at Nitra-Chrenová were made from antlers of red and roe deer, species that still live in the area around present-day Nitra. The material for working came from both shed antlers and hunted animals.

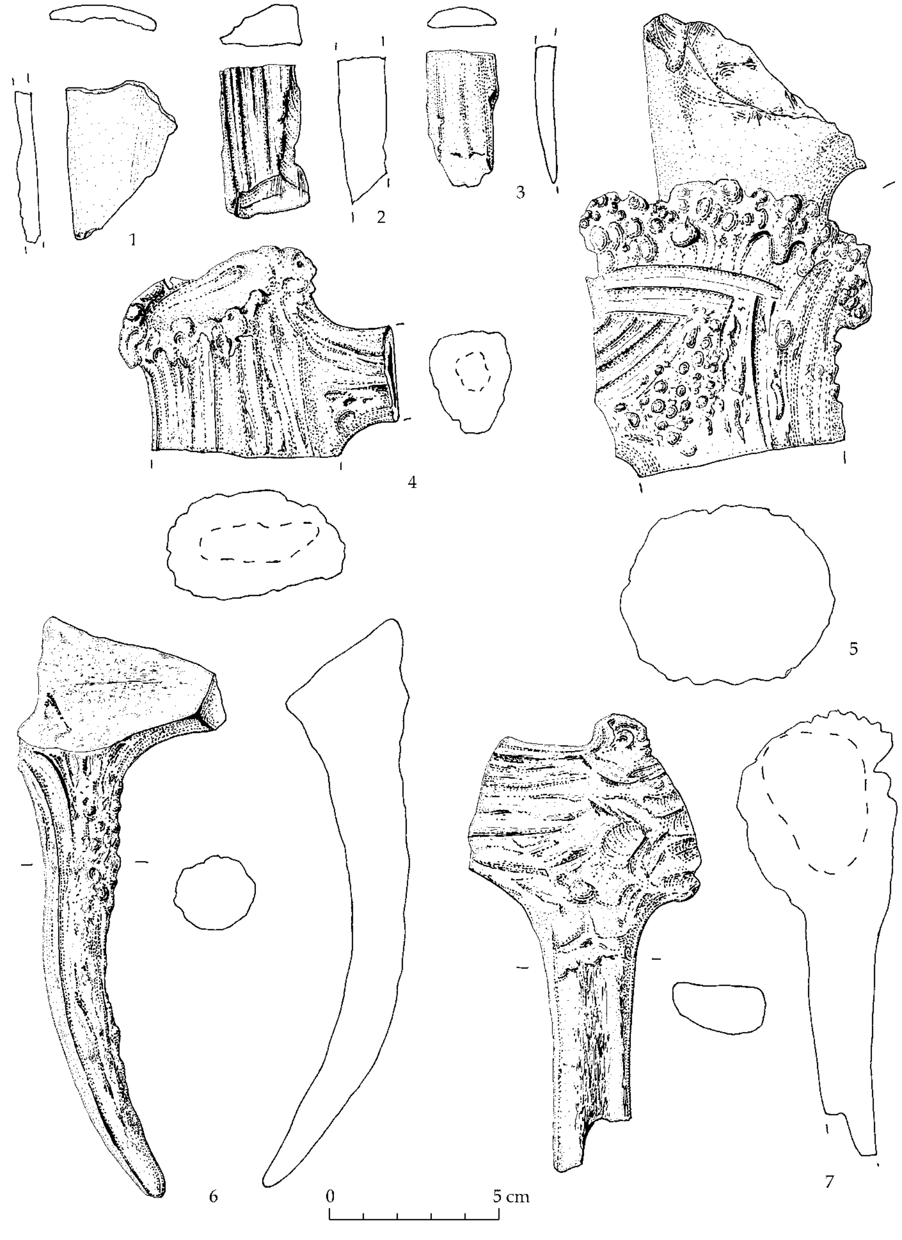

Figure 4. Half-finished products found in different places in Nitra-Chrenová.

Most of the worked antler fragments were found in the southern area of the site. None of the investigated structures had a substantial concentration of finds, but the largest number – 42 items – was found in exploitation pit no. 52. Earth extracted from this pit was used to build the settlement in its earliest phase, and the pit was later filled with waste. Another larger concentration of worked antler comes from settlement structure no. 6, whose ground plan indicates that it was a sunken-featured Germanic hut – an earth-house of two-post construction that fits T. Kolník's type II (1998, 145). Furthermore, 24 items were

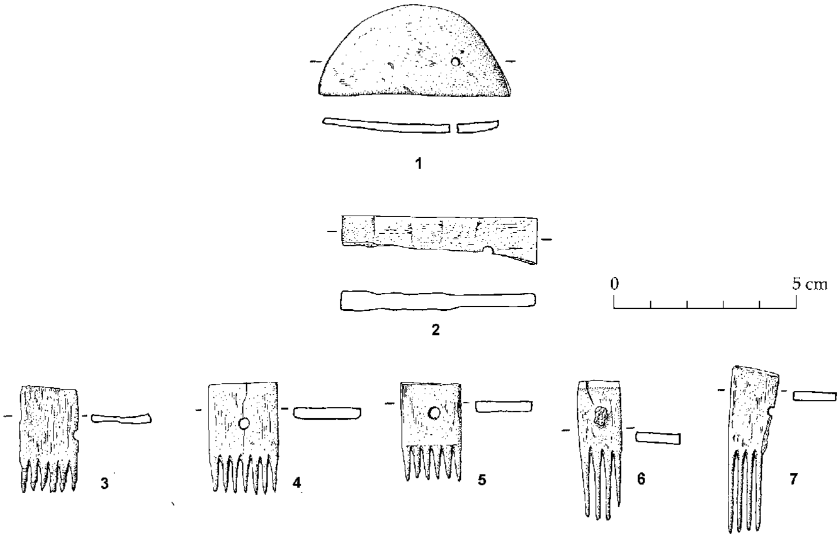

Figure 5. Parts of composite single-sided combs (Image: E. Hrnčiarik).

found in the fill of the second Germanic hut (no. 9), which is a hut of six-post construction that fits T. Kolník's type III (1998, 145). As many as 28 items lay in a settlement structure of unknown function (no. 19). The remaining structures (nos. 49, 96, and 5) produced only small amounts of worked antler (2-4 pieces).

The studied collection does not contain a single completely preserved item. All of the finds are either fragments of objects or so-called half-finished products. Ten objects can be assigned to the first group; seven of them were found in hut no. 6, the others lay elsewhere: one in the exploitation pit (no. 52), one in the gutter (no. 5), and one in a settlement ditch (no. 49). All of them were clearly parts of composite single-sided combs: tooth plates, median plates, and handles (Figure 5). Some of them had remnants of iron rivets for fastening. However, we cannot say with certainty whether these combs had ever been in use. Some of them are presumably components of a final product, and others may be damaged pieces that could no longer be repaired. The handles, for instance, have only one perforation, which was insufficient for fastening them onto the comb. The broken median plates have cut marks from crafting the teeth, which was usually done in the final stage of comb making, and it is therefore possible that the plates were broken during this process.

The second group of finds, consisting of half-finished products, contains 210 items. They include not only objects that we assume were never finished but also waste, which could not be further worked. Such items were found in all the mentioned structures on the site. Each of them bears traces of working. All parts of antlers are represented, *i.e.*, the burr, side tines, and top tines. What is missing are whole pieces of the central cylindrical portions of the main beam. However, there are many cuttings from this portion, which was the most commonly used part of antlers.

The worked half-finished products were clearly used for making various parts of composite combs (Figure 6). Their detailed macroscopic analysis provided several interesting technological details, which can shed light on antler working and the production of composite single-sided combs.

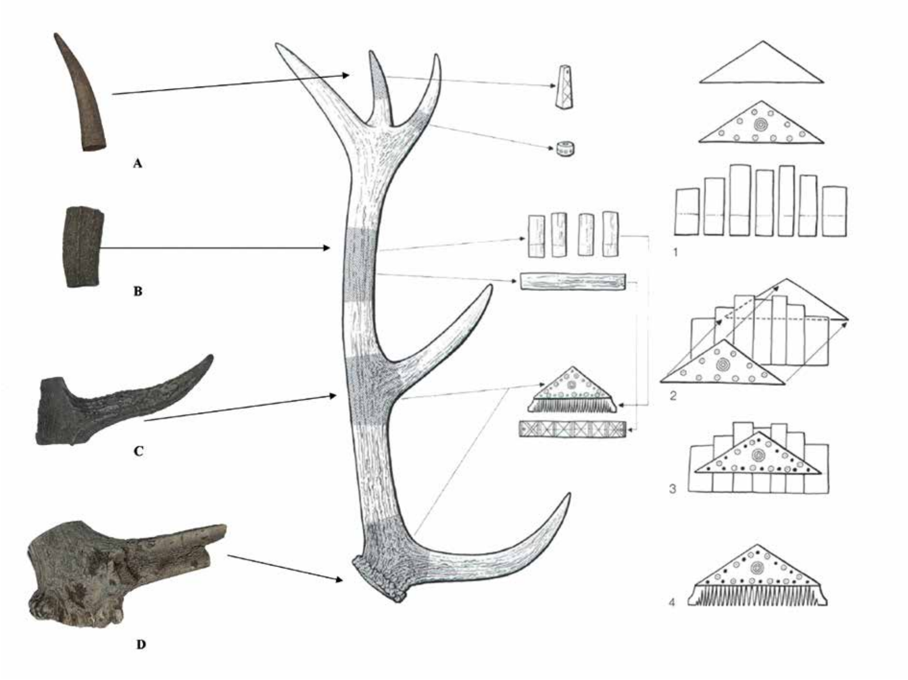

Figure 6. Half-finished products (A-D) from combs found in Nitra-Chrenová (Supplemented reconstruction from Hedinger 2000, Fig. 7, 10).

Scholarly sources usually note that the most common parts used in comb making were the thicker portions of antlers, either from the burr or the joints between the main beam and the tines, or from the central parts of antlers (see Hedinger 2000, Fig. 7, 10). Several worked fragments among the finds from Nitra-Chrenová come from top tines (Figure 6A), which attests to their use in comb-making. For instance, the exploitation pit contained not only tines that had been cut crosswise but also two tine remnants (Figure 3.13) that had been cut off lengthwise (top to bottom). These remnants were certainly waste material, while the cut-off parts were used for further working. Two other pieces found in the same structure, however, clearly represent a higher level of working. They are a plate used for making bottom parts of combs and the median plate (Figure 3.15).

The finds from the site, though not from the same structure, include items from different phases of production. There are cut-off sides of antler tines as well as half-finished products with cut-off points. One such item has all its side edges worked. Such a half-finished product was further shaved into a plate, and teeth were cut in the final stage of comb production.

Scholarly sources note the use of various saws in the antler-working process (Deschler-Erb 1998, 98). The absence of such saws among the finds from Nitra-Chrenová can be attributed to the fact that these thin iron tools are prone to corrosion. Another possibility is that after being damaged they would be melted and reused. Their use at the Nitra-Chrenová site is attested on several finds. Interestingly, the thicker parts of antlers were not sawn through at once. The hard shell was sawn round first, followed by the spongiosa inside. According to Sergiu Musteață and Alexandru Popa, saws were used for the primary sawing of antlers, mainly for removing end tines and cutting antlers into smaller parts.

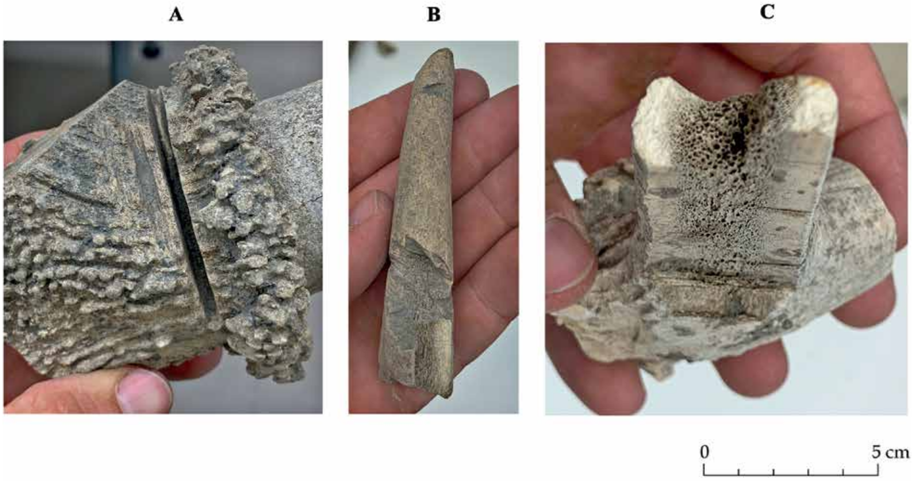

Figure 7. Half-finished products bear traces of cutting, shaving, and whittling (Photo: E. Hrnčiarik).

Figure 8. Few-millimeters-thick shavings of antler (Photo: E. Hrnčiarik).

Both authors note that such sawing may also have been done by knives with a smooth or even serrated blade (Musteață and Popa 2010, 160).

The items from the studied site indicate that antlers were usually worked with ordinary knives, axes, or chisels. Some of the half-finished products bear clear traces of cutting, shaving, and whittling (Figure 7). For instance, the object from the exploitation pit has three cuts, which show the spots where side portions of the antler were cut off by a knife. Another item, found in one of the Germanic huts, has similar traces of a chisel or smaller axe. It was postulated that the first step of the manufacturing scheme included cutting a straight line along the bottom side with a saw or knife. Afterwards, the distal end of the uppermost tine was cut off, and finally, the blank was split off. For such working, however, the antler had to be sufficiently fresh (or softened) for easier treatment (Musteață and Popa 2010, 159).

The collection of several tens of antler fragments from Nitra attests that antlers were worked with a knife or a chisel. These fragments are a few millimetres thick (Figure 8). A similar collection of shavings comes from various medieval sites in the Netherlands (Rijkelijkhuizen 2011, Fig. 12).

Discussion

Bone and antler finds in barbarian – Germanic – territory were published by T. Zeman at the turn of the millennium (Zeman 2001, 107-147). However, these were mostly artifacts found in the territory of what is today the Czech Republic. The finds from the bone and antler industry in the Suebian Quadi environment in present-day Slovakia were the subject of E. Hrnčiarik's contribution at the WBRG conference in Iasi, Romania in 2016 (Hrnčiarik 2018, 135-141). But since it was a review study, the author only paid attention to the published finds. Workshops specializing in the production of combs and jewellery have not yet been localized in Slovakia (Hrnčiarik 2017, 25), but with the following interpretation of an antler workshop at Nitra-Chrenová, we need to rectify this statement.

As we have already noted, antler had to be sufficiently soft if it was to be worked with a normal knife. Scholars studying bone and antler working have discussed this topic for several decades. Some of them think that in order to soften the antler, various agents have to be added to the water-bath, others claim that hot water is enough, and still others note that it is enough to soak antlers in cold water for several weeks (Deschler-Erb 2005, 211). Notable in this connection is the context of hut 6, which the author of the excavation believes to be a production building. Its fill contained the aforementioned six comb fragments and several pieces of partly worked antler. In the southern part of the building, a 1.5-m-deep pit was unearthed (no. 6A), which was interpreted as an exploitation pit or a destroyed well. Interestingly, groundwater was seeping out of the pit, and this was ultimately one of the reasons why it was not fully investigated (Březinová and Benediková 2003, 47-49). This opens up for another interpretation of its use as a pit for soaking antler. Even though soaking was usually done in larger ceramic or wooden vessels (Deschler-Erb 2005, 211), the function of the hut above the pit permits such interpretation. The hut also contained a fireplace, which could suggest that antler was boiled in hot water so that it would become softer. A similar situation was found in the Iron Age settlement (rectangular crates) in Rusko (modern-day Poland), where raw materials, half-finished products, and waste appeared in pits that, according to J. Baron, were used to soften the antler (Baron 2007, 376-377).

The finds, together with the worked antler, clearly attest to the existence of a specialized workshop for the production of composite combs. The workshop was not necessarily a closed room in hut no. 6 with soaking pit no. 6A (Figure 9); antler may have been worked in the open around the hut, where the craftsman had enough light. However, we must realize that the processing of the antler was only a side activity. The craftsman did not do it all day and it was not his only activity. Of course, it was possible to process antler in the hut without using light, at least in the evening and on rainy days. Analogies can be found in ethnology, where we know that similar activities were performed by shepherds or in the evening by firelight, *etc.* However, we think that the craftsman prefers to work during the

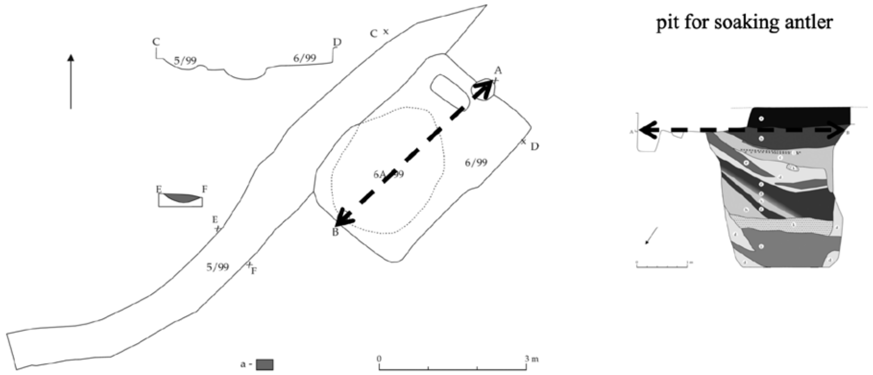

Figure 9. Pit (6A) for soaking antler located in the southern part of hut no. 6 (Březinová and Benediková 2003, Fig. 16, 17).

day in the air, in the sun, *etc.* Antler working was likely a seasonal activity (end of winter, beginning of spring) and probably played a minor role alongside activities like animal breeding and pottery making (Lang 2011, 295-303).

Evidence for specialized comb-making workshops is rather scarce. Such workshops have been identified, for instance, in Praha-Hoštice (Zeman 2001, 108) and Zlechov in the Czech Republic (Zeman 2006, 457) and in Valea Seacă in Romania (Musteață and Popa 2010, 160). Isolated finds, like antler shavings similar to those from Nitra-Chrenová, were found in Germanic settlements in Slovakia in Vajnory (Varsik 2011a, Tab. 64, 65), in Šala-Veča (Fottová 2003, 39-41) and in Chotín (Hečková and Repka 2019, 125-128.). This allows us to assume a smaller workshop (or rather a craftsman who knew how to work antler). But this is only a precondition, because direct evidence in the form of finds is still missing.

Only one worked bone artifact from Nitra-Chrenová was used as a bradawl (Figure 3.6). Such items were normally used for weaving or repairing fishing nets, but they may also have been used for perforating holes in woven fabric (Zeman 2001, 126). The negligible number of worked bones from the studied site clearly confirms an earlier thesis that Germans (the Quadi) rarely used animal bones to make tools, jewellery and other objects, although the general presence of bone tools is not surprising as on other sites, for example, Branč (Kolník and Varsik and Vladár 2007, 300), Bratislava-Trnávka (Varsik 2011a, 342), and Iža-Leányvár (Hrnčiarik 2017, 82). Such bones were used for making tools, too (Deschler-Erb 2005, 213). A wider use of bone, however, is not attested until Late Antiquity. At the same time, antler products become more common in the Roman environment, which suggests their association with the Germanic element in the Roman army (Bíró 2002, 67-69). Either such products were made by resettled Germans or the Romans adopted the technique from the Germans (Hrnčiarik 2017, 95-96).

Conclusion

The analysis of worked antler finds from Nitra-Chrenová confirmed the existence of a workshop specializing in the making of single-sided composite combs. This is the first documented workshop in the territory where the Suebian Quadi lived. The workshop can be located in huts no. 6 and 9, but it was possible that antler may also have been worked in the open around the huts, where the craftsman had enough light during the day. Notable in this connection is the context of hut no. 6. In the southern part of the building, a 1.5-m-deep pit was unearthed (6A), which was interpreted as a pit for soaking antler. Studying the preserved artifacts provided us with knowledge of antler-working techniques (like soaking, cutting, and sawing) and helped us reconstruct the process from its earliest stage to the final product.[2]

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The worked bone and tooth assemblage from Piaçaguera: Insights and challenges

Daniela Klokler

Abstract

Shell mounds and middens are among the most-studied archaeological sites in Brazil, yet their modified archaeofauna is rarely the focus of researchers. While preservation issues, expected in a tropical country, explain the lower number of publications on the subject in general, shell site matrices provide the perfect environment for lower degrees of weathering and breakage of organic remains. Indeed, almost all shell sites contain artifacts made from bone, teeth, and shells, but the assemblages are seldom fully explored by scholars. Here I present preliminary findings about the worked vertebrate assemblage from Piaçaguera, a shell midden in São Paulo state. The faunal assemblage includes hundreds of tools and adornments recovered from excavations done in the 1960s. Bone points (gorges) and modified teeth (from sharks and monkeys) are by far the most dominant tool types at Piaçaguera. Interestingly, most pieces appear to be associated with burials. Analysis indicates the prevalence of composite tools and the hafting of "apparently" unmodified shark teeth. The results demonstrate the urgency in reviewing collections in order to better understand the technology used by fisher-gatherer societies.

Resumo

Sítios conchíferos ou sambaquis estão entre os sítios arqueológicos mais estudados no Brasil, no entanto a arqueofauna modificada raramente é o foco dos pesquisadores. Enquanto problemas de preservação, esperados em um país tropical, explicam em geral o baixo número de publicações sobre o tema, as matrizes de sítios com concha fornecem o ambiente perfeito para baixos graus de intemperização e fragmentação de vestígios orgânicos. De fato, quase todos sambaquis contem artefatos feitos com ossos, dentes e conchas, mas raramente os conjuntos são plenamente explorados pelos pesquisadores. Neste artigo apresento resultados preliminares sobre o conjunto de material vertebrado modificado do sítio Piaçaguera, um sambaqui do estado de São Paulo. A arqueofauna inclui centenas de artefatos e adornos recuperados de escavações realizadas nos anos 60. Pontas ósseas e dentes modificados (de tubarões e macacos) são os tipos dominantes de artefatos em Piaçaguera. Interessantemente,

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Bones at a Crossroads: Integrating Worked Bone Research with Archaeometry and Social Zooarchaeology, Leiden: Sidestone Press, pp. 133-150.

a maioria das peças parece estar associada com sepultamentos. A análise indicou prevalência de ferramentas compostas e encabamento de dentes de tubarão “aparentemente” sem modificação. Os resultados demonstram a urgência em revisar coleções para melhor compreender a tecnologia utilizada por sociedades pescadoras-coletoras.

Keywords: shell mounds, bone points, worked bone, zooarchaeology, archaeological collections

Introduction

Among the shell mounds and middens identified along the approximately 7500 km of the Brazilian coast are various organic raw materials (such as bones, teeth, antlers, and shells). A large number of different tools, along with numerous different types of body adornment (including amulets), could be manufactured with by-products of fishing, gathering, or other activities (Fossari 1985; Klokler 2014; Saladino 2016).

Nonetheless, one seldom finds detailed information about modified fauna from shell sites in the Brazilian literature. Usually, studies and reports briefly mention their presence, but rarely explore manufacturing aspects. For this reason, archaeologists have only a partial view, and understanding, of technology, subsistence practices and strategies, identity markers, and, more generally, the use of animals by the shell-mound populations that inhabited the Brazilian coast.

In this paper I present preliminary findings about the worked bone and tooth collection from Piaçaguera, a shell midden from São Paulo state (Figure 1). The worked faunal assemblage includes more than two thousand artifacts recovered during excavations done in the 1960s that were never fully studied, with the exception of studies by Uchoa and Garcia (1971; Garcia 1972; Uchoa 1973) and later the research on shark-based artifacts by Gonzalez (2005a; 2005b). Among other goals, I aimed to identify the taxa primarily chosen for the manufacture of distinct objects, the stages of modification of the materials, and possible depositional associations of these tools.

This research distinguishes itself from most faunal studies of Brazilian shell sites by not focusing on subsistence analyses or site formation, two major themes that capture the interest of scholars (Klokler 2017a). Despite the fact that lithic and ceramic artifact studies are traditional in Brazilian archaeology, the same does not occur when the base raw materials are organic.

Analysis suggests clear differences in the selection of animals for tools. Additionally, Piaçaguera contains preforms and waste in larger quantities than previously reported (Gonzalez 2005a; Uchoa 1973), indicating that part (or most of) the process of manufacture took place at the site, as previously suggested by Borges (2015, 190). Shark teeth, perforated and modified in other ways, pose new questions about their use. There is no doubt that the inclusion of taxa used for artifacts brings a more inclusive understanding of the capture practices used by ancient shell-mound groups.

Shell sites, zooarchaeology, and worked faunal remains

Shell mounds are largely concentrated on the Brazilian southern coast, between Rio de Janeiro and Santa Catarina states, but sites also occur in the northern areas and in the interior, including in the Amazon, along certain rivers. At the end of the nineteenth century, the larger accumulations of shells composing these sites caught the attention of

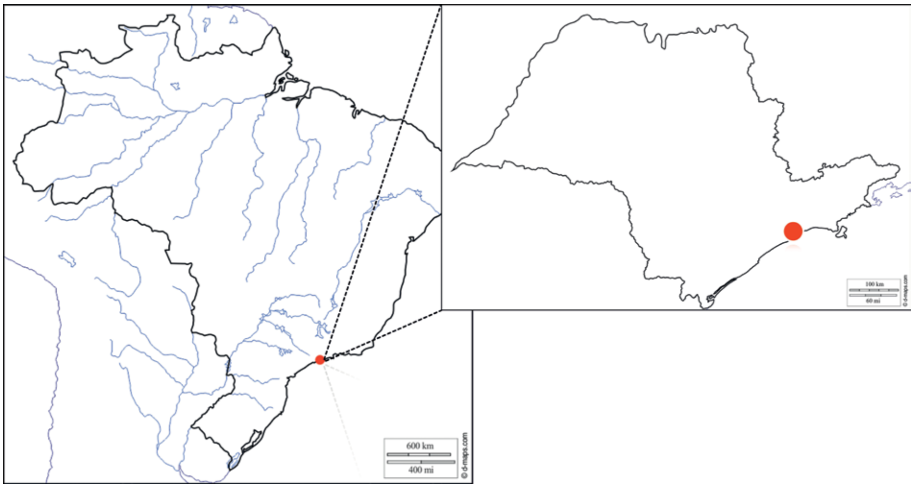

Figure 1. Map with the location of Piaçaguera.

European missionaries and travelers. From then, interest in the origins of such structures and their builders grew, capturing various generations of archaeology scholars. Shell-mound research has a long and productive tradition within Brazilian archaeology and remains to this day an important topic of research second only to Amazonian archaeology. Nevertheless, most of the Brazilian research and literature on shell mounds is focused on southern sites fueled, understandably, by their larger sizes, and the availability of grants due to their proximity to traditional research centers.

The oldest shell sites date to 6000 BC, and the occupation of coastal zones by fisher-hunter-gatherers can be traced up until approximately 1450 AD (Gaspar 2000; Lima *et al.* 2004; Villagran 2014). For most of the Holocene, these groups dominated and changed the landscape with shell accumulations of varying scales. However, archaeologists noticed an increase in the number of sites between 3000 and 4000 years ago, along with an increase in their size (DeBlasis *et al.* 2007; Klokler 2017b).

Despite a major focus on large-scale sites, and the skew of publications in favor of monumental shell mounds with over 15 m in height, shell sites located in Brazilian territory present great variability of dimensions (Gaspar 2000). Smaller sites can be almost invisible in the coastal plain landscape with just a few decimeters in height, but aside from size; their composition and contents have many similarities with larger sites (Peixoto 2008; Villagran 2013).

Site function vary as well. It is argued that many larger shell sites functioned exclusively as cemeteries while smaller sites could be habitations, processing locales, or spaces for various activities (Gaspar 2000; Klokler 2017a and b; Villagran 2013, 2014; Villagran *et al.* 2011). However, the size criteria do not always work as indicative of function, since lately small-scale sites were also recognized as graveyards, *e.g.*, Mar Virado, Piaçaguera, Morais (Fischer 2012; Plens 2010; Silva 2005).

Faunal analyses are a big part of research on southern shell mounds (Borges 2015; Figuti 1993; Garcia 1972; Klokler 2014, 2017b; Nishida 2007; Plens 2010). In Brazil, zooarchaeology developed closely alongside shell-mound archaeology (Klokler 2017a). Theoretical and paradigmatic shifts in the discipline usually occur first within shell-mound archaeofaunal studies, followed by mainstream Brazilian zooarchaeology.

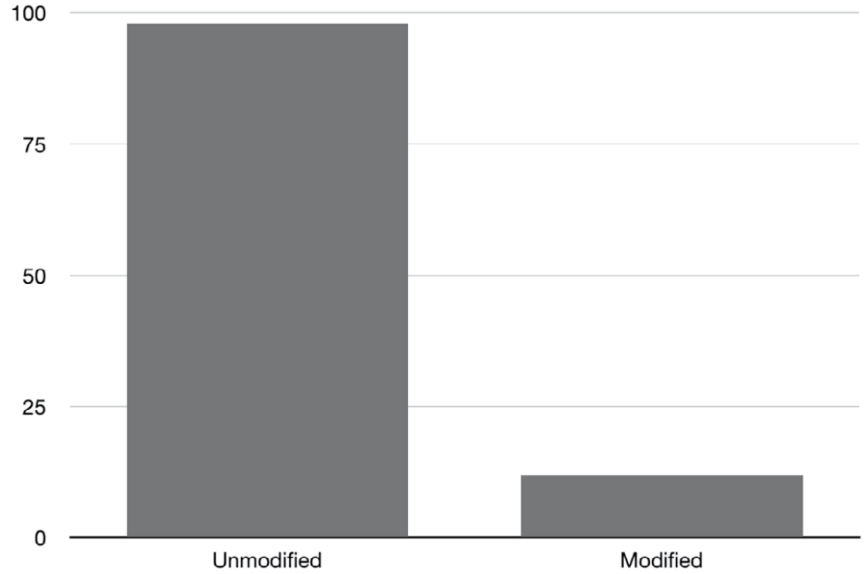

Figure 2. Difference in the numbers of publications about unmodified and modified faunal assemblages from shell sites in Brazil.

For many years, the focus of scholars studying faunal remains from shell sites was the identification and, more rarely, quantification of shells and bones with the main goal of describing subsistence practices. Shell-mound research in Brazil stagnated between the 1950s and the mid-1990s, and zooarchaeological studies also became less prolific, losing their early importance in the country. Currently, due to recent developments in shell-site archaeology, archaeofaunal studies attract more attention, particularly when they focus on formation processes and symbolic aspects of animal use by fisher-gatherer populations (Klokler 2017a).

Despite recent advances in theory and method, renewed attention to zooarchaeology, and a significant increase in the number of active professionals, modified faunal remains are still rarely the focus of research. While the presence of worked bone and shell remains is commonly mentioned in reports and publications, quantifications or descriptions are seldom provided by authors. Publications dedicated exclusively to worked bone and shell are even rarer.

A review of the specialized shell sites in the archaeofaunal literature clearly demonstrates the focus on studies of unmodified remains (Figure 2). The number of publications about worked bone and shell is approximately one-ninth the number of publications on unmodified materials. If we contrast this with the literature on lithics and ceramics, the discrepancy is even greater.

Most notably, we can cite the studies by Tiburtius (1960), Fossari (1995), Gonzalez (2005a, 2005b), Hering (2006), Klokler (2014), and Saladino (2016) as examples in which modified archaeofauna from shell mounds is at the center of research. Each of these authors have, at different times, explored the rich assemblage of tools based on faunal raw materials. Among these, Fossari and Hering tried to propose a unified nomenclature and invited researchers to take a more meticulous approach to the bone and shell industries.

Some of the reasons for the lag in studies of worked bone and shell are consequences of the education of faunal specialists in Brazil, which does not often include specific training regarding artifact analysis. Furthermore, taphonomic aspects of archaeofaunal assemblages are not explored at length by scholars. This combination of characteristics renders the recognition of unfinished artifacts and rejects much more difficult.

Traditionally, the separation of osseous and shell tools and adornments from the rest of the faunal remains occurs in the field, and these pieces are seldom sent to zooarchaeologists for analysis. Unlike other areas of the world, where some scholars are fully dedicated to the study of worked bone or shell, these assemblages are usually studied by analysts without specific training on faunal remains.

Following the assertions of Scheinsohn about artifacts being “defined by their functionality, raw material, and design” and how the interplay among these characteristics imposes limits on their manufacture (1993-94, 36), analysts must be well acquainted with their inherent idiosyncrasies, an alert also raised by Fossari (1995). Scheinsohn warns us of the particularities of raw materials and their influence on analyses. Therefore, studies of bone and shell artifacts are better performed by faunal specialists due to their familiarity with the materials (Fossari 1995).

Another peculiarity of organic materials that favors the work of specialists is taphonomy. Archaeofaunal remains are subject to particular natural and cultural processes, and such transformations are an important part of the formation of faunal assemblages. Understanding, and differentiating, modifications made by humans from those made by other agents is essential to recognizing unfinished artifacts and manufacturing waste.

In the case of intentional anthropic modifications, the transformations of faunal remains are patterned and repetitive. Therefore, understanding the response of faunal materials to distinct cutting, sawing, and polishing actions increases the probability of identification and adequate interpretation of modified assemblages.

Piaçaguera

Piaçaguera is a small shell mound located in the southern portion of São Paulo state (Figure 1). The location sits close to a mangrove area around 20 km from the coast in the foothills of Serra do Mar and close to the access to the uplands. In other words, its location is strategic regarding catchment of a variety of resources. It was originally excavated between 1965 and 1969 (Uchoa 1973). The site was approximately 850 square meters in area and reached two meters in height. Piaçaguera was impacted during the construction of an industrial complex in the region, which triggered the archaeological research. A total of 119 m^2 of the site were excavated. It is one of the oldest sites on the southeastern coast with radiocarbon dates between 5300 and 3400 calBC (Table 1). Garcia and Uchoa (Garcia and Uchoa 1980; Uchoa 1973) initially characterized Piaçaguera as a temporary habitation site, more commonly known in Brazilian literature as a shell camp.

The excavation originally identified 56 graves (Uchoa 1973) with a total of 88 individuals (Fischer 2012). The site contains 16 female, 14 male, and 15 indeterminate adult inhumations coupled with a large number of child burials (43) (Fischer 2012). The burial distribution is not equitable throughout the horizontal and vertical axes of the site; researchers could discern a greater density of graves at the center of the site and a clear concentration of inhumations on layer 2 between 10.35 and 11.25 m. The quantity

Lab #	Material	Provenience	Radiocarbon date in ^{14}C BP	Calibrated age range (calBC)	References
I4481	Shell	Layer III – 10.15 m – base	4930±110	3953-3499	Garcia 1972; Uchôa 1973, Garcia and Uchôa 1980
I4480	Shell	Layer I – 12.07 m – top	4890±110	3815-3482	Garcia 1972; Uchôa 1973; Garcia and Uchôa 1980
AA109203	Bone	Burial XV	6342±34	5375-5208	Filippini *et al*. 2019

Table 1. Piaçaguera radiocarbon dates (radiocarbon dates calibrated by the author using Calib 8.2 (Stuiver *et al*. 2020) and the calibration curve SHcal20 (Hogg *et al*. 2020)).

Shell mound	Number of burials	Cubic meters sampled	Burials per m^3	Source
Jabuticabeira II	51	373	0.137	Fish et al. 2000
Cabeçuda	191	1190	0.160	Castro Faria 1959
Forte Marechal Luz	79	240	0.329	Bryan 1993
Mar Virado	54	71.8	0.752	Barbosa 2001; Silva 2005
Piaçaguera	88	93.3	0.943	Fischer 2012; Gonzalez 2005a

Table 2. Burial density per cubic meter at five shell-mound sites in Brazil.

of burials per excavated cubic meter at Piaçaguera is high (Table 2), and recently Fisher (2012) and Silva (2005) suggested that the site shows evidence of being a cemetery (even though Silva is not adamant about its exclusive use as a graveyard). As shown in Table 2, Piaçaguera has the highest ratio of burials per cubic meter of well-known and published shell-mound sites.

Faunal assemblage

The site's archaeofauna was previously analyzed by Garcia (1972), Gonzalez (2005a, 2005b), and Borges (2015). Garcia, in the 1970s, pioneered the use of zooarchaeological collection, sampling, and quantification methods in Brazil. His research highlighted the importance of fishing as the main subsistence activity for the groups that inhabited the site. Based on the archaeofaunal materials, Garcia asserts that there is no evidence of abandonment or reoccupation of Piaçaguera (1972).

Manoel Gonzalez was interested in the relationship between fisher-gatherer groups of the area and cartilaginous fish, particularly sharks (2005a). His research focused on the role these fish had in the lives of past fishing communities. Gonzalez (2005a) not only provided an important glimpse in the roles of sharks and rays among past fisher-gatherer populations but also produced an in-depth analysis of the shark and ray specimens in Piaçaguera's assemblage.

According to Borges (2015), vertebrate fauna include a large variety of species of different biotopes, such as fish, reptiles, birds and mammals (terrestrial and marine). The faunal assemblage is dominated by estuarine animals, which represents the nearly complete dominance of coastal sites in Brazil. Scianidae and catfish make up approximately 85% of the biomass available in the matrix. Based on measurements of several skeletal elements, Borges observes the predominance of large adult fish in the site's assemblage (2015). Borges confirms Garcia's initial claim that Piaçaguera's faunal components indicate that fishing was the main activity and goes further by affirming that it reflects a specialized subsistence economy with preference to taxa present at the palaeobay with a few dominant species despite the richness of the exploited animal species (2015, 340).

Among these authors, only Gonzalez (2005a) has dedicated time and effort to the worked bone collection, but due to his particular interest in cartilaginous fish, he only analyzed material from sharks and rays. Furthermore, Gonzalez is more interested in the taxonomic identification of pieces, not necessarily in an in-depth analysis of the worked assemblage. Uchoa (1973) made an initial assessment of the lithic, osseous, and malacological artifactual assemblage of Piaçaguera and quantified 1543 pieces on shell plus 861 on worked bone and teeth. According to her, 48.7% of the site's artifacts are based on faunal materials.

Materials and methods

For this study, 2029 worked faunal pieces from Piaçaguera stored at the Museu de Arqueologia e Etnologia (USP) were analyzed.[1] First, the analysis consisted of anatomical and taxonomical identification of each specimen. The goal was to understand which taxa were primarily selected and utilized and which anatomical portions were chosen to be modified and made into tools and/or ornaments. The identification process was possible with the use of the comparative skeletal collection located at the Laboratory of Studies in Zooarchaeology and Bioarchaeology at the Museu de Arqueologia e Etnologia. For missing taxa, I also used osteological manuals (Berkovitz and Shellis 2017; Figueiredo 1977; Hillson 2005; Menezes and Figueiredo 1985) and consulted with other specialists.

Second, the morphological characteristics of each piece, including its minimum and maximum measurements (thickness, length, height) were registered. Any transformations by natural agents, such as plants (root etching), animals (gnawing, trampling), water (polish), solar exposure (weathering, which produces cracks, fissures, fractures, and splitting), and others, were recorded when observed (Lyman 1994; Mengoni Goñalons 2006-2009; Olsen and Shipman 1988). Preservation degrees were observed according to Behrensmeyer (1978).

Anthropic modifications, such as burning and its degrees (Stiner and Kuhn 1995) and the existence of cut, fracture, and scrape marks (Lyman 1994; O'Connor 2000; Olsen and Shipman 1988; Reitz and Wing 1999) were registered. More specific to the manufacture of artifacts, marks due to sawing and polishing were registered, as were decorations and evidence of use (Buc and Loponte 2007; Lyman 1994). The analysis included the types, locations, and placements of marks in relation to the bones or teeth. Digital and light microscopes (1000x magnification) were used to verify the marks and to photograph all the pieces. The photographs included, whenever deemed necessary, complete and partial views of specimens with alterations.

The second part of the analysis included an investigation of the spatial association of the pieces to identify possible correlations among artifact types (including taxa, and degree of

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[1] Discrepancies in the quantities of tools recorded by Uchoa and this study are due to the separation of pieces deemed unworked and added to the unmodified faunal collection and the inclusion of some artifacts in a temporary museum exhibit in 2019.

preservation, among others), and activity areas or graves. The idea was to try to identify areas where artifacts were concentrated and possible coincidences among areas with larger quantities of faunal remains and/or lithics, hearths, and mortuary contexts, for example. In the latter case, I tried to explore spatial associations and correlations with individuals' sex and age.

Results and discussion

The materials in the collection were previously identified as points, scrapers, spatulas, flat-ended tools, spheres, and teeth (perforated or not) (Uchoa 1973). Within the Brazilian literature, worked faunal remains are usually divided in two major categories: tools and adornments. Tools are artifacts used for transforming a variety of distinct raw materials for a multitude of purposes, not all of which are readily recognizable. Adornments, on the other hand, are pieces that were used as bodily ornaments, clothes or other object decorations. This differentiation is particularly useful in comparisons with published literature about shell-mound collections. However, as described below, the distinction between these major categories within vertebrate material is not as straightforward as anticipated, and adornments have been described as perforated teeth.

The teeth of terrestrial and marine mammals, reptiles, and fish were drilled. Adornments included pendants (made with perforated teeth) and beads. According to Andre Prous' typology, beads include any "*pieces whose fixation system is found in its central region*,"[2] while pendants include adornments with an "*elongated form, with a suspension system located in its periphery*" (1986/1990, 263).

Adornments made from gastropods are simple spire-lopped beads (according to the definition of Bennyhoff and Hughes (1987)) mostly made from *Olivella* sp. shells. They were manufactured by removing the shell's apex (95%). *Polinices hepaticus*, *Bulla striata,* and *Olivancillaria contur* were other taxa used by Piaçaguera occupants to make beads.[3]

Bone points and modified teeth (pendants and artifacts with multiple uses) are the most common worked vertebrate remains in quantitative terms in Piaçaguera. I also recorded pieces in different stages of manufacture and discarded specimens with modification marks.

The taxa identified during the analysis included birds, bivalves, gastropods, mammals, fish, and reptiles. The list contains species also identified in the faunal studies by Garcia (1972), Gonzalez (2005a) and Borges (2015).

Perforated teeth

Of the total of perforated pieces made with vertebrate materials (n=370), ninety percent are pendants made from monkey (n=242) or shark (n=101) teeth. These are followed by alligator (n=8), dolphin (n=7), raccoon (n=4), capybara (n=3), and jaguar (n=1) teeth (Figure 3). All contain just one perforation at the root, which is generally centralized.

There were six different types of perforated teeth in Piaçaguera's assemblage. The classification followed the choice of animal taxon (Figure 3). Aside from the raw materials, little variation was noticed among these pieces. The difficulty of categorizing them as adornments or pendants relates to the possibility that the teeth had different or multiple uses.

The preparation for perforation at the root of teeth included, in many instances, light abrasion of its surface to flatten it, which probably facilitated the drilling. It could

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[2] Author's translation.

[3] The malacological artifacts will be further discussed in a later publication.

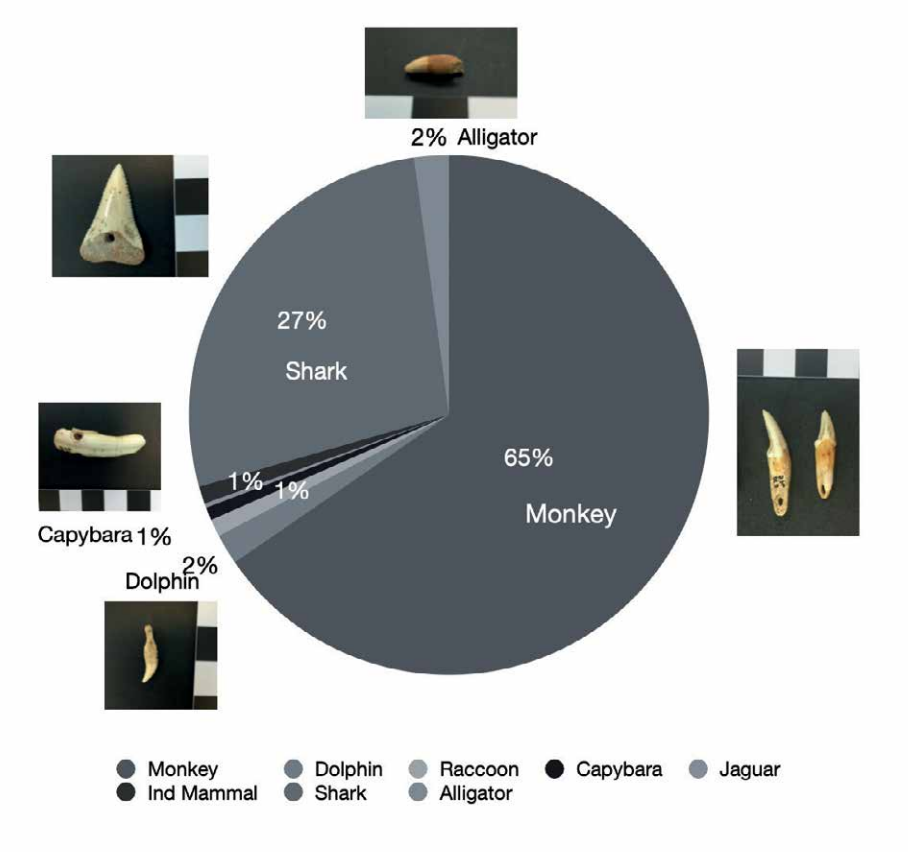

Figure 3. Perforated teeth identified at Piaçaguera and their proportions.

also help diminish the area to be perforated, decreasing the artisan's time. In the case of shark teeth, the abrasion sometimes affected the entire area of the root, suggesting an intentional major modification of its shape. Both sides and the base of the roots were straightened. This type of modification was necessary to make a pendant. However, the resulting flat surface and right angles suggest hafting or some other use as a composite tool, as do the signs of abrasion in the enamel along the sides and tips of the cusps of various pieces. Gilson's experimental study and analysis of the Rio do Meio assemblage supports our findings (this volume).

Some perforated capybara incisors could also have functioned as tools, in this case, scrapers. In at least two cases, the opposite end of a perforated tooth was smoothed and exhibited signs of use. Unfortunately, due to the fragmentary state of the materials and the absence of one of the extremities, it is not possible to ascertain how many of the perforated incisors were used as scrapers. Capybara incisor pendants could have been used occasionally as scrapers or have been suspended scrapers. The suspension of such tools could have facilitated transportation.

Macro- and microscopic analyses of the perforations and roots did not identify marks related to threads or suspension. This could suggest that these materials were not used for long periods of time or were relatively new, maybe even manufactured as grave gifts. In any case, a higher magnification will be employed in the future to discern whether marks are present.

Teeth of at least eight shark species, blacknose (*Carcharinus acronotus*, n=7), blue (*Prionace glauca*, n=10), dusky (*Carcharinus obscurus*, n=3), lemon (*Negaprion brevirostris*, n=2), sand tiger (*Carcharias taurus*, n=1), sandbar (*C. plumbeus*, n=4), tiger (*Galeocerdo cuvier*, n=22), and white (*Carcharodon carcharias*, n=21), and unidentified carcharinids (n=44) were selected to be drilled and then used as pendants or tools. Perforated teeth of tiger and white sharks are the most commonly identified. All the taxa recovered from Piaçaguera are still found along the southern Brazilian coast, but tiger and white sharks are not commonly seen. The former avoids getting close to the shore and the latter prefer colder waters.

Tools

During this reanalysis, unipoints (n=22), bipoints (n=18), scrapers (n=28), adze blades (or wedges) (n=11), bevel-ended tools (n=4), a sphere (n=1), awls/drills (n=4), and modified teeth (n=525) were identified (Table 3 and Figure 4). Points are in a morpho-functional category that encompasses a large variety of bone tools with pointed ends (Bradfield 2015). Bone points were initially divided into unipoints and bipoints, according to whether one or both extremities were pointed. Broken pieces that could not be reliably assigned to these categories are labeled solely as points (n=145). Scrapers are tools that have an acute, active edge on one end. Adze blades or wedges are usually rectangular in shape (similar to an axe), with one or two beveled extremities (on two facets). Bevel-ended tools have a single beveled straight or concave facet with a wider angle than regular points have and marks coincidental with use for scraping. Awls are tools with narrow angled extremities (narrower and thinner than points). A sphere is a modified bone shaped like a ball. It could have been used to smooth or polish surfaces of soft materials, but further research is necessary to accurately assign this particular use to the object.

Measurements of points (both uni- and bipoints), bevel-ended tools, and adzes showed that while width and thickness have little variation, length is the component that has the largest range of variation (Table 4). Since most of the points that could be measured were manufactured from fish bones (65%), more specifically ray spines, it is not surprising that their width and thickness were similar.

The bipoint lengths are consistent with materials from South African sites presented by Bradfield in 2019. Bradfield presents bipoints (or gorges) as one of the components of the oldest known fishing methods (2019, 593). By comparing the measurements of bipoints, particularly the length with the species and individual sizes of fish indicated by Borges (2015), it is possible to infer the preference for gorges as fishhooks in fishing activities. Other authors have made similar suggestions regarding the use of gorges for line fishing by shell-mound groups in São Paulo state (Figuti 1993; Garcia 1972). Extensive measurements of bipoints or gorges from other shell sites could indicate whether the length of these tools corresponds to the size of the fished taxa.

In the collection, only two pieces have previously been identified as waste, and no preforms were recognized. The re-analysis increased the numbers substantially, to 53 preforms and 23 pieces of manufacturing refuse or waste. Since Uchoa (1973) recorded the existence of both categories, it is possible that these elements were later separated from the rest of the worked bone assemblage. Most misidentified pieces in the collection were recognized as finished tools. Unfortunately, researchers rarely include information

		N	%
Modified teeth		525	69.3
Points	Unipoints	22	2.9
	Bipoints	18	2.4
	Fragmented	145	19.1
Scrapers		28	3.7
Adze blades		11	1.5
Awls/drills		4	0.5
Bevel-ended tools		4	0.5
Sphere		1	0.1

Table 3. Different tool types from Piaçaguera and their percentages.

		Length	Width	Thickness
Unipoints	Mean	31.2	6.27	2.98
	Median	30.3	6.25	2.69
	Standard dev.	4.35	1.41	1.41
Bipoints	Mean	37.3	6.05	2.98
	Median	38.3	5.53	2.74
	Standard dev.	7.83	1.32	0.9
Adzes	Mean	108	42.59	7.36
	Median	108	42.44	7.58
	Standard dev.	N/A	4.39	0.98
Bevel-ended tools	Mean	35.2	16.82	3.71
	Median	33.75	14.61	3.36
	Standard dev.	6.3	5.41	1.42

Table 4. Means, medians, and standard deviations of the measurements of the unipoints, bipoints, adzes, and bevel-ended tools found in Piaçaguera.

regarding the existence of preforms and waste. Their preference to focus on formal tools precludes adequate assessment of where the tools and adornments were manufactured.

Regarding the preferred taxa for tools, apparently terrestrial mammals (indeterminate) are most commonly chosen for the elaboration of bone points (n=44). Marine mammal bones, probably from whales, were used for making spatulas and bevel-ended tools. Capybara teeth were used for manufacturing scrapers.

Bipoints and unipoints were mostly made from fish elements (bony and cartilaginous). Among bony fish, spines were used; however, due to the extensive transformation of the bones, it is not possible to confirm which element was used. From cartilaginous fish (rays) the chosen element was the tail spine. Transverse sawing was used to section the tail spines at different lengths, and several pieces had both extremities sawed. Unfortunately, I could not identify the taxa selected, but based on the identification of elements from whitespotted eagle rays (*Aerobatus narinari*), southern stingrays (*Dasyatis americana*), cownose rays (*Rhinoptera bonasus*), and Brazilian cownose rays (*Rhinoptera brasiliensis*)

Figure 4. Examples of tools from Piaçaguera's assemblage. From left to right: unipoint, bipoint, adze, bevel-ended tool (Source: Museu de Arqueologia e Etnologia USP).

in studies by Gonzalez (2005 a and b) and Borges (2015), it is possible to infer that spines from these species could have been transformed into tools.

Shark teeth with some evidence of modification, but without perforation, predominate among tools. The evidence of alteration includes abrasion, cutting, and scraping of the roots. In some species, such as *Carcharias taurus*, the lateral cusps were removed. It is possible that teeth with modified roots are preforms of perforated teeth. Nonetheless, marks and nicks at the tips of some teeth and wear to enamel on the sides also indicate the use of these specimens as cutting implements. Similar modifications also appear on perforated pieces, which suggests that shark teeth had multiple uses, not only a decorative function.

The functions of bone points and perforated teeth are, in the majority of cases, based on ethnological or ethnohistorical descriptions. Bradfield's (2015) call for more experimental studies is welcome since archaeologists encounter substantial variability in shape and size (of points) and modifications (of teeth), which could imply alternative or multiple functions. This highlights the need for extensive experimental research (*e.g.*, the work of Gilson, this volume).

Associations with funerary contexts

Basic provenience information from the locations of the specimens demonstrates that the distribution of materials is not random but associated with the concentration of inhumations in layer 2 (Uchoa 1973). According to the field documentation, 63% of the perforated teeth and 58% of the tools were recovered from graves. Silva, in his study of the mortuary practices of coastal groups, verified the relationship between worked faunal remains and distinct burials at the site (2005).

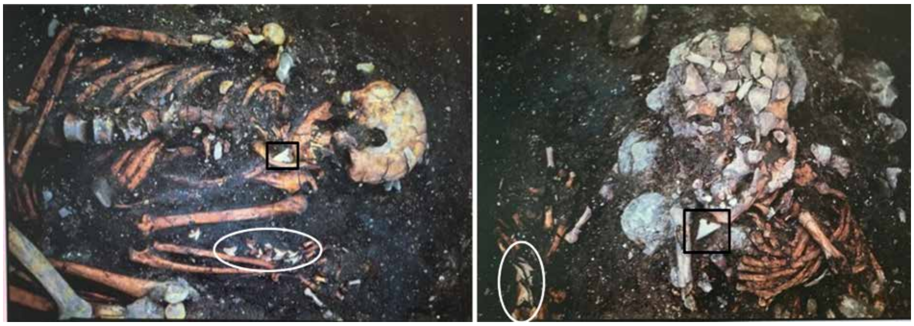

Figure 5. Burials with concentrations of *Galeocerdo cuvier* teeth (circled in white) and perforated *Carcharodon carcharias* teeth (black rectangle) (Source: Museu de Arqueologia e Etnologia USP).

The trend toward increased quantities of tools and adornments in funerary contexts is evidenced in other shell-mound sites (Gaspar *et al.* 2013; Escórcio 2008; Hering 2006; Klokler 2014). Gaspar and colleagues assert that burials seem to act as magnets for lithic and bone tools as well as adornments at shell sites (2014).

In the past, only pieces closely associated with burials, *i.e.*, touching the skeleton or inside what could be perceived as the grave, were considered offerings or associated with mortuary rituals. However, new perspectives on the function of shell mounds as graveyards have forced scholars to review the material from these sites (Klokler 2017a). If Piaçaguera functioned solely as a graveyard, then it can be argued that all its components are funerary paraphernalia.

Uchoa (1973) and Silva (2005) hint at the recurrent accumulation of shark teeth near the upper bodies of individuals. A review of field pictures of some burials provides important information about the positioning of shark teeth in relation to the body (Figure 5). Concentrations sometimes appear in quasi-linear arrangements near the hands and forearms. These arrangements suggest the use of teeth as tools, possibly composite tools used to cut, shred, or scrape. Abrasions on the roots and wear on the cusps complement the evidence. The disposition, spacing, and deposition locales of the teeth seem to indicate that these elements were significant for the people that built and used Piaçaguera. Unfortunately, 45% of these pieces were recovered during field screening or laboratory analysis, so their specific spatial arrangement can only be retraced via review of detailed photos, drawings, or field descriptions.

The populations that inhabited the Gilbert Islands in the Pacific Ocean made weapons similar to swords using teeth from sharks of some of the species found in this analysis: *Galeocerdo cuvier, Prionace glauca*, and *Sphyrna zygaena* (Drew *et al*. 2013, 4). Many of the shark-tooth weapons were collected during the nineteenth century and can be seen in museums such as the Smithsonian's National Museum of the American Indian and the Florida Museum of Natural History. An earlier example of tools with shark elements was provided by Walker in 1992 in her discussion of modified (drilled and edge-worn) teeth found at sites in southern Florida, and the recovery of composite tools with perforated shark teeth from Key Marco in Florida.

Logically, there is no suggestion of a link between these coastal populations and the pre-colonial groups that inhabited the Brazilian coast, but their tools included here as examples of tools that could have been used in the past to shed light on worked faunal assemblages from shell mounds. In 2016, Lopes and colleagues also noted that perforated teeth recovered from Rio de Janeiro shell sites could have had multiple uses.

The investigation of the association of specific individuals buried at Piaçaguera with the tools and adornments present at the site suggests that modified shark teeth are common and present at higher rates in close association with female adults and children (under 3 years of age). In contrast, the largest concentration of these pieces (n=113) was buried with an adult male. So far, no clear distinctions relating to the individual's sex and age, the mode of burial, and the types of tool or taxa have been established. More data needs to be compiled in order to assert whether the results can be compared and contrasted with previous studies (Escórcio 2008; Saladino 2016; Silva 2005).

Monkey pendants also seem to occur in association with female burials. A large set of pendants made from monkey canines was recovered from a feminine and adolescent burial (XXVII). The necklace contained the canines of the equivalent of 35 monkeys (122 canines in total).[4] Interestingly, Borges identified howler monkey (*Alouatta guariba*) bones corresponding to only two individuals (NISP 9, MNI 2) (2015, 302). This example clearly demonstrates the danger of separating the worked faunal assemblage from the rest of the archaeofauna and the impact this practice can have on the understanding of relationships between human and animal populations (see Boisvert *et al.*, this volume).

So much to be done

The reexamination of Piaçaguera's worked faunal collection is important because it expands the knowledge about past fisher-gatherer communities, particularly shell-mound-building groups. An investigation with a more current perspective on shell sites and archaeofaunal remains can shift the view of the assemblage. Scholars now have a better idea of the association of tools and perforated teeth with funerary contexts. With the understanding that Piaçaguera is a mortuary site, archaeologists can better access the relationship among certain worked materials, taxa or individuals, and depositional contexts. Previously, only pieces included in graves were considered offerings or funerary paraphernalia.

This study re-categorized preforms and waste previously identified in publications as finished artifacts (mostly unipoints and bipoints) (Garcia and Uchoa 1980; Silva 2005; Uchoa 1973). The identification of formerly misidentified preforms and waste derived from the manufacture of points dramatically increased the number of these items. The presence of pieces in distinct stages of point manufacture suggests either that bone points were produced at the site or that the elements resulting from the elaboration process were intentionally included during the funeral activities.

Furthermore, the reanalysis solidifies the indication that the series of modifications encountered in shark teeth had multiple purposes, and scholars should be careful about automatically assigning perforated teeth to the adornment category. The special spatial arrangement of modified shark teeth near the upper limbs of several individuals seems deliberate and suggests the original composite tool to which they belonged.

Investing in research focused on worked faunal assemblages can significantly advance the study of coastal groups and animals. For this, it is necessary to implement specific training for faunal analysts since it is clear that trained professionals have a better chance

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[4] This portion of the research is still underway, and hopefully, more data will be detangled in the future.

of recognizing modified materials and their taxa. Additionally, a review of previously studied collections from a more current perspective would be welcomed.

Furthermore, many faunal collections remain either untouched or incompletely analyzed. The data that can be gathered by specialists are invaluable and can change the view of not only ancient fisher-gatherers but also the social-cultural importance of animals to these populations. Finally, more investment should be made in experimental research, usewear studies, and chemical analysis since they are undoubtedly essential for revealing the details of the manufacture and use of bone tools.

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Traceological evaluation of bone instruments as an indirect indicator: Rebuilding textile technology during the Ceramic period on Mocha Island (Chile)

Helga Inostroza Rojas

Abstract

Textiles have not been extensively studied in Araucanía (southern Chile) as archaeological evidence. The idea of Prehispanic textile working mainly comes from ethnohistorical and ethnographic sources. Furthermore, the only textiles recovered are scarce and of doubtful local origin. This paper presents the results of a study focused on bone tools from the Early Ceramic period [*c.* 400-1000/1100 AD] and the Late Ceramic period [*c.* 1000/1100-1550 AD] from Mocha Island. Bone tools are considered potential indirect indicators of textile working. Morphologies and usewear traces were analyzed and contrasted experimentally. The findings suggest that textile working is visible in tools in addition to being recognized on other materials such as skin, plant-based fabric, and clay and in activities such as piercing and smoothing. Textile working is represented by spools for wool and tools for tightening, selecting fibers and sewing between *c.* 400 and 1550 AD. Based on these results, the discussion centers on the use of the weaving loom, the raw material used, and the implications of this practice in the social context of the island and the surrounding area.

Resumen

Los textiles no han sido ampliamente estudiados como evidencia arqueológica en la Araucanía (sur de Chile). La idea de un trabajo textil prehispánico proviene principalmente de fuentes etnohistóricas y etnográficas, además, los únicos textiles recuperados son escasos y de dudoso origen local. Este artículo presenta los resultados de un estudio centrado en instrumentos óseos del periodo Alfarero Temprano [*c.* 400-1000/1100 AD] y periodo Alfarero Tardío [*c.* 1000/1100-1550 AD] de isla Mocha. Los instrumentos óseos fueron considerados como un potencial indicador indirecto de trabajo textil, se analizaron las morfologías y huellas de uso y se contrastaron experimentalmente. Los resultados sugieren que el trabajo textil es visible en los instrumentos, además se reconocieron

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otros materiales como cuero, fibras vegetales y cerámica, y actividades como perforar y alisar. El trabajo textil está representado por carretes de lana e instrumentos para apretar, seleccionar y coser, entre *c.* 400-1550 AD. Basados en estos resultados, la discusión se centra en el uso de telar, la materia prima utilizada y las implicancias de esta práctica en el contexto social de la isla y sus alrededores.

Keywords: textile working, wool, bone tools, Araucanía

Study problem: Weaving in the Ceramic period?

Textiles are recognized in contemporary and Prehispanic communities for their economic, social, and cultural importance. This technology is often mentioned in the literature, where studies consider themes such as symbolism and identity, differences in use by age or gender, textile artisans, social class, and social complexity (Hurcombe 2014; Stone 2011).

In the Araucanía area, an important textile industry has been observed in historical times. Animal breeding and the constant collection of wool allowed fabrics not only to be oriented toward self-consumption but also to be commercialized in markets. This activity was very important until the implementation of the reduction system of the nineteenth and twentieth centuries and continues today (Manosalva 2015).

Textiles have been in use since the Prehispanic period (Joseph 1929; Lothrop 1930), possibly even prior to metalworking (Campbell 2004), and have been linked to phenomena of prestige and leadership (Campbell 2011). However, their antiquity is not clear, they are highly perishable, and there are only isolated fragments (Aldunate 1996).

Valuable information on groups from the area comes from Spanish, English, and Dutch ethnohistorical sources from the sixteenth and seventeenth centuries. The narratives describe textiles and camelid management as strategies for obtaining wealth, status, or leadership, and as part of the household and domestic economy. Furthermore, they report that textiles were manufactured exclusively by women and that they used camelid wool (González de Nájera [1614] (1968); IJzerman, (1926)). Hawkins ([1594] 1847) described the use of wool ponchos, and the Dutch traveler Van Noort said that the island's inhabitants spun and weaved wool on looms armed with sticks; the wool was obtained from long-necked "sheep" whose wool almost reached the ground (IJzerman 1926). The information about these "sheep" is confused and fragmented.

Ethnographically, documentation from the twentieth century mentions aspects of symbolism, design, and clothes and refers to textile production as a Prehispanic activity from the Andean area (Cooper 1946; Joseph 1929; Lothrop 1930). Furthermore, the use of sheep wool, camelids on the island, bone and wood tools, and looms have been reported in the historic period (Cooper 1946; Guevara 1929; Joseph 1929).

The known archaeological record is scanty and begins in the Ceramic period. The Early Ceramic period contains the Pitrén complex, and in this period, we have one only textile sample, which is from the funeral site Villa JMC-01 [904-1151 calAD],[1] near Labranza City. The textile was made from alpaca (*Lama pacos*) fiber (Munita *et al.*, 2011) using the twisted technique and interwoven fibers (Mera 2014). The Late Ceramic period contains the Vergel complex. In this complex at the funerary site Alboyanco [*c.* 1300-1350 AD

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[1] Beta-241265: 1060±40 ^{14}C BP (Talma and Vogel 1993); calibrated with OxCal v. 4.4 (Bronk Ramsey 2009) and SHCal20 (Hogg *et al.* 2020).

(based on a TL-date)] near the city of Angol, two textile samples were preserved in a peat context. One is thick, made from llama (*Lama glama*) fiber using the twine technique, and the other is thin, of undetermined animal fiber, and interwoven using the multiple weft technique (Benavente and Gecele 1994; Brugnoli and Hoces de la Guardia 1995). Quiroz *et al.* (2005) refer to a textile made from camelid fiber at site Co-2 near Coronel city, and Marco Sánchez, independent researcher, says we do not have enough information about this at present (pers. comm., 2017).

Another line of evidence comprises the tools used for weaving. The Early Ceramic period is represented by two ceramic spindle weights from the KM15-Lof Mahuida site [993-1412 calAD] and two lithic spindle weights from the Km20-Lictanco Chico site [773-1150 calAD] (Ocampo *et al.*, 2004; Rodrigo Mera, pers. comm., 2017).[2] On Mocha Island, the Ceramic period may be represented by bone artifacts, among them needles and spindle weights (*torteras*) (Becker 1997; Fuentes 2010; Martínez 2013).

However, critical analysis of the information shows that it is unclear whether textiles were produced locally because: 1) There is a possible Andean substrate represented in the use of the twisted and interwoven fibers technique (Bahamondes 2009; Navarro and Aldunate 2002); 2) Alpaca and llama are not recognized in the area, where only the guanaco (*Lama guanicoe*) is known (Becker 1997); 3) The northern area has been suggested as a place of exchange – were textiles obtained from afar or produced locally? (Campbell 2011; Mera 2014); 4) Fiber analysis is inconclusive; 5) Textiles have only been recovered from funeral sites; 6) Tools have not been analyzed.

Because the lack of evidence for something or some kind of activity does not mean this activity was absent in a specific group, this study explores the possibility that bone tools could have been used to manufacture textiles. Bone artifacts have been useful in other contexts where perishable objects are not preserved (Hurcombe 2014; Stone 2011). For the purpose of this research, we considered morphological analysis, an experimental program, and usewear. These lines provided information about the use of bone tools in textile manufacturing and other activities or with other materials during the Ceramic period [*c.* 400-1550 AD] on Mocha Island.

Location and Ceramic period

Araucanía is a term used to describe a territory that includes cultural and geographic aspects. It covers 50,000 km² that include the basins of the Biobío, Cautín-Imperial, and Toltén rivers, in addition to Quiriquina, Santa María, and Mocha Islands (Campbell 2011).

Mocha Island (38° 22’ S and 73° 54’ E) is located 30 km off the coast of mainland by the town of Tirúa. It has an area of 52 km² and measures 13 km from north to south and 5.5 km from west to east.

The Ceramic period has been defined with two marked periods, the Early Ceramic period and the Late Ceramic period, which are represented by the Pitrén and El Vergel complexes, respectively.

The characterization of the former is fragmented. It begins with the widespread use of pottery in Araucanía after 400 AD and has been defined based on the diagnostic features of the Pitrén complex, mainly ceramic and funerary artifacts. The island does not provide much

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[2] A-12241 (Km 15-Lof Mahuida) and A-12240 (KM 20-Licano Chico): Calibrated with OxCal v. 4.4 (Bronk Ramsey 2009) and SHCal20 (Hogg *et al.* 2020).

Figure 1. Location of Mocha Island and sites.

information on this period; currently, most of the information comes from northern sites in Araucanía, most of which correspond to funerary contexts. This period was characterized by people practicing horticulture, gathered wild plants, and hunted animals.

The Vergel complex is more ubiquitous and distinguishable on the island. Chronologically, it is located between 1000 AD and the arrival of Europeans in 1550 AD. It is characterized by the emergence of metallurgy, possible management or domestication of camelids, a greater diversity of pottery, and the use of cultigens in addition to burial practices marked by the appearance of Mapuche funerary mounds called *kuels*. Recently, studies of the social organization have portrayed an economically autonomous community whose groups show social differentiation and leadership based on prestige, although not necessarily with economic control of resources. This materializes in the quality of raw materials, which indicate intra- and inter-site differences in status that would lead to the consolidation of stable hierarchical power structures (Campbell 2011).

Studying indirect evidence: Textiles, bone tools, and usewear

Perishable technologies include objects made from the soft tissues of animals and plants. These raw materials constitute an important component of Prehispanic, historic, and contemporary groups, but sometimes, they seem absent (Stone 2011). Theoretically, this "absence" is explained by means of a relationship to invisible or minimized groups, a construction made by men, a greater emphasis on other records, or an overvaluation of the final cultural record (Hurcombe 2014; Stone 2011).

This scenario is unfortunate because interpretations and reconstructions of the past are diminished and provide a fragmented reflection of the societies they attempt to portray. In the same way, it is necessary to think about who worked with soft raw materials, how they worked with them, and, methodologically, how we access these records (López Campeny 2016; Stone 2011).

In archeology, if the final product is not recovered, we can find indirect evidence. One line of evidence is the textile structures in other materials, such as animal or vegetal cordage on pottery (Adovasio *et al.*, 2001), and another comprises the tools used (Choyke and O´Connor 2013; Jover Maestre and López Padilla 2013; Watson and Gleason 2016). In the second line, the use of bone tools may provide evidence about the manufacture or processing of plant, animal, or soft materials (Amato 2010; Buc 2005; Legrand and Sidéra 2007; Stone 2011). One of the main reasons why bone tools are used is their physical properties. They are flexible and strong and produce an ideal surface on soft raw materials (Stone 2011). In fact, tools could show usewear traces corresponding to wool work and consequently, the activity in which they were used (López Campeny 2016; Santander 2010; Watson and Gleason 2016).

In this way, the shape and size of the particles produce differences on the topography and indicate the activity and material on which the tool was used (Semenov 1981). In this regard, LeMoine (1991) points out that a groove indicates the average size of the abrasive particle and then identifies a range of materials that may cause wear marks. Buc (2005) points out that angular particles cause fractured edges, while spherical ones generate smooth-bottomed grooves with accumulations of material at the edges. In a more detailed view, Stone (2011) says that different soft materials create distinct usewear states and that perishable soft materials fall into two broad categories that leave differentiated traces: a) animal fibers leave aligned, grouped, and ordered marks, and b) vegetal fibers leave aligned, grouped or ungrouped, and less-ordered marks.

Sample and methodology

In this study, a sample of archaeological bone tools (n=108) from domestic sites on Mocha Island was examined. The bone tools were recovered during investigation projects from 1992 to 2006 (sites P31-1, P21-1, P25-1, P5-1, P22-1, and P12-1) and now are deposited in the Natural History Museum of Concepción (Biobío). Others come from studies conducted from 2009 to 2015 (sites P23-1, P5-1a, P12-1a, and P25-1a). The assemblage is mainly composed of pieces made from land mammal bones; only four were made from bird bones. Some are complete, and others are fragments with marks from usewear or manufacture.

Latin American methodological approaches have focused on determining typologies (Scheinsohn 1997), and few researchers have considered other techniques, such as usewear analysis, experimental programs, and current information (Buc 2005; Inostroza 2019b; Santander 2010). This point is important because typology does not define bone tool use; similar tools can be utilized with different materials or status, *e.g.*, an awl could be used with skin or vegetal material (Buc 2005; Santander 2010; Scheinsohn 1997). In this sense, this study involved anatomical and taxonomical determination in addition to taphonomic information. We use methods such as experimentation, morphological and usewear analysis, and comparison with ethnographic sources (Buc 2011; Stone 2011).

First, the sample was classified according to the morphological shape of the active end and cross section. The categories are: a) sharp: defined by marked convergence of the edges; b) blunt: a dull apex that is kind of sharp but with more rounded edges; and c) round: defined by a sharp blunt end with circular curvature and no angled ends. There are also other shapes, such as beveled and rectangular, and other tool fragments or fragments with use traces.

Second, to describe the microscopic patterns, we followed most of the terminology defined by LeMoine (1991). The focus was to identify diagnostic features as striations, polish, and rounding marks. The examination of tools required replicas because they cannot be removed from the museum; also this allowed us to handle them given the small size of the SEM observation chamber (Vergés 2002). The procedure consisted of cleaning the instruments with water in an ultrasound tank in three-minute cycles, varying them according to the amount of sediment on the piece and observing to ensure that no cracking or modification occurred on the surface. Subsequently, each piece was placed at room temperature and replicas of the active ends or areas with use traces were made from dental silicone and epoxy resin.

Third, the microscopic examination used a Zeiss stereomicroscope, model Stemi 2000-C, with magnifications between 6.5 and 50x. This provided general information, made traces of manufacture visible, and suggested diagnostic features while allowing easy manipulation (LeMoine 1991). For higher magnifications and during most of the study, an incident-light metallurgical microscope was used at magnifications of 50 and 100x. This equipment provided good definition of the bone surfaces (Griffitts 1993). Finally, representative artifacts were explored with an environmental scanning electron microscope: Zeiss EMEB ME10.

The archaeological patterns were compared with the results of our own experimental program and other researchers' work (Buc 2011; Santander 2010; Stone 2011). The experimental program was designed to consider the manufacture of bone tools with diverse morphologies for use with perishable materials, the activities implied, and the amount of time in use (Buc 2005; Inostroza 2019b). The focus was on working textiles in contrast with other materials, such as skin, plant fibers, and clay. Finally, the archaeological bone tool morphologies were associated with patterns of usewear.

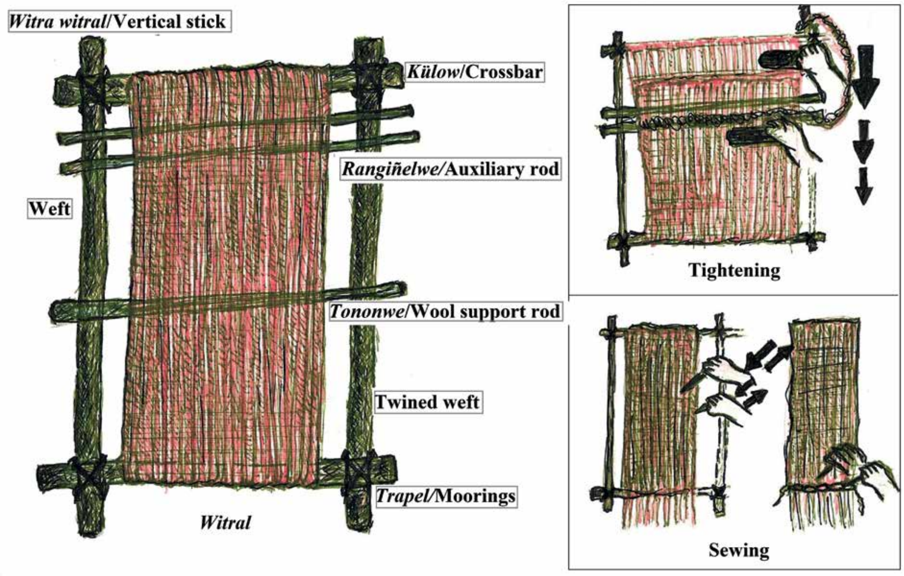

Figure 2. Mapuche loom and the experimental activities.

Results

Experimental results

As a first step, bone artifacts were made. For this, we used long sheep *(Ovis aries)* bones because it was impossible to access guanaco bones in the allotted time. The study involved different manufacturing techniques, some of which used ovoidal basalt. This is a lithological resource used for the manufacture by wear of lithic artifacts. Finally, materials and actions were defined based on ethnohistorical, ethnographic, and archaeological information.

The work involving wool used alpaca wool for two activities: a) sewing and b) weaving on a loom. The former consisted of making entry and retraction movements with respect to the tissue using longitudinal/diagonal orientations at angles between 45° and 90°. This action was done to close the textile and repeated in an area. For the latter, we used an artisan loom (10 × 15 cm) and the warp-face technique or a Mapuche loom. In this case, the artifacts were used to tighten the weave in a longitudinal orientation, and the action involved moving from top to bottom while squeezing the tissue. Both actions were performed for at least 24-36 hours.

In the case of sewing, no macroscopic changes to the tools were observed, although a slight polish began to be noticed after 45-60 minutes of work. Microscopically, this activity left scarce modifications; transverse striations that obliterated the manufacturing traces and an extensive polish were observed. This indicator becomes noticeable over time, especially at the distal end. Furthermore, we could see a little polish in the mesial proximal zone near the eyelet.

On the tool used for tightening, macroscopically, a very slight polish was observed after 60 minutes of use, and, during the process, it was necessary to remove small fiber remains. The main problem was that the instrument got stuck, which may be due to the low polish of the artifact or the manufacturing technique. Microscopically, this resulted in the obliteration of manufacturing traces and we saw very fine, superficial, transverse, non-invasive grooves after 24-36 hours of use.

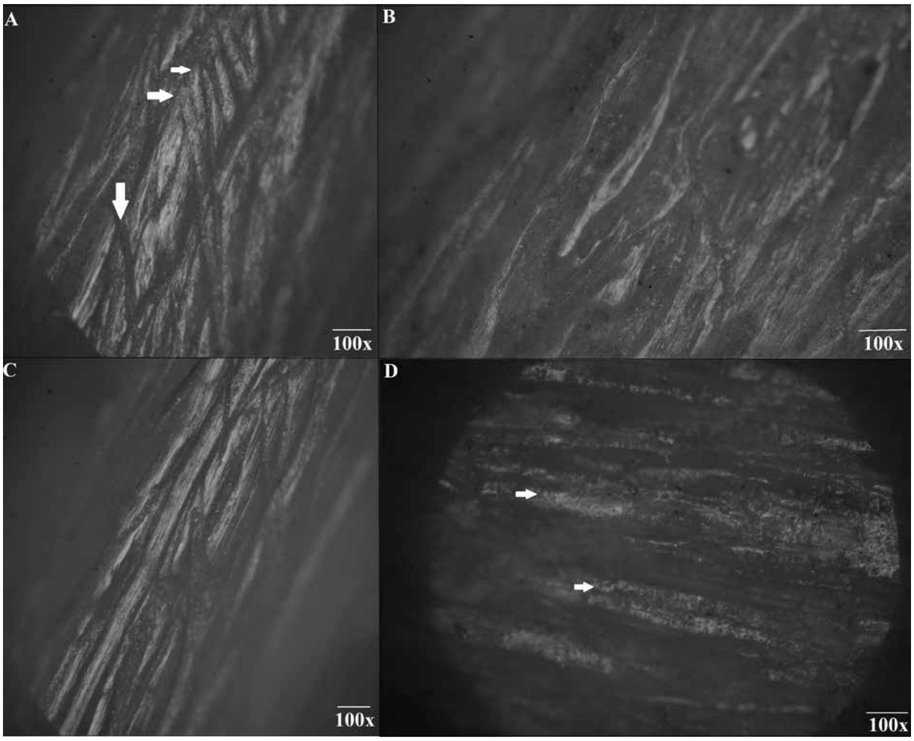

Figure 3. Sewing needle. a) After 24 hours, obliterated and polished manufacturing traces. b) Smooth and extended polish after 45-60 minutes. Tightening tool. c) Lower middle area with intensive/extended polish after 24 hours. c) Manufacturing footprints with polish on the cusps after 60 minutes.

	Raw material	
Indicator	**Skin**	**Plant**
Orientation	Transverse/Crisscrossed	Parallel/Transverse
Width	Thin	Very thin
Length	Long	Short
Shape	Straight	Straight
Internal orientation	Grouped/Spaced	Grouped
Depth	Deep/Superficial	Superficial

Table 1. Indicators: Piercing skin and plant material.

The experimental program included other perishable raw materials for contrast with the wool. These materials were fresh and dry sheepskin, a bromeliad plant called *ñocha*, and clay from the area. The actions were smoothing and piercing, and monitoring was done every 15, 30, 45, and 60 minutes.

The experiments led to different wear patterns and corresponded with the results of other studies. After the piercing action, there were consistent striations concentrated in the mesiodistal zone. The work on skin created a homogeneous and rough surface with deep striations interlaced or grouped among each other. In contrast, the work with plants produced a more homogeneous surface with superficial striations. When

Indicator	Raw material			
	Dry skin	Fresh skin	Plant	Clay
Orientation	**Transverse/Parallel Crisscrossed**	**Crisscrossed Scattered**	**Parallel Transverse**	**Transverse Crisscrossed**
Width	Thin	Thin	Very thin	Thin/Variable width
Length	Long	Long/Short	Long/Short	Long/Short
Shape	Straight	Straight	Straight	Straight
Internal orientation	Grouped	Grouped/Spaced	Grouped	Grouped
Depth	Deep	Superficial	Superficial	Variable

Table 2. Indicators: Smoothing skin, plant material, and clay.

the skin and plants were dry, there was greater grouping, and the stretch marks were more notable.

The smoothing action on the plant material showed a pattern of superficial, parallel, and grouped grooves. In contrast, the skin had deeper, interlocked grooves, and the pottery showed grouping with deeper grooves as well as variability in thickness and extension. These differences are related to the intrinsic properties of the materials; the cellular arrangement is stricter in plants than in animals, where the hair is in opposition or fat remains (Stone 2011; Buc 2011). The pottery even presented intra-stria differences due to the irregularity of the clay or temper used (Buc 2011; Inostroza 2019b).

Archaeological results

The overall assemblage is composed of 108 artifacts: Four from the Early Ceramic period [*c*. 400-1000 AD] and 104 from the Late Ceramic period [*c*. 1000-1550 AD].

First of all, the taphonomic results showed that the bone tools are in a good state of conservation. This implies that the bone tools are in stages zero and one of the Behrensmeyer scale. In contrast, the sample has a low incidence of natural or cultural agents. The main agents were manganese stains and roots. Both have been linked to the humid environment typical of the area. In some cases, the artifacts were labeled, which made it necessary to observe other sections of the bone. However, the macroscopic and microscopic examinations were positive.

The artifacts from the Early Ceramic period were made from the long bones of land mammals. The results showed that: a) Two sharp-pointed tools were used for piercing, one for skin and the other for plant fibers. Another was used to sew wool, and b) blunt-pointed tools were used to sew wool.

For the Late Ceramic period, the morphology of the active extremity was classified as sharp (32%), blunt (41%), or rounded (13%), followed by isolated cases of bevelled (2%) and rectangular (12%). Others were fragmented. Most tools were made from the long bones of land mammals (36%) and large land mammals (40%); in particular, 18.3% of the bones were from camelids and 3.8% from birds and a small deer called pudú (*Pudu puda*). In these groups, some instruments with sharply pointed ends were made from camelid metapodia and bird bones. Other tools with blunt active extremities were made from the long bones of land mammals, two pudú antlers, four unidentified bones, and one land mammal rib. Exceptionally in this group, we identified two camelid bones: a proximal diaphysis from a right tibia and a distal radioulna without fusion.

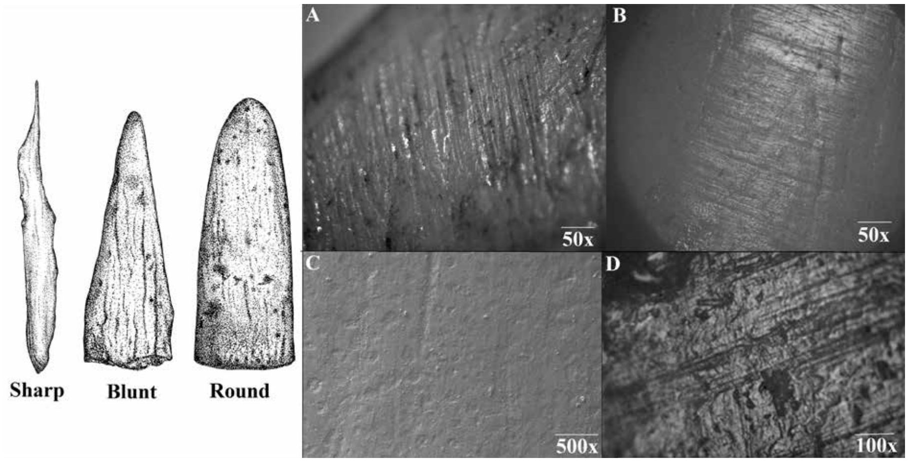

Figure 4. Representative active extremities were sharp, blunt, and round. Main microscopic results: a) Dry skin piercing: Transverse and diagonal striations that are deep, grouped, and parallel; some are crisscrossed (50x). b) Plant fiber piercing: fine, disperse, crisscrossed striations (50x). c) Wet skin piercing: Fine and more superficial striations (SEM 500x). d) Clay smoothing: Variable-thickness striations in multiple directions (100x).

The most frequent cross-section shapes are circular (33%), square (28%), and semicircular (25%). In smaller numbers, there are flat (8%), oval (3%), and other shapes. If we consider the cross-section and the active extremity, we can see that the sharp morphology has a greater diversity of cross sections. The recurrence of circular and semicircular sections may be related to the bone types (long bones) and their uses.

The usewear traces indicate that they are mainly linked to activities involving soft raw materials. In these groups, 65.7% are from animals, of those, 45.3% were used in working skins and 14.8% were used in textile work. Furthermore, 3.8% were used with plant fibers and 2.8% with clay. In other cases, we could only conclude that archaeological tools were used on an unknown soft material (4.62%) or now are undetermined.

Usewear traces show that these tools are related to activities such as piercing (38%). Most were used on dry skin and some on fresh skin (four sharp, four blunt, and one fragment), or their state was undetermined. One tool has polish and striations that are related to longitudinal or diagonal action on skin. We argue that it could be from “sewing” skin (one sharp tool). Another sharp tool and other fragmented tools have usewear patterns similar to those described by Stone (2011) for skin scrapers/smoothers (3.8%).

Only two tools were made from pudú antlers. They have a moderate polish and microscopic traces on their extremity that could be from puncturing skin or impact (Buc 2011). However, they are not entirely diagnostic, and whether these traces are anthropic is under discussion (Inostroza 2019b; Buc, Acosta and Loponte 2019).

Piercing (2.8%) and smoothing (n=1) activities are performed on plant fibers only with blunt artifacts. Additionally, rectangular tools and some fragmented tools were used to smooth pottery (n=3). In this case, the natural morphology of the rib may have offered a flat and rigid surface whose grooves are concentrated on the mesial and distal sectors. Finally, in some cases, it was impossible to identify the function because the striations are isolated.

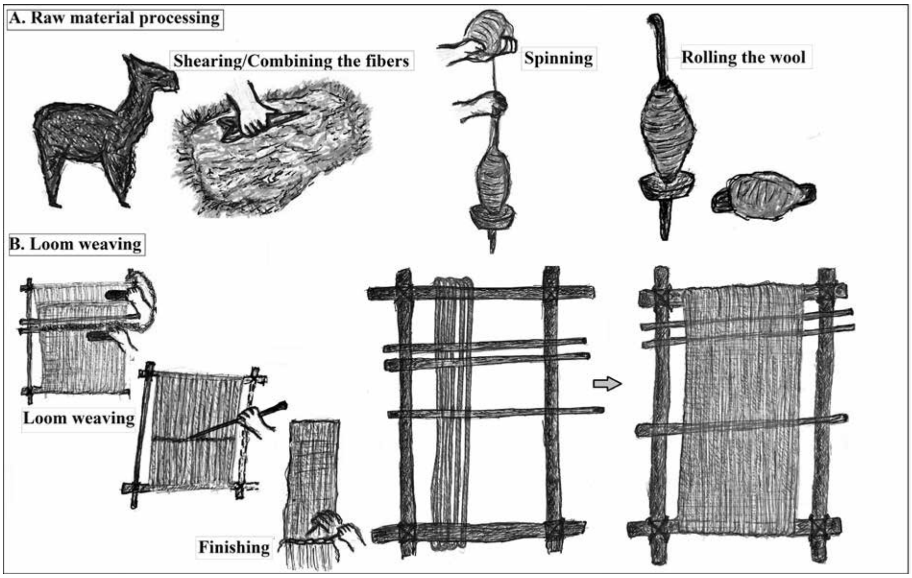

Figure 5. Textile chain and main activities. a) Raw material processing, called *ruwelkan.* b) Weaving with the type of loom called a *witral.*

Textile technology: From ruwelkan *to* witral

The tools related to textile processes comprised 14.8% (n=16) of the assemblage. In order to reconstruct the "textile chain," we considered the "textile production" model by Arnold and Espejo (2013), which relates traditional tools used in communities from the Bolivian Altiplane. Moreover, ethnographic sources were fundamental to understanding the textile practices of Mapuche groups and their names (Joseph 1929; Manosalva 2015).

There are two marked stages: a) Raw material processing, which is called *ruwelkan,* and b) weaving with a loom called a *witral.* The former consists of extracting fiber from the animal and processing it. The steps are combing, washing, drying, untangling, and cutting the fiber. The main activity is spinning, which is called *füwen*; it requires a skein and an implement called a *ñimkun*. The *ñimkun* consists of a spindle made of a stick called a *coliu* and a spindle weight called a *chinqued*, which is commonly known as a *tortera*. Subsequently, the wool is rolled into reels, a process known as *treko,* and can be dyed.

The second stage involves the warp-weighted loom. Traditionally, Mapuche groups have used a vertical loom known as a *witral,* which uses different tools for weaving. These include a tool for tightening called an *aspahue,* which is passed from one side to the other and squeezed downward to tighten the fibers. This tool has a variety of names based on its particular function and size. These include *ngürewe* or tightener, *zipülwe*, which refers to the type commonly used for details in the weave, and *zipülwe ngülluzwe*, which refers to a small *zipülwe*. There are also fiber sorters, which are used to separate fibers or colors, and needles are used for finishing.

Based on this information, the initial steps are represented only in 3.7% of the artifacts. We interpret these pieces as a large spool for wool (1.9%) and a small reel (1.9%). In this study, "*torteras*" are not analyzed because they are made from cetacean bones and require a particular type of analysis. However, this use is uncertain, and maybe they were not used

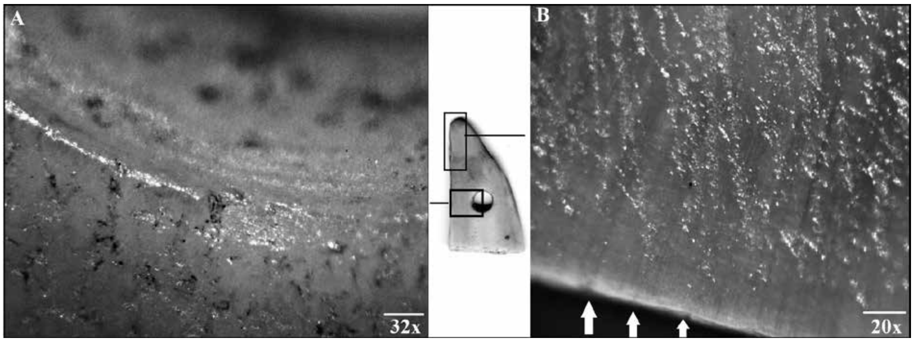

Figure 6. a) Central drilling with polish obliterating manufacturing traces. b) Polished edge with clearer footprints; the arrows indicate edge wear.

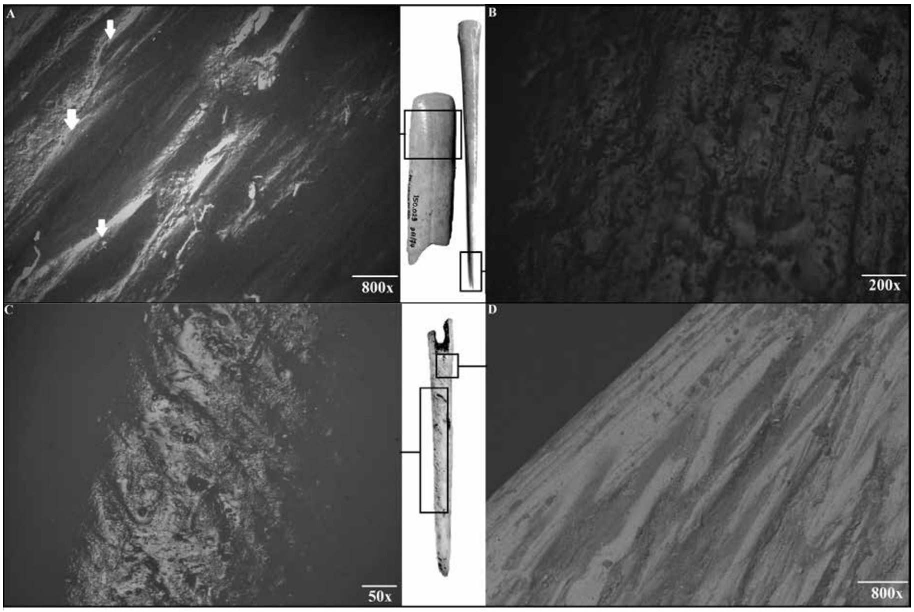

Figure 7. a) Tightener with extensive polish and polished cusps (SEM 800x). b) Fiber selector with extensive polish (metallographic 200x). c) Sewing: Manufacturing traces obliterated by polishing and a cleared area (metallographic 50x). d) Amplification, intensive, and extensive polish (SEM 800x).

for spinning. Boris Santander, professor of archaeology at Alberto Hurtado University, has proposed an alternative hypothesis: they could be spools for wool (pers. comm., 2018).

For the second phase, we propose some instruments that may have been used for tightening the weave. These tools are more rounded and rectangular in shape with semicircular ends and flat sides. They could be *zipüllwe* or *ngürewe*, however, it is impossible to assign them with greater precision.

Additionally, we interpreted some tools as fiber selectors. These mainly have sharp extremities. Even their morphologies and manufacture are consistent with the *wich´uña* of contexts in the Andean area; this term refers to a category that includes a diversity of morphologies with similar

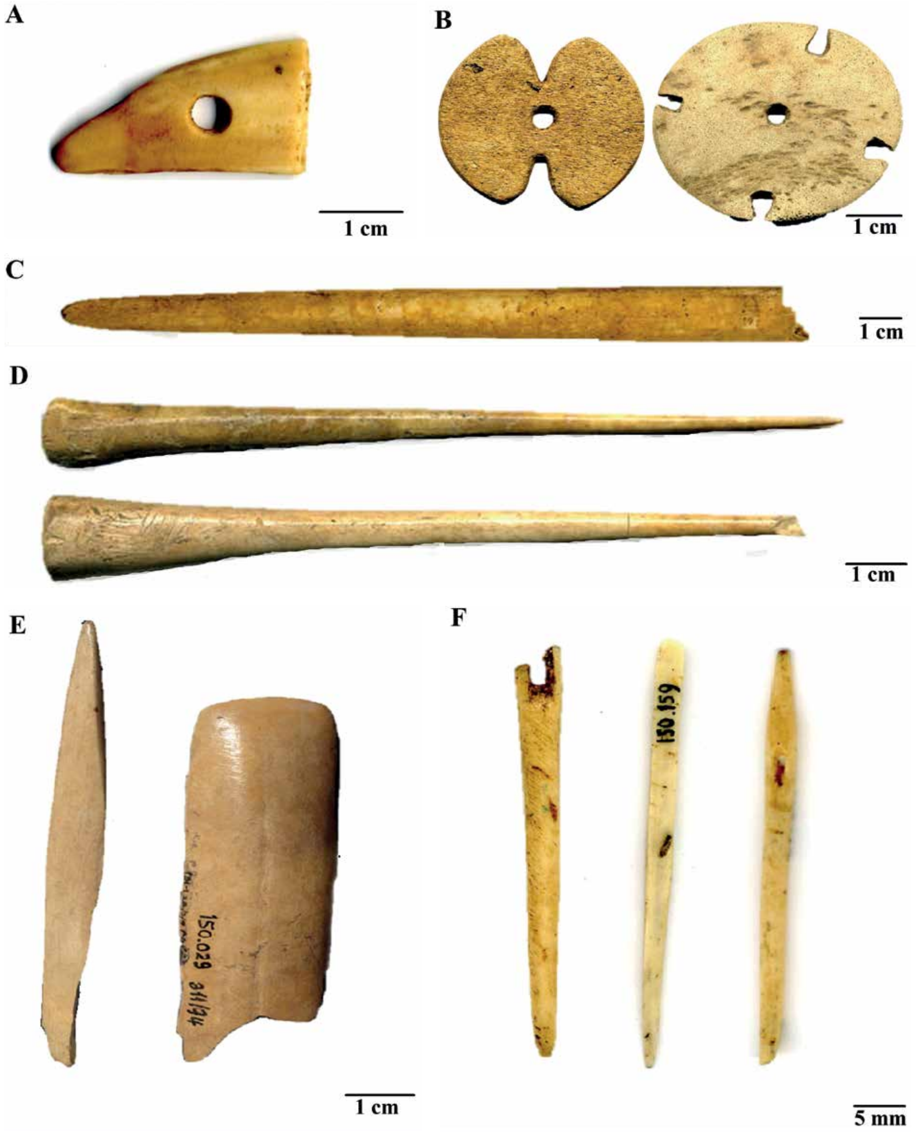

Figure 8. a) Possible small spool for wool. b) "*Torteras*": Spindle weight or wool spool? c) Large spool for wool. Tools for d) selecting fibers, e) tightening, and f) sewing.

uses (Arnold and Espejo 2013). Specifically, they are similar to artifacts made from metapodia and have longitudinal shafts with flat or semicircular cross-sections. Finally, there are sewing artifacts that are commonly associated with edge completion to prevent tissue from opening. Another potential use is to reinforce or maintain textiles and incorporate decorative accessories.

The results show varied uses of the bone tools used in working textiles between *c*. 400 and 1550 AD. This evidence is scarce, nevertheless, it was possible to identify instruments from the Early Ceramic period and a larger number from the Late Ceramic period. Most of them have been used during the second phase of textile production and suggest that weaving looms were used.

Discussion and conclusions

The present study has explored the functional correspondence of bone tools and textile activities during the Ceramic period on Mocha Island. The bone tools of Mocha Island are a privileged sample in Araucanía because they are the most ubiquitous in the area, have been preserved well, and were recovered from domestic sites. The results indicate textile working, which is significant because it provides further support for the idea of Prehispanic labor on Mocha Island and in southern Chile. Furthermore, it suggests a local manufacturing tradition from the Ceramic Period onwards [*c.* 400-1550 AD].

However, these results should be viewed with caution because they are not conclusive. One point to be gained from this idea is that wool was less abrasive, which makes it difficult to assign a specific use. A second idea is that it is necessary to deepen the reference collection with other tools and activities involved in weaving. In this case, one can identify more tools from the weaving stage. Some factors that explain this are a) the substantial diversity of tools involved, b) the diagnostic features obtained from the experimental exercise, and c) the use of a weaving loom. But this study excluded the analysis of tools from the first stage, including *torteras.* This is justified because *torteras* are made of cetacean bone and it was not possible to access these materials during this study, in addition to the lack of experience in traceology with marine mammal bones. We consider it necessary to deepen this analysis with clear functional hypotheses to determine its suitability, mainly because *torteras* are light and would not be optimal for spinning. Maybe they could be reels or have another function.

Additionally, this study showed that tools are related to other materials and activities, such as working with skin, plant fibers, and clay. This is interesting because it provides information about other uses for bone tools with similar morphologies, resources, raw materials, and the understanding of other processes.

Archeologically there are no records of skin or plant fibers. The use of bone tools on skin has only been recorded at the Cueva de Los Catalanes, an Early Ceramic site located in a valley (Inostroza 2019a). The use of skin has been related to perforating holes on skin contours, scraping, and manufacturing ropes, bags, and clothing (Bibar [1558] 1966; Joseph 1931). The worked plant fibers showed marks of piercing and possible smoothing, but we do not have the products, only archaeobotanical studies that propose how macroscopic remains could have been used for activities such as basketry. In this regard, ethnohistorical and ethnographic sources relate the construction of housing (such as the traditional Mapuche dwelling or hut called a *rukas*), ropes, and the manufacture of baskets and mats (Bibar [1558] 1966; Guevara 1929; Joseph 1931; González de Nájera [1614] 1968).

Pottery has an extensive archaeological record, but nothing is known about the bone tools associated with its manufacture. This study identified smoothers. Ethnographic sources only describe wood, metal, and shell artifacts being used to combine pieces of clay or for post-drying smoothing (Carvalho and García Rosselló 2012; Coña [1930] 2002; Joseph 1931).

To discuss the implications of textiles for the area requires considering questions such as what raw material was used? How was it obtained? What does this practice imply in the Ceramic period on Mocha Island and in Araucanía?

The first and second questions are impossible to answer given the current state of research. According to archaeological sources, we only have the evidence mentioned previously, and the artifacts are made from llama and alpaca wool. However, the faunal remains have only been identified as belonging to the Camelid family, including guanaco. Additionally, one recent study of mitochondrial DNA from camelid bones identified as guanaco (Westbury *et al*., 2017).

To complicate the matter, ethnohistorical sources provide interesting and significant information that relates an animal characterized by its "long wool," prior to the use of sheep. Furthermore, they report people using the animal for loading and plowing; these animals and textiles were of very social high value (González de Nájera [1614] 1968; IJzerman 1926). The animal was probably a camelid; notes mentioned an indeterminate type called "*hueque / rehueque / chilihueque,*" and *luan* or guanaco. It has been suggested that camelids called *chilihueque* are guanacos that had been "tamed" or "aguachado" (Becker 1997), this term suggests semi-domestication of camelids. Since camelids are not native to the island, people needed to transport these guanacos from the mainland and maintain a local breeding while keeping them semi-captive (Becker 1997; Campbell 2011). Whatever the animal, most archaeologists consider the absence of domestic camelids, such as llama and alpaca, in the area.

If considering guanaco wool, this can be used for weaving, but is not more suitable than that of other South American camelids. Maybe wool could also have been obtained through exchange. If we consider the possibility of long-distance trade, the territorial dynamics implies social networks and the flow of raw materials, objects, people, ideas, and information. In this context, the wool could have been obtained through exchange and then woven. Wool and textiles could reflect these interactions and incorporate or transfer information in a context of increasing complexity.

To determine what this practice implies for Mocha Island, it is necessary to situate the evidence and start from the idea that textiles and textile working indicate social organization. First, we currently have few artifacts used for textile working and no other evidence. Second, the evidence is from sites P5-1 A, P12-1 A, P25-1, and P31-1, nearly all of which are located in the northern part of Mocha Island; only P25-1 is in the southwest (facing the sea). Third, chronologically, all the tools are situated in the Late Ceramic period or "Vergel complex" except the few artifacts recovered from P25-1, which have been assigned to the Early Ceramic period or the Pitrén complex.

At the present, archaeological research suggests economic autonomy with areas of higher status during the Late Ceramic period where processes of social differentiation are compatible with strategies based on prestige and authority. Nevertheless, substantial differences based on craft production, wealth accumulation, and exchange are not recognized (Campbell 2014). Exceptionally, site P31-1 has the highest status, and its *kuels* represent areas of social and political importance, but not a settlement hierarchy.

Along the same line, in this study, the bone tools used in textile working, neither provide evidence for nor correlate well with high wealth or status. Therefore, textile working seems to have been pursued on a small scale. However, its public use and importance for political economics has also manifested, since textiles may have been part of some type of wealth strategy that provided greater status or leadership (Campbell 2011).

Ethnohistorical accounts describe textiles as being produced by females in the household using spinning and loom weaving. The details mention clothes, women wearing long skirts, and men wearing ponchos (Hawkins [1594] 1847). The importance of textile production in leadership activities is also clear and we think it had an important role in the construction of social networks, perhaps related to social ostentation and competition among communities or leaders.

It should be kept in mind that these groups were a direct chronological antecedent of Mapuche groups, where textile practices were exclusively for women and performed at home and therefore, related to domestic economics. This activity has been considered a process of socialization and learning as well as a sign of passage to adult life (Manosalva 2015). Therefore, weaving could have been done by women, young women, girls, and possibly other people. Additionally, information on Reche-Mapuche groups indicates that textiles were relevant at the political level as indicators of power and authority and in the commercial sphere until pre-reduction times (the nineteenth and twentieth centuries).

Finally, the theoretical-methodological approach is ideal for identifying the modes of use and the materials worked on. An important part of this study was the experimentation and analysis of usewear traces. Although this approach was positive, some limitations emerged. These included the difficulty of working with wool, identifying traces and diagnostic elements due to the low abrasiveness of the material, and accessing high-resolution microscopes.

We emphasize that it is crucial to evaluate or reevaluate the different archaeological records for a better interpretation of the societies under study. On this matter, it is essential to pay attention to the use of other tool analyses and methods that allow us to progress toward more certain determinations. It is also necessary to expand the reference collections for the Araucanía area. This premise is important for textile research and other records whose preservation and tools are scarce or nonexistent and that are extremely important for reconstructing the groups we studied.

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A microscopic view of Maya needle and perforator production at Ucanal, Guatemala

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Abstract

Evidence for Late Classic Maya worked bone production was discovered in a deposit of bone debitage intermingled with carbon, lithics, and shell in the platform fill of an elite residential group at Ucanal, Guatemala. Preliminary analysis shows that bone tools and ornaments were made from both white-tailed deer and human remains, along with a suite of mammalian and avian species. Production debitage included preforms and discards of perforators such as pins, awls, and needles, but it was difficult to visually differentiate used and unused objects in the final stages of production. Microscopic analyses, digital magnification, and scanning electron microscopy (SEM) revealed unsmoothed production marks on unfinished tools and ornaments. Usewear visible on bone perforators and dog canine beads suggests that finished tools also were reworked into new products and that biconical drilling was the preferred technique to make bead perforations, while needle eyes were formed by bilaterally incising the proximal shaft. Both technologies were common across Mesoamerica, but patterns for needle production based on preferred size and perforation style may have varied over space and time. This paper presents a pilot study of the *chaîne opératoire* of Maya needle production as part of a larger analysis of bone tool production at Ucanal.

Resumen

Evidencia de producción de artefactos de hueso datando para el Clásico Tardío ha sido descubierto en un depósito que contiene desecho de hueso mezclado con fragmentos de carbón, lítica y concha; tal depósito se encuentra en el relleno de una plataforma residencial en un grupo de élite de Ucanal, Guatemala. El análisis preliminar muestra que las herramientas y los ornamentos de hueso se produjeron empleando huesos humanos

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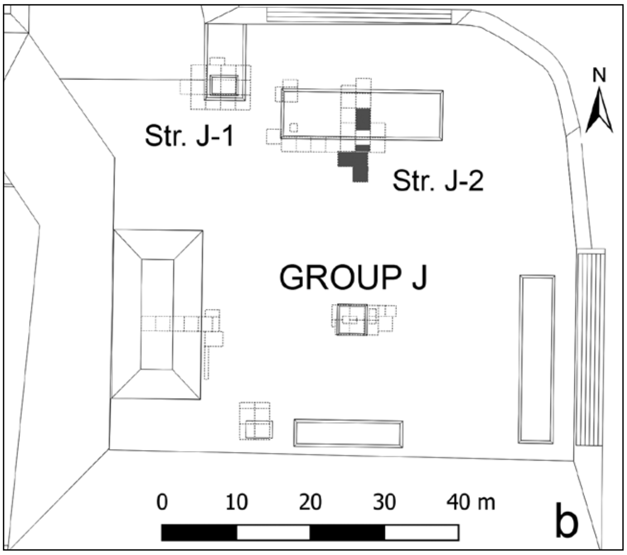
Figure 1. Map of Ucanal: (a) Location of Ucanal in the Maya lowlands; (b) map of Group J showing location of deep excavation units (in grey) that exposed the bone production deposit; (c) location of Group J within the context of the central zone of the site of Ucanal.

y de venado cola blanca, así como especies de mamíferos y aviarias. Los desechos de producción incluyeron preformas y perforadores descartados como alfileres, agujas, y punzones, aunque fue difícil diferenciar visualmente objetos no usados en las etapas finales de producción de los elementos usados. Análisis microscópicos, magnificación digital y microscopia electrónica de barrido (SEM) revelaron marcas de producción no lisas en las superficies de herramientas y ornamentos no terminados. Marcas de uso visibles en las superficies de perforadores de hueso y en los caninos perforados de perros sugiere que los objetos terminados también eran transformados en productos nuevos y que la perforación bilateral fue la técnica preferida para producir las perforaciones en las cuentas. Por otra parte, las perforaciones de agujas se formaron mediante incisiones bilaterales en el extremo proximal. Las dos técnicas fueron comunes en Mesoamérica, aunque los patrones de producción de agujas se basaban en el tamaño deseado por lo que el estilo de perforación pudo haber variado en temporal y espacialmente. Este trabajo presenta un estudio piloto de la *chaîne opératoire* de producción de agujas mayas como parte de un análisis más grande de producción de herramientas y ornamentos de hueso en Ucanal.

Keywords: zooarchaeology, Maya, SEM, needles, bead

Introduction

Ucanal was a Maya city located on the Mopan River in the semi-tropical lowland forests of northern Guatemala (Figure 1). Its initial occupation dates to the Preclassic period (*c.* 600 BC-300 AD), and its later history is tracked through epigraphic inscriptions that testify to military, ceremonial, and political interactions across the Maya region and perhaps as far away as central Mexico. The site of Ucanal is intriguing in part because the city flourished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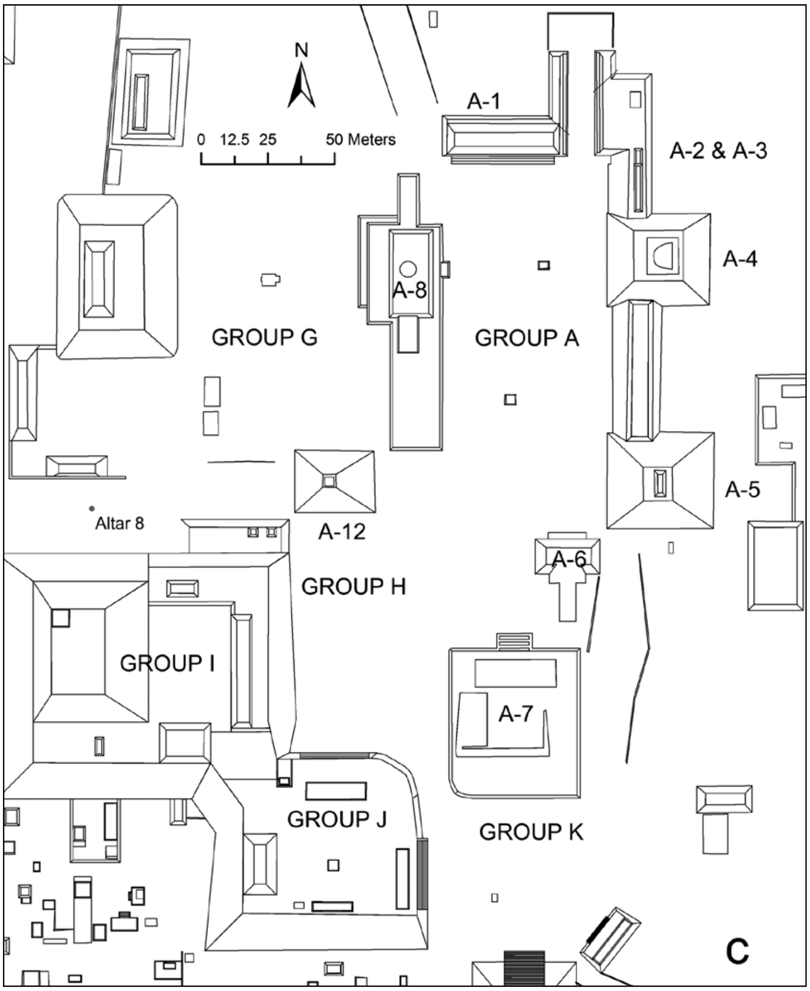
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during the Terminal Classic period (830-1000 AD) as other Maya centers were depopulated and abandoned at the end of the Classic period (Halperin and Garrido 2019, 2020).

Excavations during the 2018-2019 field seasons revealed another intriguing discovery at Ucanal: a deposit with thousands of bone fragments from the production of bone tools, including debitage from all stages of production and partially finished tools (Halperin *et al.* 2019; Perea and Dubois-Francoeur 2020). Large faunal deposits are uncommon in the semitropical Maya lowlands, and discoveries of bone tool production loci are rare (Emery 2010, 2004). The bone fragments predominantly consist of white-tailed deer (*Odocoileus virginianus)* and human bones formed into a variety of ornaments and tools, including perforators. However, it is difficult to differentiate finished from unfinished products and expedient tools discarded as general production debris. Even more complex is the identification of perforator types using incomplete and unfinished specimens, such as differentiating needles used in cotton textile production from those used to make nets (Ciaramella 1999, Figures 8 and 9), awls used in weaving or hideworking, or pins that served as ornaments or bloodletting implements. Therefore, this paper seeks to identify microscopic differences between unfinished and finished/used bone tools as well as to identify tool types based on partial metrics from fragmentary specimens.

We studied a sample of 232 bone perforator fragments and identified 65 specimens with eyes that we could identify as needles and classify using metric and non-metric parameters. A combination of microscopic analyses of 119 perforator fragments and SEM imaging of 14 perforator, bead, and stingray spine fragments was employed to better differentiate production from usewear. Our results show that the Ucanal bone production deposit contained more unfinished products or production failures than finished items. In addition, we find that the gradient of needle widths reflects different functions of this type of tool and reveals one or more needle-making patterns that may have endured for generations.

Ucanal and Maya worked bone assemblages

Ucanal was part of a network of kingdoms in the Maya lowlands connected by river systems, limestone *sacbes* or roads, and interconnected sociopolitical systems and trade networks. While the Maya civilization was characterized by regional diversity in burial practices, diet, and myriad aspects of material culture, important aspects of the subsistence economy were widely shared. Animal proteins came from wild rather than domesticated species, which were limited to dogs (*Canis lupus familiaris)*, and some turkey, bee, and duck species at different points in time. The most important large game species consisted of artiodactyls, including white-tailed and brocket deer (*Mazama* ssp.) and collared and white-lipped peccaries (Tayassuidae), which along with smaller forest animals, provided meat, hides, and raw osseous materials for toolmaking. These species, along with jaguars, rabbits, snakes, and tropical birds such as eagles and quetzals, also provided powerful religious metaphors connecting people to the natural and supernatural worlds (Looper 2019).

However, most Maya sites have only small-to-medium-sized faunal assemblages that consist of fewer than 1,000 specimens (Emery 2004b) and provide limited information on how species were managed, acquired, used, and exchanged, despite recent innovative research combining isotopic, genetic, and morphometric studies (McKillop and Aoyama 2018; Meissner and Rice 2015; Sharpe *et al.* 2018; Sugiyama *et al.* 2018; Thornton 2011;

Thornton *et al.* 2012, 2016; Yaeger and Freiwald 2009). Worked bone poses even more of a puzzle because it forms a small percentage-usually less than 5%-of faunal assemblages, and individual specimens are generally fragmented and incomplete (Boileau and Stanchly 2020; Emery 2004a; Freiwald 2010; Götz and Emery 2013; Newman 2015). Bone products are most often found where they were deposited in burials and caches or discarded in middens rather than where they were produced.

A Terminal Classic period bone-tool workshop at the site of Dos Pilas is an important exception (Emery 2010, 2009, 2008) that offers a glimpse into where bone tools were made, how they were produced, and who made them. Bone tool and/or ornament production also is reported at El Zotz, Pook's Hill, Tikal, Uaxactun, and Aguateca, although production debris is usually from different contexts or time periods (Emery 2010; Emery and Aoyama 2007; Newman 2015). Discoveries of bone workshops are uncommon enough that Emery (2010, 206) suggested there were few specialized producers of bone tools and ornaments, a pattern that also is possible for the production of marine shell (Boileau and Stanchly 2020; Freiwald 2018; Powis *et al.* 2009).

The Ucanal worked bone deposit was discovered in the Group J architectural group, an elite residence that was located adjacent to the site core (Halperin and Garrido 2020; Halperin *et al.* 2019). The deposit consisted of worked and unworked bone fragments intermingled with large quantities of chert production debitage and expedient tools, some obsidian blade fragments, marine and freshwater shells, ceramic sherds typical of an elite domestic context, and large quantities of carbon that were directly on and within the fill of a Late Classic period version of the building platform. This Late Classic residential architecture was later covered and sealed by a massive Terminal Classic remodelling of the group, helping to preserve the bone tool production debris. The bulk of the excavated deposit dates to the Tepeu 2 phase of the Late Classic period (*c.* 700-830 AD), but some bone production debris was also found in the Terminal Classic fill. Only a small portion of the Late Classic building platform was exposed (20 m^2), and the continuation of the bone deposit along the edges of the excavation units suggests that the bone production debris extends into unexcavated areas across the platform. We turn our focus to understanding one of those activities, perforator production, and the production sequence or *chaîne opératoire* of needles.

The *chaîne opératoire* of needle production

The process begins with the selection of the animal. Maya bone-tool makers appear to have preferentially used bones from specific species, which suggests both specialized animal acquisition and a symbolic relationship between the tool makers and tools (Gates St-Pierre *et al.* 2016; Zhang *et al.* 2016). The two most common species chosen as raw material for bone production at Ucanal's Group J were white-tailed deer, and to a lesser extent, humans, although analysis of the deposit is ongoing. White-tailed deer were an important source of both food and raw material for tools in the Americas (*e.g.*, Emery 2004a; Feinman *et al.* 2018; Wake 2001). Hunting scenes and archaeological deposits link the use of deer to elite contexts, although deer remains are recovered from non-elite contexts as well (Montero López 2009). Isotopic studies indicate that at most Maya sites sampled to date, wild terrestrial mammals came from multiple catchments, indicating that there were complex hunting networks or provisioning of markets for wild animals (Sharpe *et al.* 2018; Thornton 2011; Yaeger and Freiwald 2009).

Figure 2. Ucanal bone fragments discarded at different stages of production, scale in mm. From left, epiphyses removed from bone, limb shaft core, debitage from blank production (all UCA.1B.26.8.2422), and smoothed edges of a partially finished blank (UCA.1B.2.8.1336).

Worked human remains have been identified in burials, caches, middens, and in some rare cases, as part of bone tool and ornament production refuse (Emery 2010; Hammond *et al.* 2002; Iglesias Ponce de Leon 1988; Schnell 2017). Across Mesoamerica, particular bones of enemies or ancestors, such as femur, cranial, and finger bones, were curated and may have retained the essence or power of those individuals (Burdick 2016; Duncan and Hofling 2011; Hinojosa 2019; Campos-Martínez and Pérez Roldán 2016). At various Classic and Postclassic sites in Mexico, human bone was used to produce tools and instruments such as rasps and potentially perforators, although identifying different mammal species using finished tools is notoriously difficult (Feinman *et al.* 2018; Martín *et al.* 2018; Pereira 2005).

The next step included a butchery and/or defleshing stage. It is not clear where bones were stored-or for how long-before tool production began. Storage of bones in pits (Gates St-Pierre 2007) is not reported for the Maya, although the use of buried bones is unlikely as they would be prone to breakage and unpredictable fracture patterns (Campana 1989; Lyman 1994). Dry bone breaks more easily under dynamic pressure as the fracture begins in outer layers and progresses inward (Lyman 1994). Bones are best worked when fresh, and although boiling or soaking dry bone improves its workability, the process mainly softens the outer layers (Campana 1989). Cut marks on human bone rasps in Michoacan from removing flesh from bones (Pereira 2005), provisional or temporary tombs in the Maya area (Źrałka and Koszkul 2015, 405), and the possibility of houses of decomposition at Teotihuacan (Campos-Martínez and Pérez Roldán 2016) offer some evidence for human bone processing; however, cut marks are uncommon in Maya faunal assemblages (*e.g.*, Freiwald 2010; Ledogar 2018).

The next step in the *chaîne opératoire* is the production of the tool or ornament, which likely was conducted by only select households within a site or region. For example, bone butchery and processing was identified among most sampled elite residences at the Classic Maya site of Aguateca, but only one of the sampled residences showed multiple stages of tool production in addition to butchery and processing (Aoyama 2007; Emery and Aoyama 2007). Emery's (2010, 2009, 2008; see also Maeir *et al.* 2009; Newman 2015) model outlines the major stages of bone tool production: (1) debitage removal of epiphyses, (2) core production, (3) blank production, (4) blank finishing, and (5) production of the artifact (Figure 2). Implements used in Mesoamerican bone working can include chert, sandstone, obsidian, and string abrasion (Emery 2010; Maldonado and Pérez Roldán 2010). Aoyama's (2007, 15-16) usewear study on lithics from elite residences at the site of Aguateca found that 17.5% of the chert materials may have been used to work bone or shell, in contrast to obsidian tools, which showed very little to no evidence of bone or shell-working.

The type of object produced is often only identified near the end of the production sequence. Needles are defined as perforators with an eye (Inomata *et al.* 2014), while perforators without eyes are called "pins," and thicker perforators with "u" versus "v" shaped points are designated as "awls" (see also Halperin 2008). There is a large size range, however, of needles that surely served distinct purposes. In his study of Paleoindian needles (~15,000 to 12,000 BC), Lyman (2015) proposed a functional division between needles greater and less than 3 mm wide. Emery (2010, 260-261) used shape to differentiate perforators, with flat, rectangle, and square perforators being larger than oval or round ones, and different average widths at Dos Pilas and Mundo Perdido, Tikal for perforators with similar shapes. The final finishing steps of production specific to these tool types are not well-understood and are therefore further explored in our study.

Completed tools and ornaments were probably distributed, and therefore absent from production contexts with two exceptions: expedient tools used in the production process and finished tools that were repurposed or repaired. These objects can provide information on how they were used. Usewear polish can create a shiny surface on the bone, wear down the tool, and at a microscopic level, smooth the striations left as production marks. Usewear can result in striations that show how the tool was used, from the depth and direction of the activity, to the material being processed (Campana 1989; Stone 2011). The marks change with increased use, with the polish going from dull to bright and the number of striations increasing (Gates St-Pierre *et al.* 2016). The tool's surface may be reduced by flattening or chipping and subsequently resharpened. Some materials leave little wear, and different activities can leave similar wear, a problem confounded by multi-functional tools (Gates St-Pierre 2007; Zhang *et al.* 2016).

We employed three methods to better identify the final stages of production and to differentiate production from usewear as part of our study of needle and other perforator production. We also observed beads and stingray spines to understand tool production in general. The next section describes the method and sample used in our analysis.

Method

Needle and other perforator fragments were initially identified in the field laboratory in Flores, Peten, Guatemala in 2019 by Freiwald, Dubois-Francoeur, and Jacob Harris, and a sample (n=232) of the Ucanal bone production deposit was selected and exported by Halperin for specialized analyses. Analysis of the perforators included (1) identifying the shaft shape (round, oval, square, rectangle, or triangle), tip type (u- or v-shaped, *sensu* Emery 2010), (2) measuring the width, thickness, and length (if complete), and (3) documenting the technique of forming the eye (incised or drilled, from one or both sides). A subset of perforators was analyzed by Halperin and Dubois-Francoeur at the University of Montréal (n=113), and the remainder were analyzed at UW-Madison by Schlinsog and Bauer (n=119), which Freiwald supplemented by studying the shaft shape and taphonomy using a Dino-Lite Premier digital microscope with variable magnification (10x-220x).

Fourteen objects were selected for analysis using the scanning electron microscope (SEM) at UW-Madison's Department of Geoscience. A Hitachi S3400 variable-pressure scanning electron microscope operating in variable pressure mode was used to create images of one side of two perforated tooth beads, one tibia awl, two flat perforators, two complete needles, and seven other bone fragments with different attributes such as polish that might indicate completion or use. The fragments were observed without coating, which limits the image quality, but allows non-destructive examination of the materials. Each sample was observed along the entire length of one side, with images magnified to 10.0 kV × 500 BSE3D and recorded digitally. The observations were made before the bone fragments were washed, which limited visibility but allowed us to employ electron dispersive spectroscopy (EDS) to look for additives to the bone fragments. The data yielded normalized weight percentages of elements present with variability expected and not measured against standards. We observed no iron oxides or other minerals that might result from end-stage decoration and did not further explore this line of research.

Results

Identifying needles

Our initial sample included 232 objects identified as perforators that were finished or in the final stages of production, including needles, pins, and awls. All but six of the objects were fragmentary or broken. Most Ucanal perforator shafts in this sample were classified as round or oval shaped, with some rectangular and triangular shafts that likely represent unfinished tools with points that had yet to be formed. We hesitate to classify these fragments as distinct tool types since proximal and distal ends have different shapes (see next section), and our sample consists of 41% shaft, 23% proximal, and 28% distal fragments (excluding the six complete specimens).

The maximum width of the perforators in the sample ranged from 0.49 to 6.3 mm, forming a gradient of size classes with no clear groups. However, a core sample (n=105) of small perforators with an average width of 1±0.3 mm form a normally distributed sample (median=0.98 mm) after systematic removal of outlier values from the mean and standard deviation. We classified 65 specimens as needles based on the presence of an eye. The needle eyes were formed by incising a longitudinal groove and then scraping the perforation within this incision. Of the needle eyes that could be observed, most (n=46) were incised on both sides to form the perforation. Only nine needles had incisions on

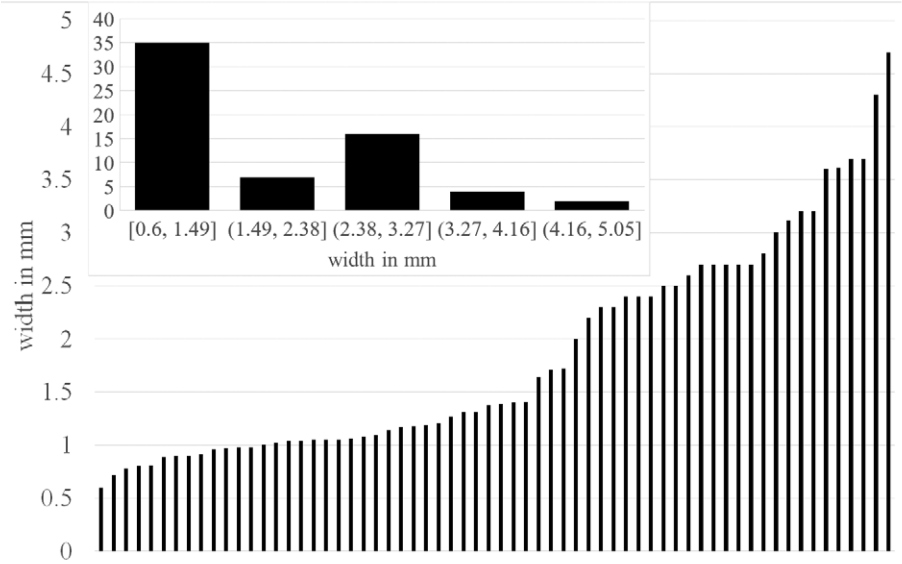

Figure 3. Maximum needle width (n=65). Inset shows two main size classes (by maximum width) in needle production.

one side, and just four needles had eyes that were drilled from one or both sides. The incised eyes on the Ucanal needles were small, less than 1 mm (n=9) or 1-2 mm (n=4) wide, except for a single 4-mm-wide drilled needle eye that was broken. We emphasize that the needles may not have been finished as forming the eye was where mistakes often occurred. However, following Lyman (2015) we consider the tool provisionally complete once the eye was drilled or perforated even if additional finishing had yet to occur.

The proximal end is the widest part of the needle, so it provides a good measure of its potential purpose. The proximal end also was worked to a point that might easily be mistaken for a fragmented distal end but for the flattened shaft. The maximum needle width has a similar distribution to the total perforator sample (Figure 3). However, most needles were between 0.5 and 1.5 mm wide, with a second mode ~3 mm wide. Variation may result from the size differences of proximal and distal needle fragments and the possibility that some needles broke before they were reduced to their final form. We hope to compare these data with measurements from finished products to better understand the level of standardization the Maya required from Ucanal needle production.

Differentiating production marks from usewear

Microscopic analysis showed that some tools in the deposit were finished or used, but most retained traces of manufacturing and were probably unfinished. These specimens could represent practice pieces, production failures, or work planned for the future that never occurred. Figure 4 shows examples of different stages of use and production. Two flat perforators (Figure 4a) have smooth, polished surfaces with diagonal and horizontal striations on the distal ends. One of the objects was repurposed; the distal end was removed, presumably leaving the undamaged shaft as raw material for a new flat perforator or other object.

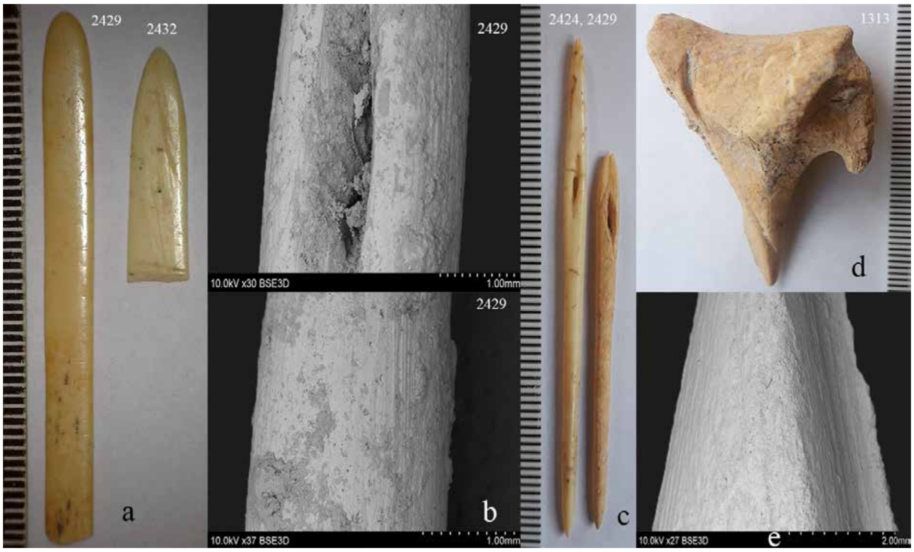

Figure 4. Perforators from Ucanal: (a) Two flat perforators with usewear (UCA.1B.27.8.2432); (b) SEM images showing production marks on a needle from Lot UCA.1B.26.10.2424; (c) complete needles UCA.1B.26.10.2429 and UCA.1B.25.7.2424; and (d) white-tailed deer proximal tibia awl with (e) an SEM image of the distal end, revealing thin lateral production marks. Image scale in mm, with higher magnification in SEM noted on each image.

Parallel scrape marks from production are visible on the eye and shaft of a needle from Lot 2429 (Figure 4b), which also has smooth striations on its distal end but no strong evidence for use. At Dos Pilas, Emery (2010, 227) found evidence for the production of tibia awls that may represent expedient tools, but the specimen in Figures 4d and 4e retains unsmoothed scrape marks. Stone tools leave production marks such as scraping along the longitudinal axis of the tools (Zhang *et al.* 2016). Marks left by chert, obsidian, or other materials differ, but less so than other factors such as the type of tool, the consistency and level of force applied, the characteristics of the material, or the method used to analyze the marks (Greenfield 2006). It may not be possible to differentiate lithic materials (*i.e.*, chert *v.* obsidian) using marks on bone, but the bone may also leave distinct damage on lithics. Preliminary analysis of the chert from the Group J bone production deposit indicates that several chert flakes that would have been appropriate for cutting bone possessed a polish that is consistent with bone tool production, and several chert drills within the deposit may also have been used to work the bone (Hruby 2019). In addition, a modified ceramic sherd may have been employed to polish thin needles since a thin object was abraded on the edges of the sherd, forming 1-2 mm grooves. The ceramic paste of the sherd had volcanic ash inclusions. Since volcanic ash is composed of microscopic vitric or glassy particles, the ceramic sherd may have worked similar to sandpaper.

In all, ten of the SEM samples evidenced longitudinal striations that we interpret as production marks from stone tools, most likely chert. Examination of 116 samples under a lower-magnification digital microscope also shows longitudinal striations on 76% of the fragments observed including the 10 identified using SEM (Table 1). Twenty-six percent of those were smoothed, which can indicate either final polishing or some use, a difference that

	Longitudinal striations	Diagonal striations	Horizontal striations	No striations observed
Distal shaft (n=41)	31	1?	5	6
Proximal shaft (n=26)	21	3	6	3
Shaft (n=49)	39	2	1	5

Table 1. Perforator fragments observed using low level magnification (250x; n=116)

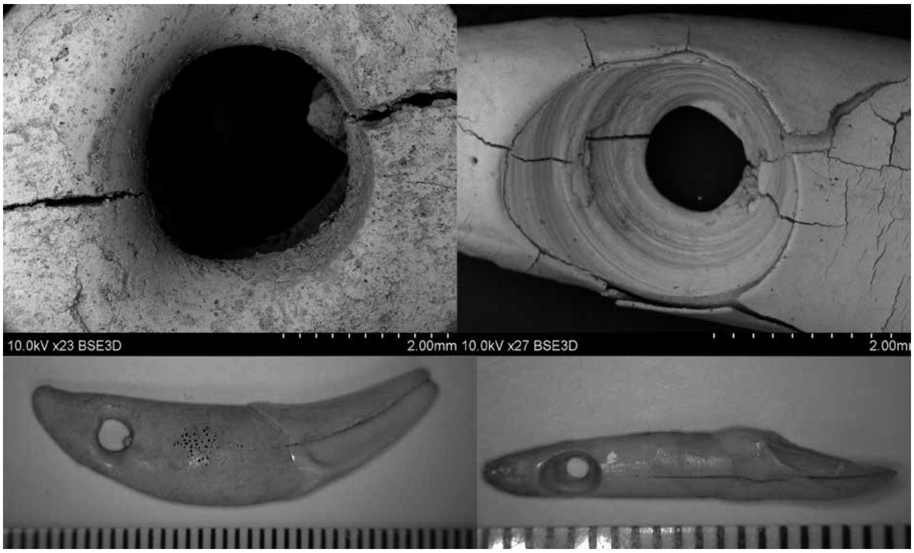

Figure 5. Left images show dog upper right canine bead UCA.1B.26.9.2406 (lateral view) with grooves worn lateral to drilled hole and visible on SEM image in black and white. A periosteal infectious process also is visible in the tooth root (medial view). Right images show a bead produced from a white-tailed deer right second incisor UCA-1B-25-8-2429; SEM image and the tooth bead, both lateral views. Image scale in mm, with higher magnification noted on SEM image.

might be explored quantitatively using SEM. Horizontal and diagonal marks on fragments that lack the clear longitudinal striations we interpret as production marks might reflect use of the tools that were too limited to leave visible usewear patterns (Stone 2011).

Three animal tooth beads show that the deposit contained both used and unused ornaments in addition to tools. The biconically drilled perforation of a dog canine bead (Figure 5, left) shows smoothed edges and grooves lateral to the hole where it was attached to another object (*e.g.*, Falci *et al.* 2020). A longitudinal crack in the tooth is the result of post-use taphonomic factors (time and burial), but a reaction from an infectious process is visible on the root's medial surface, reflecting the health of the dog. In contrast, the white-tailed deer incisor (Figure 5, right) was likely unused as there is no visible wear on either side of the bead. The SEM image shows where drilling began and was then redirected. Like the dog tooth and other tooth beads in the deposit, the hole was drilled from both sides, similar to other tooth beads (peccary, dog, and small carnivore) from Ucanal and other sites across the lowlands (Freiwald, personal observation, 2020; see also Newman 2015).

Figure 6. Dog upper right canine bead (UCA.1B.2.8.1336) with incised perforation and usewear, lateral view (left and upper) and medial view (lower).

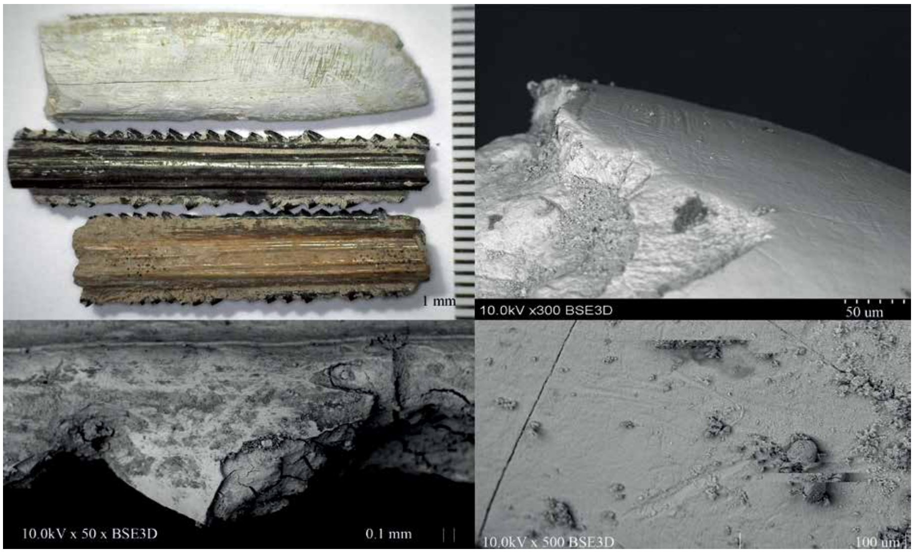

Figure 7. Three stingray spine fragments (clockwise from upper left): Three barbs with cut marks visible under low magnification on the calcined barb (upper); cut marks near the break of the central blackened barb (central); and multidirectional striations and broken serrations on the brown barb (lower) (UCA.1D.14.2.1349).

At least one dog canine bead was perforated by incising versus drilling (Figure 6), and the bead appears to have been used, retaining a bright polish on the root. Like the flat perforators with usewear in Figure 4, the “used” beads may have served as raw materials to re-purpose into new objects.

Stingray spine use is generally assumed when barb fragments are found, but high-resolution imaging reveals this in more detail. Burned and broken stingray spines, or barbs, were recovered from a small Terminal Classic shrine, Structure J-1, that was used after the lithic and bone debitage was sealed in an earlier phase of the Group J complex. Three spine fragments were exposed to heat at different temperatures, and the most calcined fragment shows visible cut marks (Figure 7). Horizontal and longitudinal striations as well as the broken serrated edges are visible in SEM images on the other two fragments.

Conclusions

This pilot study shows some of the information a microscopic view of Maya bone tools can provide. First, the Ucanal bone working deposit contained mostly unfinished products, but included used tools and ornaments that were repurposed into new products or that were part of domestic debris associated with the Group J inhabitants. Although finding unfinished tools and ornaments is not surprising considering the presence of other production stage debris (debitage removal, primary reduction, secondary reduction, *etc.*) in the deposit, the microscopic signatures we identify are useful for understanding the use life or biographies of bone objects in more isolated contexts (*e.g.*, Falci *et al.* 2020). The white-tailed deer proximal tibia awls that we interpret as expedient tools may have played a role in bone tool production, as low magnification observations reveal some usewear striations and breakage on samples.

A second finding is that multiple techniques were employed in tool production, including both drilling and incising of perforations. Although preliminary analysis suggests that some chert flakes from the deposit were used to cut bone (Hruby 2019), an experimental usewear study like that conducted on lithic assemblages at other sites, such as Pook’s Hill and Aguateca, is needed (Aoyama 2007; Emery and Aoyama 2007; Stemp *et al.* 2010). Obsidian also may have been used in bone tool production, including the fine incising work required to produce the bone needle eyes (Martínez Guzmán *et al.* 2007). However, even with high magnification SEM of bone, it is difficult to identify the raw material used to cut and incise tools (Greenfield 2006; but see Campos-Martínez *et al.* 2016).

The preference at Ucanal for making needle eyes by incising and scraping is also found among finished products at a range of sites in Mesoamerica, including in Postclassic central Mexico (Martín *et al.* 2018) and Late Classic and Postclassic Maya sites in Guatemala’s Peten, such as Motul de San José, Tayasal, and Nixtun Ch’ich’ (Halperin and Freiwald, personal observations, 2019). In contrast, the needle eyes from the Early Classic Mundo Perdido sample from Tikal (Emery 2010, 250) are described as biconically drilled (n=101) with fewer vertically perforated ones (n=17). Needle eyes from Classic period sites in Oaxaca (Feinman *et al.* 2018, 47) were also biconically drilled. Correlations between eye perforation technique and needle size, as well as further comparisons between sites, will elucidate whether such patterns relate to needle size, since thin needles may be more cracked or splintered by drilling, or to social and spatial patterning in shared production techniques.

The variation in the needle sizes from the Ucanal deposit shows that some were likely produced for sewing delicate materials, such as attaching small ornaments or feathers to textiles or embroidering and tailoring of fine cotton cloth. Needle tip shape, the presence of an eye, and other factors are useful for classifying perforator style, and microscopic analysis might prove useful in identifying where they were used and what they were used for. Needles produced at Ucanal, Tikal, and Dos Pilas had different average sizes. The size comparisons, however, are only preliminary since finished products – including the length – rather than tool fragments are needed to better understand potential standardization of needles and other perforators.

Standardization also relates to the selection of animals used to provide the raw osseous materials. The use of white-tailed deer in Mesoamerica, and to some extent humans, may represent specialized raw material selection (*e.g.*, Maeir *et al.* 2009). The choice of animals and the specific bones reflects a particular strategy that had symbolic as well as practical considerations.

The reduction sequence for needle or ornament production is but one part of the *chaîne opératoire*, and this analysis is one piece of a larger project that will reconstruct the life histories of the bone tools, from the dog with a lesion on its upper canine to the production of the canine tooth bead, its use and discard, and then to the workshop where it may have served as raw material for a new product that was never made, before the deposit was created and sealed and life in the residential group continued.

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Warm it up! Using experimental archaeology to test shark teeth extraction hypotheses

Simon-Pierre Gilson and Andrea Lessa

Abstract

Archaeological and ethnographical artifacts made with shark teeth are found worldwide. However, no research has been undertaken to examine the processes used to extract teeth from shark jaws. During the processing of shark samples in preparation for a reference collection, we observed that shark teeth were easily removed. In order to more vigorously test this observation, six experiments were developed. We discuss in more detail the methods used by native groups to obtain shark teeth, as well as the presence of shark teeth in Brazilian archaeological sites. The experiments exposed shark jaws to heat using two techniques: immersion in hot water, and direct contact with flames from burning wood and coal. Results demonstrated that: a) both techniques are suitable for the task, although there are disadvantages to both; and b) the structural integrity of the teeth was compromised when they were exposed directly to fire. We believe that shark teeth were carefully treated by native groups, and their presence in archaeological contexts should be thought as the result of intentional behaviors based on pre-defined socio-cultural insights.

Resumo

Artefatos arqueológicos e etnográficos feitos com dentes de tubarão são encontrados em todo o mundo. No entanto, nenhuma pesquisa foi realizada para examinar os processos usados para extrair os dentes da arcada do tubarão. Durante o processamento de tubarões para uma coleção de referência, observamos que os dentes de tubarão expostos a uma fonte de calor foram facilmente removidos. Para testar de forma sistemática esta observação, foram desenvolvidos seis experimentos. Foram discutidos detalhadamente os métodos usados por grupos nativos para obtenção dos dentes de tubarão, bem como a sua presença em sítios arqueológicos brasileiros. Os experimentos expuseram arcadas de tubarão ao calor usando duas técnicas: imersão em água quente e contato direto com chamas e carvão. Os resultados demonstraram que: a) ambas as técnicas são adequadas para o destacamento dos dentes, embora ambas apresentem desvantagens; e b) a

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integridade estrutural dos dentes foi comprometida quando foram expostos diretamente ao fogo. Acreditamos que os dentes de tubarão foram tratados com cuidado por grupos indígenas, e sua presença em contextos arqueológicos deve ser pensada como resultado de comportamentos intencionais baseados em percepções socioculturais pré-definidas.

Keywords: experiments, shark tools, osseous technology, Brazil, coastal groups

Introduction

Shark teeth, with or without anthropogenic alterations, are commonly found at coastal archaeological sites. Even today they are used for the making of various artifacts by people around the world. In Brazilian archaeology, they are often present in the numerous shell mounds (Cardoso 2018; Rohr 1977a; Manoel Mateus Bueno Gonzalez 2005; Lopes *et al.* 2016; Pavei *et al.* 2015; Bandeira 2015; Borges 2015) and in the so-called shallow sites (Gilson and Lessa 2021; Mayer 2017). Shallow sites are coastal pre-colonial settlements that are different from the well-known sambaquis in many ways. The stratigraphic layers, formed by very dark sediment, rarely exceed one meter. They can be placed directly on the sand of the beach, or on the top of sambaquis. The shells appear in a much smaller quantity, grouped or spread in thin layers, with no constructive intention. In all sites, there are the presence of many burials, in addition to post holes and different artifacts associated with daily activities (Rohr 1977b, 1984; Lessa 2015; Prous 2019).

In these pre-colonial sites, shark teeth are found at varying frequencies, usually in funerary or combustion structure contexts, or even dispersed in archaeological layers. According to ethno-historic accounts, they are also associated with post-contact groups. The European chroniclers who lived on the Brazilian coast between the fifteenth and eighteenth centuries describe different techniques of catching various sharks in shallow water without boats, as well as the use of teeth as arrow points (Gilson and Lessa 2019).

Despite the high frequency of shark teeth in Brazilian archaeological collections, few specific zooarchaeological studies have been developed (*e.g.,* Gonzalez 2005; Mayer 2017; Souza 2019; Gilson and Lessa 2021). Gonzalez's work (2005) represents an exception in the lack of studies on shark capture techniques by ancient populations. According to Gonzalez and Amenomori (2003), the faunal elements found in the coastal archaeological sites, associated with larger and more aggressive species such as great white shark (*Carcharodon carcharias*), shortfin mako (*Isurus oxyrinchus*), and blue shark (*Prionace glauca*), would be obtained as a result of the outcropping of teeth from Pleistocene deposits, or more commonly after stranding of shark carcasses.

As opposed to the reports of the European chroniclers (Gilson and Lessa 2019), for Gonzalez and Amenomori (2003) the capture of great sharks requires the use of watercraft, for which there are no systematic studies. Discussions on this issue have been made only indirectly, based on geoarchaeological (Calippo 2011), zooarchaeological (*e.g.,* Borges 2015;

Table 1 (Right). Some examples of published data on number of shark teeth (NISP), Minimum Number of Individuals (MNI), frequency of burn mark (BM%), and identified species in South Brazilian coastal archaeological sites (* not specified; ^{1} date without correction by the carbon 13 have been calibrated following Gilson and Lessa 2020; ^{2} following Scheel-Ybert 2019). Calibrated using OxCal v. 4.4 (Bronk Ramsey 2009) and the calibration curves Marine20 (Heaton *et al.* 2020), SHCal20 (Hogg *et al.* 2020), Marine13 (Reimer *et al.* 2013), and SHCal13 (Hogg *et al.* 2013).

Site	^{14}C BP	Cal BP	Information	NISP	MNI	BM%	Identified species	References
Sambaqui do Mar Casado	4400±130 (Gif-1194)	5600-4247	SHCal20 95.4% Wood Without δ^{13}C[1]	1645	28	*	*Carcharinhus* sp., *Carcharinhus leucas*, *Carcharias taurus*, *Galeocerdo cuvier*, *Isurus oxynrinchus*, *Rhizoprionodon* sp., *Sphyrna* sp.	Gonzalez 2005; Borges 2015
Sambaqui Maratuá	3865±95 (Gif 9185)	4848-3640	SHCal20 95.4% Charcoal Without δ^{13}C[1]	38	9	*	*Carcharhinus acronotus*, *Carcharhinus limbatus*, *Carcharias taurus*, *Galeocerdo cuvier*, *Carcharodon carcharias*, *Rhizoprionodon* sp.	Gonzalez 2005; Borges 2015
	3935±145 (BAH 382)	5264-3583						
	3350±40 (Beta 205339)	3875-3366	SHCal13-Marine13[2] R: 220±20 95.4% Human bone					
Samaqui Buração	2050±100 (Gif 1056)	2303-1721	SHCal20 95.4% Without δ^{13}C[1]?	570	17	*	*Carcharinhus* sp, *Carcharinhus leucas*, *Carcharinhus obscurus*, *Carcharias taurus*, *Galeocerdo cuvier*, *Isurus oxynrinchus*, *Carcharodon carcharias*, *Prionace glauca*, *Rhizoprionodon* sp.	Gonzalez 2005; Borges 2015
	1950±100 (Gif 1055)	2087-1610						
	1600±95 (Gif 1054)	1698-1294						
	1240±95 (Gif 1053)	1290-931						
Sambaqui Cosipa 4	2590±80 (GIF 6781)	3167-2111	SHCal20- 95.4% Charcoal Without δ^{13}C[1]	231	6	*	*Carcharinhus* sp., *Alopias* cf. *vulpinus*, *Carcharias taurus*, *Rhizoprionodon* sp.	Gonzalez 2005 Borges 2015
Piaçaguera	4930±110 (I 4481)	5993-4858	Marine20 R: 220±20 95.4% Water salt shell Without δ^{13}C[1]	1689	38	*	*Carcharinhus* sp., *Carcharinhus leucas*, *Carcharinhus obscurus*, *Carcharias taurus*, *Galeocerdo cuvier*, *Isurus oxynrinchus*, *Carcharodon carcharias*, *Prionace glauca*, *Rhizoprionodon* sp., *Sphyrna tiburo*, *Prionace glauca*	Gonzalez 2005; Borges 2015
	4890±110 (I 4480)	5975-4830						
	4481±110 (unknown)	5658-4448	SHCal13 Marine13[2] R: 220±20 95.4% Human tooth Without δ^{13}C[1]					
Tenório	1875±90 (I 5306)	1311-2321	SHCal20 95.4% Charcoal Without δ^{13}C[1]	698	13	*	*Carcharinhus* sp., *Carcharinhus leucas*, *Carcharias taurus*, *Galeocerdo cuvier*, *Carcharodon carcharias*, *Prionace glauca*, *Rhizoprionodon* sp., *Sphyrna tiburo*	Gonzalez 2005; Borges 2015
Sambaqui Mar Virado	2570±70 (Beta 154721)	2843-2370	Marine13 R: 220±20 95.4% Sea urchin	10238	146	*	*Carcharinhus* sp., *Carcharinhus leucas*, *Carcharinhus obscurus* *Carcharias taurus*, *Galeocerdo cuvier*, *Isurus oxynrinchus*, *Carcharodon carcharias*, *Prionace glauca*, *Rhizoprionodon* sp., *Sphyrna* sp., *Prionace glauca*	Gonzalez 2005
	2640±70 (Beta 154722)	2930-2495						
	2640±70 (CSIC 1803)	3575-3827	SHCal20 95.4% Charcoal					

Site	^{14}C BP	Cal BP	Information	NISP	MNI	BM%	Identified species	References
Sambaqui Bombinhas	*			123	101	11.9%	*Carcharinhus leucas, Isurus paucus, Isurus oxynrinchus, Mustelus canis, Carcharinhus plumbeus, Carcharias taurus, Negaprion brevirostris, Sphyrna mokarran, Carcharhinus porosus*	Cardoso 2011
Galheta IV	980±40 (Beta 211734)	956-791	SHCal13 Marine13^2 R:220±20 95.4% Human bone	281	15	11.7%	*Carcharodon carcharias*, *Carcharias taurus*, *Prionace* sp., *Sphyrna* sp., Carcharhinidae	Cardoso 2018
	1360±40 (Beta 280010)	1347-1176						
	830±43 (UGAMS 30089)	897-673						
	990±44 (UGAMS 30090)	963-785						
	950±40 (Beta 280012)	929-745						
	1070±40 (Beta 280011)	1053-801	OxCal4.4 SHCal20 95.4% Sea mammal					
Rio do Meio	600±30 (Beta 451660)	631-516	SHCal20 95.4% Charcoal	1809	47	28 %	*Lamna nasus, Negaprion brevirostris, Carcharinhus obscurus, Carcharinhus plumbeus, Carcharinhus brachyurus, Carcharinhus leucas, Carcharinhus falsiformis, Galeocerdo cuvier, Rhizoprionodon sp., Squatina sp., Sphyrna sp., Carcharodon carcharias, Isurus paucus, Carcharias taurus, Mustelus* sp.	Mayer 2017; Gilson and Lessa 2021, 2020
	620±30 (Beta 451661)	639-526						
	780±60 (Beta 178077)	654-473	Marine13 R: 220±20 95.4% Salt water Shell					
	870±30 (Beta 451662)	675-541	Marine13 R: 220±20 95.4% Otolith					

Table 1. continued.

Gaspar, Klokler, and DeBlasis 2011), bioarchaeological (*e.g.*, Lessa and Coelho 2010; Lessa and Rodrigues-Carvalho 2015; Rodrigues-Carvalho 2004), and ethnographical (Gilson and Lessa 2019) data, due to the lack of the evidence of boat use. Perhaps due to these circumstantial inferences, some archaeologists accept the hypothesis that sharks were found on the beach after stranding (*e.g.,* Costa *et al.* 2012), even though zooarchaeological studies support the hypothesis of capture at sea (*e.g.,* Cardoso 2018; Borges 2015; Klokler 2014). However, the most significant absence of data and discussions on the relationships between human groups and sharks is the next step of the operational chain regarding the use of their teeth: the extraction from the jaws. If shark teeth were opportunistically obtained from shark carcasses on the beach, this could be understood as an easy task, since the animals would be found in different stages of decomposition. But this hypothesis is not supported by scientific data since stranding of sharks on the coast is rare, and when they occur they are usually associated with accidental catching and subsequent discard

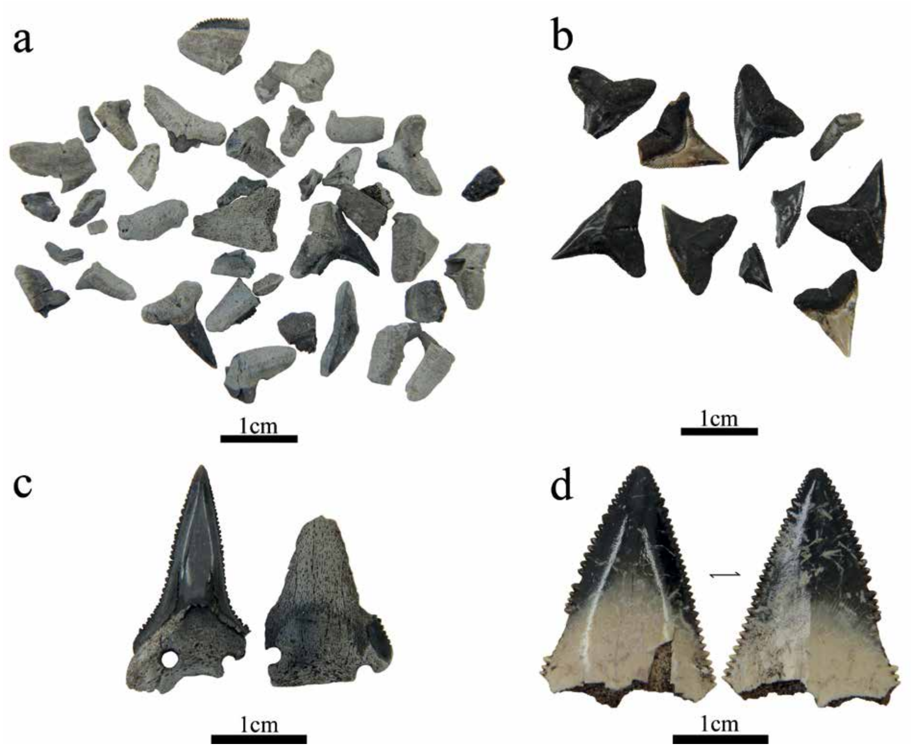

Figure 1. (a) Calcined shark teeth from the Rio do Meio site; (b) burned shark teeth from the Rio do Meio site; (c) burned, worked shark teeth from the Rio do Meio site; (d) burnt shark tooth from the Rio do Meio site.

during trawling and commercial fishing activities (Garrone Neto, Caltabellotta, and Gadig 2013; Sampaio *et al.* 2016). Indeed, sharks sink due to the absence of a swim bladder, the buoyancy system used by most teleost fish (Compagno 1984; Ebert, Fowler, and Compagno 2016; Kozuch 1993). Therefore, high frequencies of teeth from Brazilian archaeological sites (Table 1) indicate purposeful shark capture.

Recent isotopic studies focusing on the diet of pre-colonial coastal groups not only indicated that marine resources were their food basis, but also that some individuals ate mainly top-chain species (Bastos *et al.* 2014; Bastos *et al.* 2015; Colonese *et al.* 2014). As suggested by the zooarchaeological analysis on Sambaquis groups by Klokler (2014), Borges (2015) and Cardoso (2018), and demonstrated for shallow sites by Gilson and Lessa (2021), sharks were an important part of the diet, therefore they would have been caught fresh. The ethnographic information from the Pacific Ocean populations about fishing methods, and the use of shagreen, reinforce the human ability to catch fresh sharks (Kozuch 1993; Gonzalez 2005).

So, assuming that precolonial groups caught sharks themselves, some questions arise regarding tooth extraction techniques. After the death of a shark occurs, rigor mortis sets in, making it difficult to open the mouth to extract teeth. Additionally, due to the shape of the roots and the rigidity of the connective tissues, the teeth are firmly attached. This situation also remains after some decomposition, since part of the connective tissues do not disappear, but may dry out and more tightly bond to the teeth. Besides being quite difficult and time-consuming, the extraction of teeth may also be a dangerous task, considering how sharp they are.

Considering these aspects, the main objective of this article is to discuss, for the first time, possible techniques of shark tooth extraction, as well as some taphonomic results of this task. The discussion of choices and ways in which these groups deal with everyday challenges, and their impact on recovered material from archaeological sites, are important approaches for advancing the knowledge on lifestyle and adaptive strategies of pre-colonial coastal groups.

Our introduction to this research question occurred while processing a fresh shark carcass in preparation for a reference collection. Although at that time, tooth extraction was not one of our research questions, the effect of hot water on tooth rootedness was noted, *i.e.*, heat allowed teeth to become loose. This led us to raise questions about the use of direct fire for the same purpose. The presence of burned shark teeth from several archaeological contexts supports this hypothesis (Figure 1 and Table 1).

The experimental archaeology study presented here tests the viability of shark teeth extraction using heat. Although, following Outram (2008), experimental archaeology seeks to test hypotheses but can never be a perfect reproduction of past experiences, since some variables may act in each process.

The anatomy of shark teeth

Shark skin has particular scales called dermal denticles, which are small teeth embedded into the epidermis. Shark teeth are, in essence, just a kind of dermal denticle which have evolved to form teeth (Berkovitz and Shellis 2017; Ebert, Fowler, and Compagno 2016; Wheeler and Jones 1989). Thus, shark teeth are not rooted inside the jaw and are not connected to it, but are simply positioned inside the gum and connected at their base by a very strong fibrous membrane (Berkovitz and Shellis 2017; Ebert, Fowler, and Compagno 2016; Wheeler and Jones 1989). Nearly all sharks have what is known as a subterminal mouth, located on the ventral surface (underside) of the head. The jaw is suspended below the skull, attached by ligaments, muscles, and other connective tissues. The lower jaw is connected to the upper jaw at the corner of the mouth.

The structure of the teeth is the same as dermal denticles: a central core of dentine penetrated by a pulp cavity, containing blood vessels and nerves and covered by a layer of enameloid tissue (Berkovitz and Shellis 2017; Enault *et al.* 2015; Wheeler and Jones 1989). Another particularity of sharks is that, unlike some vertebrates, they do not keep the same teeth throughout life but instead shed teeth continually. The loss and replacement cycle is different inter-species and intra-species, and may even vary in a single individual. Variables such as age, diet, water temperature, or other seasonal factors can influence the tooth-shedding cycle. The time range of the shedding could be between days to several months (Berkovitz and Shellis 2017; Ebert, Fowler, and Compagno 2016). As pictured by Wheeler and Jones (1989), the replacement system could be compared to a moving staircase. Indeed, the shedding occurs in a linear mode and the new tooth takes the place of the old one and so on. As a consequence, the teeth inside a shark's mouth are arranged in successive rows of four to seven, each one in a different stage of development. However, some teeth that are still in a non-functional position remain folded under a layer of skin (with the tips of the teeth pointing toward the throat) inside the mouth while they're still developing, and thus are hidden from view.

General methodology

Experimental archaeology is widely used because it is essentially multidisciplinary (Busuttil 2008; Coles 1979; Gifford-Gonzalez 1991). Fundamental principles guide its practice, especially regarding the way experiments be conducted and results be presented (Coles 1979; Gifford-Gonzalez 1991; Kelterborn 2005; Mathieu 2005; Lubinski, Shaffer, and Ferguson 2010; Outram 2005; 2008; Schmidt 2005). The present work follows Kelterborn (2005), who highlights the importance of a well-defined objective and the replicability of the experiments. He also emphasizes the need for good planning of the experiment steps, although improvisation may also occur. Another important possibility is the use of some inauthentic materials, which do not compromise results (Coles 1979; Outram 2008).

The main objective of this work was to understand the reaction of shark teeth subjected to heat exposure. More specifically, our interest was focused on three reactions: 1) the release of muscles and subsequent opening of the mouth, 2) the dissolution of connective tissues holding the teeth, and 3) the subsequent taphonomic results and structural integrity of the teeth. The experiments were performed to achieve these objectives, although we were forced to compromise with the use of some modern materials as it is difficult to reproduce traditional forms. We measured our results as best we could, and replicability was achieved.

A total of six experiments were performed that exposed shark teeth to heat. Experiments #1 and #3 aimed to test the feasibility of the extraction by immersing the jaws in hot and boiling water; experiments #2 and #4 tested the feasibility of tooth extraction by exposing the jaws to intermittent, direct contact with flames; experiments #5 and #6 tested the structural integrity of the teeth exposing them to heat through direct contact with fire.

Two campfires were used for experiments #1-4 (see Table 1). Experiments #1, #2, and #5 were performed in a fire pit formed by a hole in the ground surrounded by small rocks (Figure 2a). This is similar to those used by native groups (Fossari 2004). Experiments #4 and #6 were performed in an above-ground fire pit, which was protected against the wind (recorded video: https://doi.org/10.5281/zenodo.3985947). It was not possible to maintain the same conditions for all the fire pits because the first experiments were carried out in Brazil, with an average temperature of 25°C, and the last ones during winter in Canada, when the soil was frozen (average temperature of -8°C). We sought to replicate the same heat conditions as much as possible among all experiments.

The experiments' locations (Brazil and Canada) and the shark species used were determined by access to shark carcasses.

The jaws used in experiments #3 and #4 were previously unfrozen and kept in a refrigerator. It is difficult to evaluate the possible influence of freezing on the shark tissue and the consequences for the experiment. Nonetheless, the teeth were still firmly attached to the jaw at the beginning of the experiment and no visible alterations were noted.

Next, each experiment will be presented with its own materials, methods and results (summarized in Table 2). The experiments work in pairs, and #1 and #2 were the pilot ones.

Experiment #1

The first experiment was carried out in Florianópolis (Santa Catarina state, Brazil) with a fresh jaw from the species narrownose smoothhound (*Mustelus schmitti),* measuring 60 cm (fork length), offered by the LABITEL/UFSC (*Laboratório de Biologia de Teleósteo e Elasmobrânquios* – Federal University of Santa Catarina; Figure 2b). Adult sharks of this species measure between 60 cm and 103 cm (total length; Ebert, Fowler, and Compagno 2016).

Experiment Number	Sample Description	Fork Length (cm)	Mouth Diam. (cm)	Technique	Mean Temperature (C°)	Time of Exposure (min)
1	Fresh jaw of *Mustelus schmitti*	60	±5	Extraction in water	77	25
2	Whole shark of *Sphyrna lewini* in formaldehyde	68	±5	Extraction over fire	101	25
3	Fresh frozen jaw of *Prionace glauca*	173	±18	Extraction in water	80	15
3	Fresh frozen jaw of *Prionace glauca*	178	±18	Extraction in water	80	20
4	Fresh frozen jaw of *Prionace glauca*	237	±30	Extraction over fire	Unknown	25 (est.)
4	Fresh frozen jaw of *Prionace glauca*	242	±30	Extraction over fire	Unknown	25 (est.)
5	Teeth of *Prionace glauca*	242	±30	Test structural integrity	162	1 to 15
6	Teeth of *Prionace glauca*	242	±30	Test structural integrity	599	5

Table 2. Summary of materials and methods.

The aim was to test the opening of the dental arches and reaction of the teeth in relation to the adhesion when exposed to heat inside water. The fresh jaw was immersed in water at 50°C inside a clay pot over the campfire (Figure 2c). The temperature of the water, behavior of the arches and adjacent tissues, and the adhesion of the teeth were checked every 2 minutes until the extraction was possible. The temperature of the water was checked with a laser infrared thermometer gun (IR gun) that measures the thermal radiation emitted by an object. It has the great advantage of allowing measurements to be taken from a distance. The small size of the mouth was a limitation for this experiment since it hindered observations and manipulations inside the hot water. Access to the teeth was only possible with the use of tweezers.

The first observation resulting from the exposure of the fresh narrownose smoothhound jaw to the hot water was the softening of the resistant tissues that connect the upper and lower arches after 2 minutes of immersion. After 6 minutes of immersion, it was very easy to open the shark's mouth to get access to the teeth, due to the complete softening of the muscular tissues that connect the lower and upper jaws. After the immersion in water for 12 minutes at a mean temperature of 75.5°C it was possible to easily extract the teeth.

Figure 2 (right). (a) Experimental set for experiments #1, #2 and #5 with the campfire, TP100 sensor and photographic equipment; (b) narrownose smoothhound species for experiment #1; (c) position of the clay pot over the fire for experiment #1; (d) scalloped hammerhead (*Sphyrna lewini*) species for experiment #2 and #5; (e) position of the scalloped hammerhead over the campfire for experiment #2; (f) and (g) pictures with IR camera of the scalloped hammerhead before and after the exposure to heat during experiment #2. Results of experiment #2: (h) the jaw of the scalloped hammerhead after exposure to fire, (i) scalloped hammerhead row teeth without expressive thermal alteration.


a
b
10cm
d
10CM
c
e
f
Point 21.5
Cercle
Max 21.6
Min 18.9
Moy 20.1
Ligne
Max 26.8
Min 18.3
Moy 22.1
27.0
17.3
FLIR
g
Point 88.5
Cercle
Max 86.0
Min 27.0
Moy
92.7
20.5
FLIR
h
i

Experiment #2

The second experiment was carried out in Florianópolis (Santa Catarina state, Brazil) with a complete shark from the species scalloped hammerhead, measuring 70 cm (fork length), offered by the LABITEL/UFSC (Figure 2d). Adult sharks of this species measure between 140 cm and 420 cm (Ebert, Fowler, and Compagno 2016). It was pre-treated by the Department of Biology of the UFSC with formaldehyde to inhibit the decomposition process.

This treatment may represent a variable with some influence on the reaction of the whole shark, consequently limiting observations of the experiment. However, at the beginning of the experiment the specimen was in a perfect state of preservation and had no apparent change in the stiffness of the connective tissue (not more than could be expected, Compagno 1984). The mouth was firmly closed, such as it would be for a fresh specimen. The use of this shark was chosen due to the difficulty in obtaining fresh shark carcasses with heads.

The aim was to test the movement of the dental arches and the reaction of the teeth in relation to the adhesion when exposed to the heat of flames. The complete shark was placed over the campfire, supported on a grid 30 cm above the coals, with direct and indirect contact with flame, depending on the intensity and direction of the wind (Figure 2e). A grid was chosen because it allows the direct exposure of the shark to heat and promotes a better control on the shark's position. This technique corresponds to the use of the so-called *moquém* by Tupiguarani groups, abundantly attested by post-contact chroniclers and ethnographers (*e.g.*, Ayrosa 1934; Cardim 1978; Gondim 1938; Léry 1980; Navarro 2013). Basically, the grid and *moquém* techniques have the same principle, which is to keep the animal suspended over the fire in a gridded support with quadrangular or triangular shape. The goal is to allow the transmission of heat, but also to control the degree of exposure and the direct contact with flames.

The experiment was carried out for 24 minutes, when the reaction of the material to heat had completely ceased. This observation period corresponds to twice the time of experiment #1. The temperature inside the jaw was measured with an IR gun, and inside the shark's body was measured with a TP100 sensor (Figures 1a and 1e). This equipment is a resistance thermometer that measures the temperature with a sensor inserted inside the goal element. The sensor is made of pure material, like copper, and presents a wide operating range with high accuracy. The body and the jaw were checked every 2 minutes. An IR camera (Flir One model) was used to measure the global temperature of the complete shark body before and after the exposure to fire (Figures 1f-g).

The first observation was that the shark's mouth opened spontaneously under the action of the heat, without any manipulation (Figure 2h). Secondly, the teeth of the scalloped hammerhead remained firmly attached to the arches during the first 10 minutes of exposure to heat. It was only after this time that the resistance of the fibrous connective membrane decreased, allowing some movement of the teeth by strong traction. It was not possible to extract the teeth from the arches until the end of the experiment. This subtle reaction to heat is probably associated with the pre-treatment with formaldehyde suffered by this specimen, since the connective tissue and other soft tissues responded differently when compared to the fresh shark (experiment #1), creating a strong barrier around the teeth. However, it was interesting to note that even after an intense burning process, with the jaw directly exposed to the flames, only the teeth of the first row presented evidence of thermal alteration (Figure 2h-i).

Experiment #3

The third experiment was carried out in Montréal (Canada) with two complete jaws of the blue shark (*Prionace glauca*) species provided by the Bedford Institute of Oceanography (Dartmouth, Nova Scotia, Canada). The jaws came from sharks with 173 cm fork length (jaw #1) and 178 cm fork length (jaw #2). An adult specimen reaches the maximum size of 380 cm (Ebert, Fowler, and Compagno 2016).

This experiment was undertaken based on the results of the experiment #1, so it was conducted according to the unsolved questions due to methodological limitations. The small size of the narrownose smoothhound (experiment #1), besides hindering the manipulation and observation of the events, restricts the inferences. Teeth present in the coastal archaeological sites are of greater species, with fork lengths more than 100 cm up to 700 cm. They have, therefore, stronger connective tissues in the feeding apparatus than the specimen observed in the experiment #1.

So, the main questions that guided this experiment were: a) does hot water cause the softening of the connective tissues of the feeding apparatus of medium and great sharks?, and, b) how exactly were the teeth detached from the jaws? In order to answer these questions, the experiment was carried out in two steps to test the influence of two variables on the movement of the arches, and on the teeth adhesion: temperature and time of exposure.

In the first step, both jaws were immersed in a modern pot over a modern stove (Figure 3a-b). The water was maintained at a stable temperature under the boiling point for jaw #1 (Figure 3b), and over the boiling point for jaw #2. Based on the time required for teeth extraction observed in experiment #1, both jaws #1and #2 were withdrawn from the water after 10 minutes and the accessibility and adhesion of the teeth was checked.

It was first observed that the connective tissue of the upper and lower arches had lost all rigidity, allowing the opening of the mouth by minimal manipulation. Then an unexpected pattern was observed since, for both jaws, the whole row system of teeth detached from the arches (Figures 3c-e). That is, the dental set remained linked once the connective membrane preserved sufficient rigidity to resist spontaneous detachment and even against light traction (Figure 3e). However, it was possible to extract the teeth individually without the aid of any tool, although a great deal of connective tissue has remained adhered. So, the extraction of the teeth was easily performed on both jaws, indicating that the boiling point was not a determinant variable for this task. Only a few teeth were detached from the set, preserving the others for the next step of the experiment.

The aim of the second step was to test which variable (exposure to a higher temperature or to a longer time) would be the most efficient to further soften the connective tissues of the row system, and consequently to allow an easier individual extraction of cleaner teeth. The results observed in this step may be useful for inferences regarding greater size sharks, in which the general structure of the feeding apparatus is more robust than those discussed here.

The time elapsed between the first and the second step of the experiment was 15 minutes and the dental sets were sheltered at a room temperature of 22°C. This time was enough for the connective membrane to recover part of the rigidity. The experiment consisted of the immersion of both dental sets in water over the boiling point. Dental set #2 remained immersed for 5 minutes, and it was observed that the connective membrane lost all resistance. Teeth detached at the slightest touch, and were clean, with no adhered connective tissue (Figure 3d). Dental set #1 remained immersed for 10 minutes and the

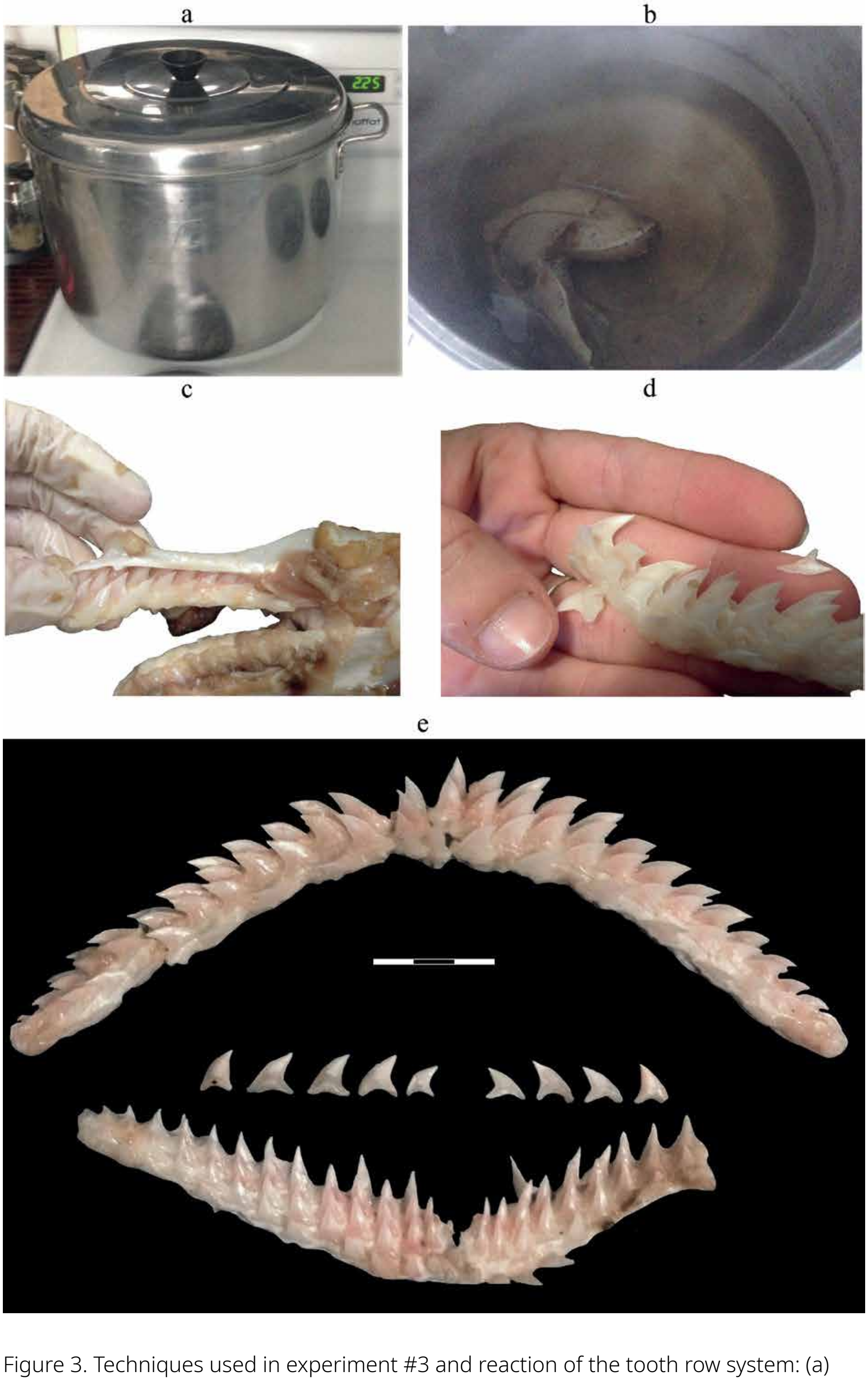

Figure 3. Techniques used in experiment #3 and reaction of the tooth row system: (a) modern pot used for experiment #3; (b) the jaw #1 of the blue shark (*Prionace glauca*) species submerged in hot water; (c) cleaning of the jaw and removal of the row system; (d) detachment of teeth from the connective tissue; (e) complete row system (superior and inferior) extracted from the jaw with some spontaneous falling teeth.

same behavior was observed. No difference was observed between the two sets regarding the connective tissue resistance. So, the results demonstrated that temperature is a more important variable than time of exposure to heat.

In summary, experiment #3 demonstrated that: a) immersion in hot water allowed easy opening of the shark's mouth and extraction of the teeth, corroborating the result of experiment #1 where; b) it was not necessary for the water to reach the boiling point, however, when exposed to higher temperatures, the teeth detached more easily and were cleaner; and c) the fibrous membrane that connects the shark's teeth together is extremely firm, resulting in a detachment of the whole row from the jaw.

Experiment #4

The fourth experiment was carried out in Montréal (Canada) with two complete jaws of blue sharks (*Prionace glauca*) provided by the Bedford Institute of Oceanography (Dartmouth, Nova Scotia, Canada). The jaws came from sharks of 237 cm fork length (jaw #1) and 242 cm fork length (jaw #2). Sexually mature individuals measure from 182 cm to 380 cm (Ebert, Fowler, and Compagno 2016). This experiment was undertaken based on the results of experiment #2, since the pretreatment of the shark with formaldehyde may have biased some results. Thus, experiment #4 aimed to answer the following questions: a) Do the dental arches open spontaneously when exposed to the heat of flames? b) Does the heat of the flames favor the extraction of teeth from the jaws? and c) How exactly were the teeth detached from the jaw? So, the focus of the experiment was to observe the reaction of the teeth, rather than on the time and temperature. Data on these variables were used from the previously presented experiments.

Jaws #1 and #2 were placed over the campfire, supported on a grid 30 cm above the coals, with intermittent direct contact with the flames depending on the intensity and direction of the wind (recorded video: https://doi.org/10.5281/zenodo.3985947). The jaws were processed one after the other. They were successively placed and removed from contact with the flames at 5 minute intervals for regular examination of the progress of detachment. Jaw #2 was divided in two parts, lower and upper, to favor the observation of the phenomena and preserve part of the sample for a future usewear study.

The experiment offers interesting results. In relation to the movement of the arches, spontaneous opening was observed in both jaws, although the connective tissue did not soften. On the contrary, exposure to the fire usually dehydrates the most exposed soft tissues. The contraction of the muscles that connect the arches, and the consequent opening of the mouth, would be a natural movement. This result is similar to that observed in experiment #2, suggesting that the pretreatment with formaldehyde did not interfere with arc movement. The presence of this agent did not inhibit dryness and contraction of the connective tissues.

Another relevant result of experiment #4 is regarding the extraction of the teeth: the indirect heat technique worked well to ensure an easy task. The connective membrane, when exposed to the intense heat of the flames, soften and then melts. This result, contrary to that observed in experiment #2, indicates that pretreatment with formaldehyde interfered with the teeth extraction process. In this case, the chemical agent caused hardening of the connective membrane, making it impossible to detach the teeth.

An unexpected, but very interesting reaction, was observed. After the end of the experiment and removal of the jaws from contact with heat, the connective membrane recovered stiffness. It did not present the same degree of solidity, but the fibrous tissue gained elasticity, which, along with the smooth texture and shape of dental crowns, made traction difficult and dangerous. This circumstance was empirically observed by the first author and other members of the team who participated in the experiment. They cut themselves performing the extraction while the tissue was regaining its stiffness.

Finally, experiment #4 provided data on the effect of the flames with teeth. It was observed that, in both jaws, not only the active teeth (located in the first row) were affected by thermal alterations, however they did present the highest frequency. Of the 166 examined teeth, 26 (15.5%) presented burning, from which 16 (61.5%) were from the first row. These alterations are more or less extensive over the teeth but are strictly limited to the enamel (Figure 4a). This result presents a difference in relation to that observed in experiment #2, in which only the teeth of the first row showed burning. This difference is certainly due to the use of two different species for the experiments, since the shape of the arches and the position of the teeth influence the intermittent exposure to flames. Small alterations of the jaw position on the grid can also act as a variable in the burning process of the teeth. Therefore, it is not possible to establish any standard for thermal alterations, even when the teeth were not directly exposed to flames.

Experiment #5

The fifth experiment was carried out as a continuation of experiments #1 and #2, and aimed to test the structural integrity of the teeth when directly exposed to fire, that is, how heat affects their physical integrity. The results of this experiment are useful for discussions about the presence/absence of burned shark teeth in combustion structures in archaeological sites, and their meanings.

Experiment #5 was performed placing the shark jaw of narrownose smoothhound (experiment #1) and the whole body of scalloped hammerhead (*Sphyrna lewini*) (experiment #2) directly over the flames and burning coals. This continued for 30 minutes, until the flames began to naturally extinguish. Approximately 90 minutes after the beginning of the experiment, there was no sign of embers. The ashes were then carefully screened in sieves of 1 and 0.5 millimeters to recover all teeth fragments.

Teeth of different species usually present a better resistance than any other organic material to general taphonomic processes due to the natural mechanical resistance of the enamel. However, the result of the screening showed that all the teeth were totally destroyed due to the direct contact with the flames. At this point it is important to note that shark teeth are covered by enamaloid material, richer in fluoroapatite, as seen in other species. Even if they were as hard as human teeth (Enax *et al.* 2012), the chemical composition of shark teeth is different, and the layer of enamaloid thinner (Berkovitz and Shellis 2017; Compagno 1984; Enault *et al.* 2015). As shown by the works of Lebon and others (2010; 2008), this difference of composition and heterogeneity can have an influence on the preservation and can be an element to explain the higher susceptibility of shark teeth to heat.

Experiment #6

The sixth experiment was carried out in the continuation of experiment #4, and aimed to test the color alterations and structural integrity of the teeth when directly exposed to flames.

The experiment was performed placing the shark teeth of the bigger blue shark (experiment #4) directly over the burning coals. The available set of twenty teeth was divided and the experiment was performed in two different steps. Firstly, 15 teeth were arranged on a piece of wood and placed on the coals (a grid was laid on the charcoal just to preserve the balance of the wood; Figure 4b). Wood was used because it was a widely available material in the studied contexts, and sufficiently fire resistant for the accomplishment of the experiment. The support was used to avoid the direct contact between the teeth and the burning coal, although there was direct, but intermittent, contact with the flames. The intention was to simulate the natural falling of teeth into the combustion structure, but not in the most active central area, to observe their behavior in relation to thermal alterations. The teeth and the fire's temperature were measured with an IR gun, and the teeth were removed from the support at intervals of one per minute.

The result of direct exposure of the teeth to the flames was the presence of burn marks that follow the same color pattern. The colors always ranged from white to shades of brown, and finally to black, following the increase in the temperature and time of exposure. As expected, this is the same pattern observed on the first-row teeth exposed to the flame in experiment #4 (Figure 4a and 4c). However, the intermittent direct exposure of the flames, varying according to the direction and intensity of the wind, limited the detailed observation of the burning process. The lack of constant heat did not permit the observation of a strict correlation between specific temperature, time, and color alterations. During the 15 minutes of the experiment the mean temperature over the wood was 162°C. Under these conditions, although some teeth had partially reached the carbonization stage, all of them remained intact. Therefore, from a broader perspective, the structural integrity was preserved.

In the second step of the experiment, the five remaining teeth were placed in direct contact with the flames and the burning coals (the grid was laid on the coal to prevent the loss of the teeth and enable observation of the process) (Figure 4d). The intention was to simulate the natural falling of teeth into the core area of the combustion structure to observe their behavior in relation to thermal alterations, specifically to structural integrity. The teeth were checked every minute until their visual destruction.

The result of direct exposure of the teeth to the flames and the burning coals was the straight coloring alteration from white to black. Between 2 and 5 minutes after reaching the calcination stage the teeth became totally destroyed, under a mean temperature of 599°C. Therefore, these data agree with those observed in experiment #5 regarding the reaction of the teeth when exposed directly to the fire. Although considered the most resistant organic animal tissue, it is susceptible to high temperatures and may completely disappear from the archaeological record.

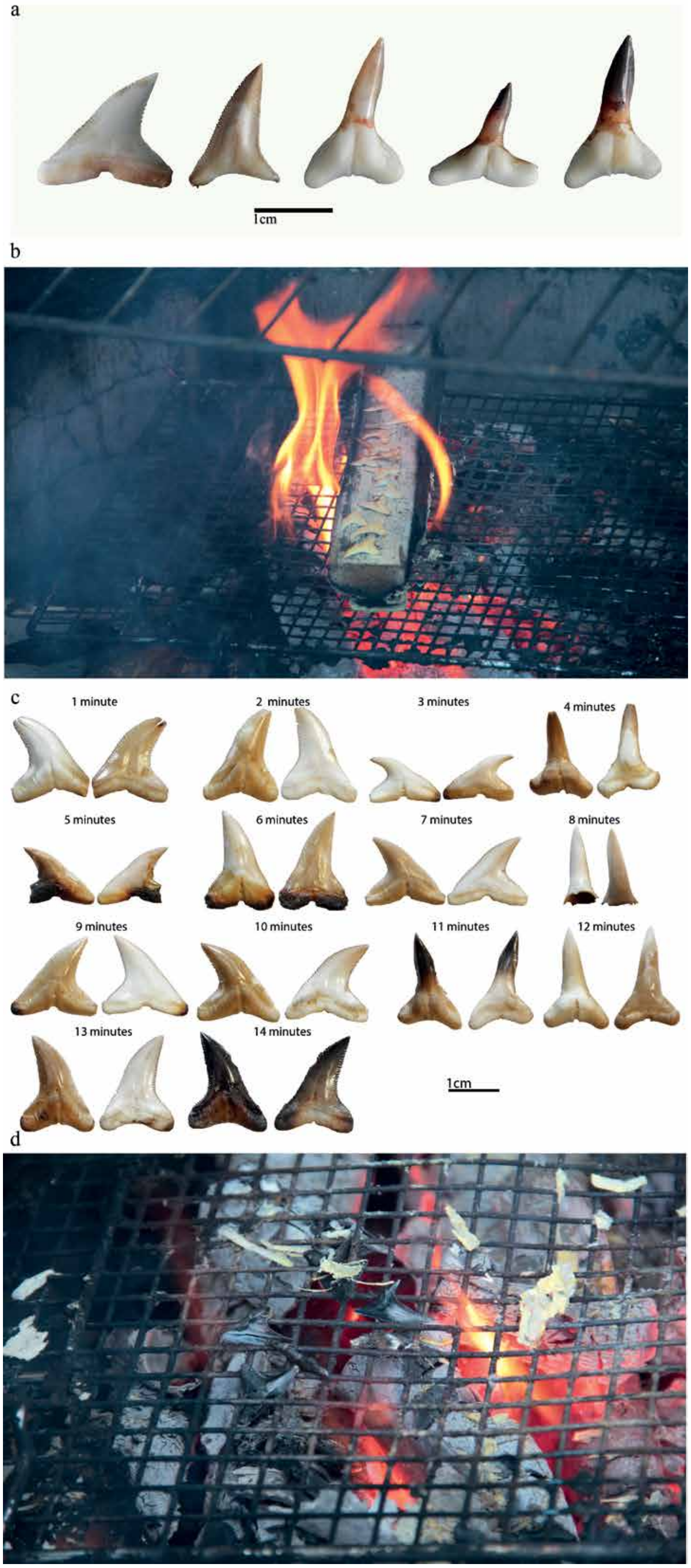

Figure 4. Techniques used in experiments #5 and #6 and reaction of the teeth: (a) Experiment #5 – burn marks recorded on the teeth of blue shark jaws; (b) Experiment #6 – teeth over a piece of wood; (c) Experiment #6 – color pattern of the teeth in direct contact with flames; (d) the teeth in direct contact with flames.

Discussion

Data obtained from the experiments performed with fresh sharks are quite interesting for discussions about the ancient techniques used for teeth extraction, as well as on the burn marks observed in those from archaeological collections. This issue goes beyond the scope of approaches to prehistoric technology, since it also relates to the lifestyle and interaction between coastal groups and the environment.

The courage, willingness, and knowledge needed to catch different shark species demonstrate the intense personal and social investment represented by this task. So, it seems natural to appreciate both the subsistence and symbolic significance. Certainly, there was a specific use for the different parts of the shark's anatomy, including the teeth. Being unique nonperishable elements, teeth were used by indigenous people for various purposes, during their life and after death.

However, the acquisition of this remarkable raw material did not constitute a simple task given the anatomical peculiarities of the shark's feeding apparatus. At this point it is important to remember that the task occurred in two stages: the opening of the mouth, and the detachment of the teeth. Nevertheless, the high number of shark teeth recovered in Brazilian archaeological sites, with anthropogenic alterations or not, clearly demonstrates how much they were appreciated and valued under different perspectives.

So, the use of appropriate techniques for the extraction of shark teeth is a relevant theme for discussions on daily activities, and their presence in archaeological contexts. However, this subject has not been studied until now, thus the experiments presented here should be considered as preliminary. As previously argued, heat extraction techniques were favored in this study and the positive results suggest that they have been effectively used. Eventually, other techniques could be contemplated but the arguments presented below do not support them.

Perhaps the first technique to be considered is the burial of the shark resulting in tissue decomposition and subsequent collection of the teeth. Although it does not require specific expertise, this technique has a major disadvantage: the high probability that the teeth will be lost to taphonomic processes. The south Brazilian coast, with a tropical climate and surrounded by the Atlantic forest, was inhabited by a rich fauna of varied species. Scavengers and the intense taphonomic processes of this environment (Compagno 1984) would be the main risk factors for teeth loss. If they were buried on the shore, coastline degradation and the permeability of sand are the main taphonomic factors. At this point, it is important to note how important it would be to choose the most appropriate technique for the task, since not all the teeth present in the jaw of a shark are suitable for the manufacture of artifacts. Indeed, a usewear study (Gilson *et al.* 2021) demonstrated that only the teeth of the first and second rows (the active teeth and those ready to take their place) are suitable to be used as part of a tool. Teeth located in the posterior rows are in different stages of formation, so do not have the necessary stiffness to be crafted. Considering these arguments, it is plausible to discard the use of this technique for teeth extraction by the native coastal groups.

Another considered technique would be the extraction of the teeth by using tools and manual labor. However, as discussed above, the connective tissues that surround the dental arch of the teeth are extremely rigid. Therefore, the application of this technique would involve maneuvers potentially risky to maintain the physical integrity of the teeth. On the other hand, percussion or cut marks indicating the use of tools or unsuccessful extractions were not observed in the roots or dental enamel analyzed in this work, nor were they reported in other studies. Once again, the waste of a valuable raw material, besides the risk of injury, allows the rejection of this technique.

Naturally, new studies may argue in favor of the use of other techniques for the extraction of shark teeth by native groups that occupied the Brazilian coast. But given the presently obtained data, the use of heat can be considered the most appropriate technique.

The hot water experiments (#1 and #3) demonstrated that this technique is perfectly adequate for the extraction of teeth, in that it facilitated the opening of the shark's mouth. It was also demonstrated that the water does not need to reach the boiling point, since the temperature was close to 80ºC in the clay pot. However, when exposed to higher temperatures the teeth detached more easily and cleanly. Another advantage of this technique is that it allows the full exploitation of the raw material, since the whole row of teeth disconnected as a set and any fallen teeth may be recovered in the bottom of the pot.

Shark teeth and clay pots are directly associated with the pre-colonial fishing-hunter-gatherer groups that occupied the Brazilian coast from the south to the natural barrier formed by the Serra do Mar (the so-called shallow sites) at a more recent time (Gilson and Lessa 2020), as well as with post-contact groups. This does not mean that only these coastal groups could use the hot water technique for shark teeth extraction. The immersion of the jaws could occur in other recipients than clay pots, also capable of heating water. For example, based on pre-colonial coastal evidence, Prous (2006) argues that some shell-mound builders (the so-called Sambaquis) that occupied the present Santa Catarina coast, dug small pits in accumulations of shells, which were covered with clay to make them impermeable. Thus, they could use them as containers for liquids and even to boil water, throwing hot rocks in it.

The fire contact experiments (#2 and #4) presented another appropriate technique for the teeth extraction, although some disadvantages were observed. The jaws of sharks opened spontaneously, and the exposure to heat melted the membrane that connects the teeth. Moreover, this technique does not require any container. In the case of bigger sharks, this could be an advantage even for coastal Brazilian pre-colonial ceramic groups due to the small size of their clay pots. According to Schmitz and coauthors (1988), Rogge and Schmitz (2010) and Rogge (2013), the pottery found in the shallow sites have small dimensions not exceeding 22 cm in diameter.

The downside of exposing the jaws directly to the fire is that some teeth may detach spontaneously and be lost in the coals, rapidly calcining and becoming unfit for use. This would explain the low frequency of teeth present in the combustion structures. But surely this situation could be minimized through careful monitoring of the process. At this point it is important to note that no experiment is able to estimate the number of teeth lost by the use of this technique, since the melting of the connective membrane and the spontaneous detachment depends on many variables.

The burn marks observed on the teeth (experiments #5 and #6) were also very relevant for the discussions at hand. The extraction techniques presented here demonstrated that the color changes present in shark teeth from archaeological sites may either be the result of direct intermittent exposure to the flames, or the result of contact with the hot coals in peripheral areas of the combustion structure. That is, they may be associated with the process of heating the jaws, or even with the discarding of teeth unsuitable for use as tools or adornments. Usewear analysis now under way will bring more light to this issue.

In both cases, the presence of these teeth with thermal alterations are not likely to be random, but guided by intentional behaviors based on predefined socio-cultural insights.

In feeding contexts, the teeth would be parts of hunting implements, such as arrowheads, which were inside the slaughtered animal taken to the campfire. This is a plausible situation, although the arrowheads could be recovered for reuse. The cartilaginous structure of sharks would not cause any damage to the teeth physical integrity.

Another possibility is that the shark's head would have been exposed to fire along with other parts of the body for consumption purposes. In this case, the presence of teeth with thermal alterations would be a fortuitous circumstance. This hypothesis, however, seems less plausible since consumption of the shark's head is unlikely, especially considering the dietary value of the large postcranial portion. Certainly, the head could be appreciated for symbolic or taste reasons, but it will hardly be possible to make this statement. Thus, functional coherence is the only analytical tool available to date, and from this perspective the use of heads would be for the extraction of teeth. It is important to note that studies on zooarchaeology, traceology, and experimental archaeology may provide data for consistent discussion on these issues. As already mentioned, this is a first approximation to the topic, which deserves greater investment through multidisciplinary approaches. The association between shark teeth and ritual fires has also not been the subject of specific studies, although it certainly seems promising.

Finally, it should be taken into consideration that the absence of burn marks on shark teeth does not negate the possibility they were subjected to heat for extraction. The use of hot water, or of the suspension system controlling the exposure to the heat of flames, may result in teeth without any thermal alteration. This is a typical case in which the absence of evidence is not evidence of absence.

Final remarks

The relationship between human groups and the much-feared sharks certainly became increasingly complex over time. During millennia of observation, errors, and successes, the techniques for the capture and processing of these animals were improved and the contact between both species intensified. Certainly, the more humans knew these lords of the seas, the more they admired and respected them. The presence of teeth close to their body, during life and after death, argues in favor of this idea.

Weapons, multifunction tools, amulets, ornaments. It does not matter here what purposes they had, but rather to emphasize that they were valuable elements carefully manipulated. The presence of shark teeth at archaeological sites, in any context, should be thought of as intentional, related to the various aspects of the native group's lives. The experiments presented here reinforce the idea that shark teeth with thermal alterations or their presence in combustion structures should not be understood as fortuitous situations, but rather as the result of intentional actions aimed at the use of raw materials.

Thousands of shark teeth remain stored in archaeological collections and many more will still be found. The experiments discussed here, when seeking to focus more closely on the lifestyle of ancient groups, open a new perspective for the study of this material and may raise relevant reflections to form a more consistent picture on the occupation of the Brazilian coast.

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Crafting white-tailed deer (*Odocoileus virginianus*) bone and antler at Cerro Juan Díaz (LS-3), Greater Coclé Culture Area, Panama

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Abstract

This paper refers to a feature at Cerro Juan Díaz (LS-3) in the Central Pacific coastal plains of Panama bordering Parita Bay. Covering 200 ha, this site was occupied between 300 BC and 1600 AD. The feature was cross-dated with pottery of the Cubitá stylistic horizon to 500-700 AD and contained abundant fragmented cultural and faunal materials. Analyses of human-modified mammal bones indicated that this feature, named "Operation 1/1B," represented a craft-specific work area. In Operation 1/1B, white-tailed deer (*Odocoileus virginianus*) remains were used for making tools and ornaments. Their taphonomy and usage are the primary concerns of this paper. The refuse in Operation 1/1B at Cerro Juan Díaz clearly represents the waste of a deer bone and antler workshop. In this site, we did not find the final products that were found at elite graveyards such as Sitio Conte. This workshop appears to have prepared tubes from long bones of white-tailed deer. Knowledge of bone industry techniques and methods may have been passed down from generation to generation within a family nucleus.

Resumen

Este capítulo hace referencia al yacimiento arqueológico de Cerro Juan Díaz (LS-3) localizado en las sabanas de la Bahía de Parita en la costa central del Pacífico de Panamá. Este sitio tiene una extensión de 200 ha y fue habitado entre 300 a. C. y 1600 d. C. En particular este capítulo se centrará en la operación 1/1B, la cual fue datada a partir de la presencia de la cerámica de estilo Cubitá entre 500 y 700 d. C. Esta excavación además de presentar abundante cerámica también tenía gran cantidad de restos de fauna. Nos enfocaremos en los restos modificados de venado de cola blanca (*Odocoileus virginianus*)

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los cuales fueron empleados para la fabricación de herramientas y ornamentos. Para tal fin se presenta un análisis zooarqueológico y tafonómico detallado. Los resultados encontrados evidencian que la operación 1/1B representa un área de taller en el que se usaron huesos y astas de venado. En este taller no se hallaron productos finales como los que se encontraron en las tumbas de élite de Sitio Conte. En este taller la producción de tubos elaborados con huesos largos de venado fue la prioridad. El conocimiento de las técnicas y métodos para la elaboración de dichos artefactos pudo haber pasado de generación en generación dentro de núcleos familiares.

Keywords: white-tailed deer, bone, antler, workshop, Panama, complex societies

Introduction

The white-tailed deer (*Odocoileus virginianus* Zimmermann 1780) is widely distributed from southern Canada to Brazil (Eisenberg 1989; Smith 1991). It is a polytypic species that has become well adapted to a wide range of habitats from temperate to subtropical, and semi-arid environments to rainforest and savannas (Eisenberg 1989; Emmons 1999). This species is well adapted to Neotropical wooded savannas (Emmons 1999). This biome prevailed over much of the Holocene landscape of Lower Central America, especially along the seasonally dry Pacific side of Panama, where it became one of the most important species over time to human populations that inhabited this area (Cooke *et al.* 2007, 2008; Cooke and Ranere 1992; Eisenberg 1989).

White-tailed deer antlers and bones served as raw materials to craft artifacts and ornaments throughout the Americas, for instance in Canada (Berg and Bursey 2000; Gates St-Pierre 2010; Gates St-Pierre, Boisvert, and Chapdelaine 2016; Gates St-Pierre *et al.* 2016), United States of America (Byrd 2011; Martin 1976; Moore 2017; Penders 2005; Wheeler and Coleman 1996), Mexico (Blasco Martín *et al.* 2019; Paris *et al.* 2020; Pérez Roldán 2005, 2013; Valentín and Pérez Roldán 2010), Guatemala (Emery 2008, 2009; Emery and Aoyama 2007), Belize (Boileau and Stanchly 2020), the West Indies (Giovas 2018), Panama (Cooke 2004; Cooke and Jiménez-Acosta 2010), Colombia (Correal Urrego 1990; Groot 1992) and Ecuador (Stahl and Athens 2002). In archaeological sites from these areas, deer bone workshops are connected with a particular social and economic organization and in some cases, they could also be linked to a symbolic and ritual world.

Wealth is seen through prestige items; rare, or highly desirable items meant to be displayed, rather than subsistence goods such as food, drugs, and production technology, used to meet basic household needs (Brumfiel and Earle 1987). Objects made from bone were powerful symbols of status and could represent the prestige value of the animal in the spiritual or symbolic world (deFrance 2009).

Animal bone artifacts are usually produced by a specialist. Specialized artisans are usually a minority of the group, and they dedicate most of their time to the manufacture of their products, which prevents them from dedicating themselves to other basic subsistence activities, being forced to exchange their crafts for basic products (Brumfiel and Earle 1987). That means that specialization involves economic differentiation and interdependence. One definition of specialization focuses on differential participation in economic activities (Costin 1991). In the archaeological record, the most common evidence of specialization is: 1) the presence of raw materials; 2) the concentration of manufacturing debris; 3) the abundance of tools; and 4) facilities associated with production (Costin 1991).

The production, exhibition, and distribution of wealth are politically important activities, therefore political development is usually accompanied by an intensification of elite-sponsored artisanal production. It is partially through the use of these artifacts that leaders define their own social status, and that of others, while at the same time, defining their associated rights and obligations (Johnson and Earle 2000).

This paper addresses the crafting of tools and ornaments made from white-tailed deer bone and antler based on a single feature (Operation 1/1B) within an extensive village known as Cerro Juan Díaz (LS-3). This is one aspect of the multi-faceted symbiosis between the white-tailed deer and pre-Columbian human groups on the Isthmus of Panama. Based on the literature available and the characteristics of the Gran Coclé culture, we expected to find evidence of specialization such as the presence of raw materials and concentrations of production debris within the same space in the settlement.

Presentation of the site

Cerro Juan Díaz (LS-3) (Figure 1b) is located on both banks of the La Villa River (Figure 1a). Today this river divides two provinces in the Azuero Peninsula: Herrera to the north and Los Santos to the south. A multi-annual archaeological project (1992-2001), supervised by Richard G. Cooke, documented human occupation at Cerro Juan Diaz (LS-3) (Figure 1c). Excavations began as a salvage operation requested by Panama's Institute of Culture because looters (known regionally as *huaqueros*) violated graves containing goldwork and caused damage to the site (Cooke and Sánchez Herrera 1997; Cooke *et al.* 1998). Fieldwork had to adapt to extensive damage caused by random looting (Cooke and Sánchez 2004). Over nine years, eleven excavation operations were undertaken. These varied in size from 2×1 m test-pits (Operations 3a and 22) to ~800 m^2 (Operation 31). The features identified during the operations varied greatly with regards to depth, topography, complexity, function and cultural and biological content. All the operations except one (Operation 2) showed evidence for some form of mortuary activity. Structures at Cerro Juan Díaz including domestic ones had puddled clay floors and roofs supported by stout poles. One that was completely cleared was circular and associated with a small family-type cemetery (Carvajal-Contreras, Sánchez, and Cooke 2006).

Cerro Juan Díaz was an archetypal ecotonal settlement. Subsistence practices reflected this: agriculture had plentiful maize fields in alluvial zones; fishing in inshore marine waters and in the mixing zone of estuaries; invertebrate collection in marine-coastal habitats and tidal rivers; hunting of iguanas, birds, medium-sized mammals, and deer along river banks, in open areas and in wooded savannas; and gathering of wild fruits mostly from human-tended palms (Carvajal-Contreras 1998; Cooke, Jiménez-Acosta, and Ranere 2007, 2008; Cooke *et al.* 2013; Dickau 2010; Jiménez-Acosta and Cooke 2001).

The first clear indication of human settlement at LS-3 goes back to about 300 BC. Potsherds of the La Mula Phase of the Greater Coclé ceramic tradition (Cooke 2011; Cooke, Isaza Aizpurua *et al.* 2003; Labbe 1995) are abundant in the basal layers that accumulated on the southern side of the 42 m-high eponymous hill (Cerro Juan Díaz) where the original inhabitants terraced the land behind. This small earthen platform was used for burials (Operations 3 and 4) (Figure 1c). Pottery from all the diachronic sub-divisions of the Greater Coclé ceramic sequence are recorded at LS-3. This confirms regularity of occupancy although occasional withdrawal from the site cannot be ruled out. Pre-Columbian people stopped living there after violent Spanish incursions in the second

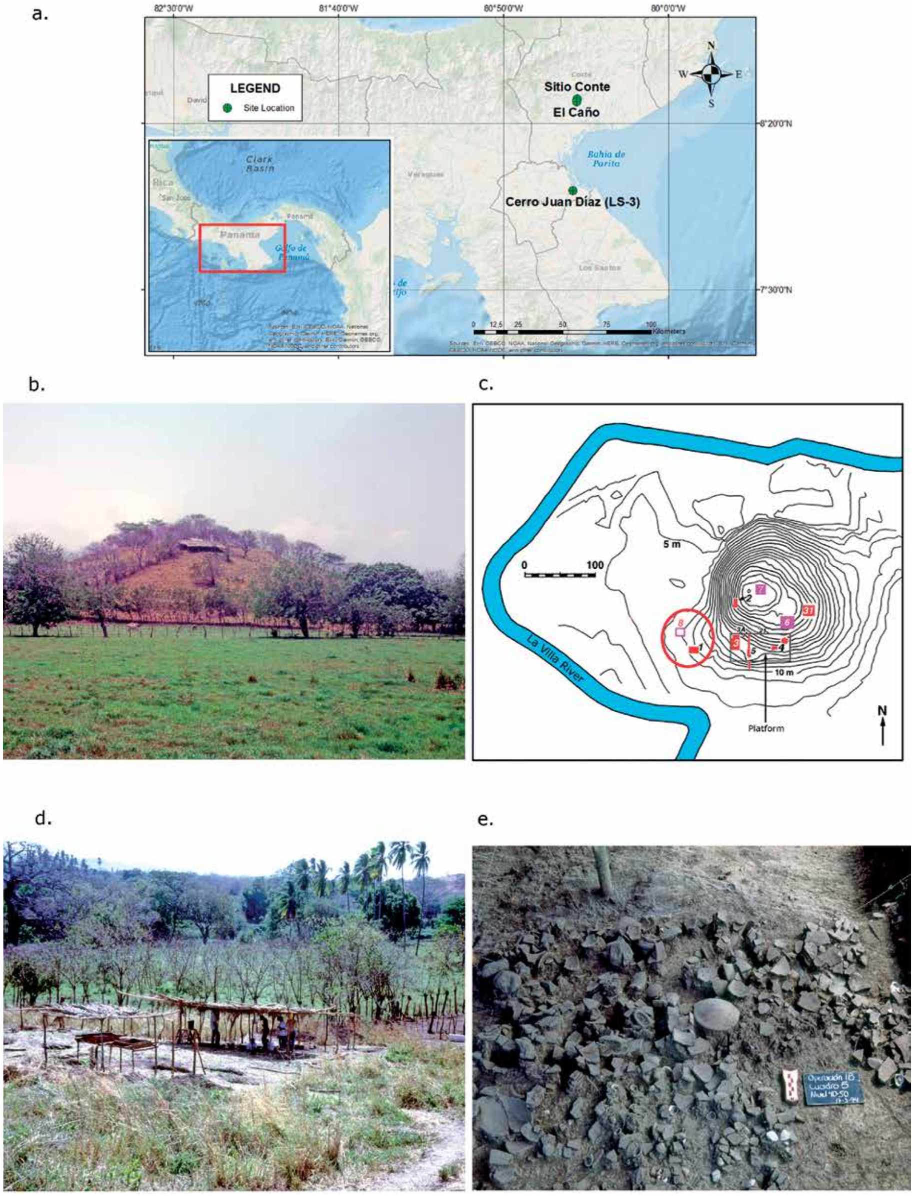

Figure 1. a. Cerro Juan Díaz (LS-3), Sitio Conte, and El Caño geographical location; b. View of Cerro Juan Díaz; c. Operations location at Cerro Juan Díaz, Operation 1/1B is located at the southwest corner of the archaeological site near Operation 8 (red circle). Adapted from Cooke and Sánchez Herrera (1997); d. Operation 1/1B during excavation. e. Detail of square 5, level: 40-50 cm, Operation 1/1B.

decade of the sixteenth century AD (Sauer 1966). However, the site was briefly occupied later in this century (*c.* 1575 AD) when an "Indian town" or "*pueblo de indios*" was founded by colonial managers on and around the central hill with non-local indigenous Americans of mixed cultural heritage (Cooke, Sánchez Herrera, *et al.* 2003).

The treatment and placement of the dead varied both synchronically and diachronically. These behaviors show a ranked society where some social groups had more privileges than others as evidenced by the associated burial elements that accompanied them. These were made with shells and in some cases with animal bones such as deer, also lithic and pottery and in a few cases, gold elements were found (Carvajal-Contreras 1998; Cooke, Jiménez-Acosta, and Ranere 2007, 2008; Cooke *et al.* 2013; Jiménez-Acosta and Cooke 2001; Díaz 1999). Field work in 1992 suggested that one individual in Operation 3, Feature 2, either had a high relative rank in the community or age group or practiced a particular occupation (*e.g.*, that of shaman-healer) (Cooke *et al.* 1998, 104-107). The objects that support this interpretation are two hammered high-carat gold plaques with convergent raised spirals, *Spondylus* beads, and 24 jaguar (*Panthera onca*) and puma (*Puma concolor*) canines. The inventory of artifacts in Operation 3, Feature 1, also included two ribbon-handled and red-slipped pottery incense burners. These have stylistic counterparts in graves in the south of the Azuero Peninsula where mortuary pottery belongs to the Tonosí Phase (200-500 AD) (Cooke *et al.* 1998).

In the shaft of Operation 3, Feature 2, seven tight bundles were carefully placed together in the west and south quadrants. Four AMS dates run on bone from four individuals in this group have a combined 2σ range of 345-583 calAD (Smith-Guzmán 2017). A polished agate bead (cf. Ichon 1980, Figure 86a) was found with package 8 in this group, which was a probable female aged between 18 and 21 years old (Smith-Guzmán 2017). Other agate beads of the same type were found with package 7 (a 35-year-old probable male) as well as with the very commingled packages 2 and 11. Five perforated canines of jaguar and puma were deposited in package 2.

In Operation 3, Feature 16, all artifacts were deposited with children (Smith-Guzmán 2016). Artifacts made of marine shell and animal teeth prevail. For example, 33 *Spondylus* shell pendants were found with an infant aged one or two years. In another bundle, a six- to seven-year-old child wore the most impressive array of ornaments in the grave unit: a hammered pure copper ring suspended (probably from the nasal septum) with twisted cotton string; 31 dog-shaped *Spondylus*; two polished stone bars, the largest of which was made from an unidentified bluish stone and is perforated longitudinally, and 74 perforated canines (55 puma canines in one group, while the other contained canines of two pumas, 12 ocelots [*Leopardus pardalis*], and four raccoons [*Procyon lotor*]). In terms of the relative material and symbolic wealth this group of children appears to have been internally ranked. If this holds true, it would suggest that their families or descent groups were also hierarchically ranked.

A different use for the sub-oven graves at Cerro Juan Diaz was provided by Feature 94 in Operation 3, which was cut by one of the stone-walled ovens. Consisting of a box-shaped tomb, it was used twice. The second burial ^{14}C dates to 436-648 calAD (Beta-147878: 1500±40 ^{14}C BP; calibrated with OxCal v. 4.4 (Bronk Ramsey 2009) and IntCal20 (Reimer *et al.* 2020)). The second interment, that of a young woman, was primary and flexed on the back. After being placed in the grave, large sherds from three deep ceramic bowls painted in the Cubitá style (typological age: 500-700 AD) were thrown in along with a legged metate of volcanic stone (Cooke and Sánchez Herrera 1997, Figure 6a; Cooke, Sánchez Herrera, and Udagawa 2000, Figure 8.6 bottom right). The Cubitá style is the one that prevails in the crafters' middens in Operation 1/1B. Also buried with the young woman in Feature 94 was a carved and polished frog with an anomalously long tail (Cooke, Sánchez Herrera, and Udagawa 2000, Figure 8.7u.), which had been mended with a string. The shiny white shell is likely a Pacific giant conch (*Lobatus galeatus*) and therefore possibly crafted in Operation 8, that is described as a shell workshop (Mayo 2004). Underneath the young woman, scattered human remains from an earlier interment were found intermingled with 97 ornaments made of mother-of-pearl (*Pinctada mazatlanica*) and a single perforated margin snail (*Prunum sapotilla*), a small ivory-colored marine gastropod.

The likelihood that the burials in the platform at Cerro Juan Díaz related to a descent group or one of its components is corroborated by the placement of graves in Operation 4 (Díaz 1999). This cemetery was used later in time rather than the sub-oven graves in Operation 3. Mortuary pottery and ^{14}C dates point to usage between 900 and 1200 AD. The cemetery is dominated physically by a large, deep pit cut into bedrock (Operation 4, Feature 4). Diaz estimated that 27 individuals were buried in Feature 4 (20 adults and seven children and infants) (Díaz 1999, Table 3c). The person buried at the bottom of Feature 4 was an adult woman placed near a very fine polychrome urn painted in the Late Macaracas style (Cooke, Sánchez Herrera, and Udagawa 2000, Figure 8.9a.). Seven extended burials were laid around the edge of Feature 4 but not in the center of the pit. Perhaps these individuals represented lower-ranked individuals of a particular descent group or sub-division thereof.

Other burials in Operation 4 were remarkably heterogeneous in size, form, and numbers and types of burial treatments. A family or descent group focus is indicated by single graves housing many forms of burial: in urns; primary extended; primary and secondary flexed, alone or in groups; and niches cut into bedrock (often containing several skeletons or parts of skeletons). Skulls without bodies were included in some graves. Tombs were constantly re-used (Cooke, Sánchez Herrera, and Udagawa 2000, Figure 8.6a-d). This funerary behavior is remarkably similar to the one observed at Playa Venado, *c.* 200 km east. The few artifacts that were placed with the dead in Operation 4 are comprised of monochrome and polychrome ceramic vessels, *Spondylus* animal effigies, abstract mother-of-pearl pendants and bone ornaments including trapezoidal plaques with perforations probably fashioned from deer long bones and deer tooth pendants (Díaz 1999; Cooke 2004, Figure 8k).

White-tailed deer bone and artifacts Operation 1/1B

Our study of white-tailed deer bone artifacts and ornaments refers to Operation 1/1B (Figure 1cde). The first excavation named Operation 1 was directed by Luis Alberto Sánchez and Adrián Badilla in 1992. They opened a 2×5 m area of excavation in a small alluvial flat on the south-western edge of Cerro Juan Díaz (LS-3) and about 30 m from the La Villa River (Figure 1b). They identified an ellipsoidal accumulation of sherds, lithics, shells and animal bones about 1.1 m on the longer axis, and about 0.2 m in depth (Feature 1 – *Rasgo* 1–, Operation 1). It seems to have built up quickly, as many sherds could be refitted indicating little post-depositional disturbance. The sherds were mixed with large amounts of marine shells and vertebrate remains: fish, amphibians, reptiles, birds, and mammals. The pottery belongs to the Cubitá ceramic group, which, as described above, dates between about 500 and 700 AD. The frequency of the "Ciruelo" type of plates confirms contemporaneity with burial feature 94 among the sub-oven graves in Operation 3.

Two years later, in 1994, Olman Solis expanded the original excavation to 6×13 m and revealed the full extent of the feature, which rested in a slight depression on a flat terrain (Figure 1de). The refuse lay stratified with post-holes, which form the edge of a circular or oval structure (Cooke and Sánchez Herrera 1997). The pristine artifact-bearing layer (Stratum B) is consistently about 20 cm thick but it would originally have been thicker as it extends into the 30 cm plow zone above it whose materials were collected but were thrown away for analysis (Stratum A). The matrix is mostly fine silt and ash (Figure 1e). Only one organic sample in the midden was radiocarbon-dated: a well-carbonized fragment of a maize cob. Its AMS date of 410-773 calAD (TO-4594: 1470±90 ^{14}C BP (calibrated using OxCal v. 4.4 (Bronk Ramsey 2009) and the calibration curve IntCal20 (Reimer *et al.* 2020)) is consistent with the ceramics associated with the feature but needs to be re-run since δ^{13}C was not calculated.

Materials

We analyzed white-tailed deer remains recovered during excavations conducted in 1992 and 1994 in Operation 1/1B at Cerro Juan Díaz. An undisturbed layer about 20 cm thick (Stratum B) was selected for analysis. It contained 3379 bone fragments inferred to belong to white-tailed deer, since this species is the only deer reported from this seasonally dry area of Panama, and the only one identified by zooarchaeological analysis at other sites. In Operation 1/1B, the term "Stratum A" was used for the plow zone. It was not included in the deer bone analysis because of the possibility of sediment-mixing. These remains were analyzed and identified by using a modern reference collection housed at the Smithsonian Tropical Research Institute (STRI) Archaeology Laboratory in Panama City.

Methods

María Fernanda Martínez-Polanco's zooarchaeological analysis employed several units of quantification:

1. *Number of Remains* (NR): This metric refers to the total number of remains that make up the zooarchaeological assemblage. It takes into account the total of the remains conserved as a whole, without considering the precision of the taxonomic or anatomical determination (Reitz and Wing 2008, 166).
2. *Number of Identified Specimens* (NISP): This index considers only the bone remains that were identified taxonomically (class and below). This index usually provides lower numbers than the NR (Reitz and Wing 2008, 167).
3. *Minimum Number of Elements* (MNE): Lyman (1994, 290) defines MNE as the "minimum number of complete skeletal elements necessary to account for all observed specimens." This index quantifies the elements belonging to an individual, whether they are whole or fragmented. For this quantification, it is necessary to take into account different variables of each identified bone fragment, such as the area of the bone, the face, its position in the skeleton, the number of times that it appears in the skeleton and its age.
4. *Minimum Number of Individuals* (MNI): This index is calculated by summing the most frequent anatomical element that belongs to a taxon, taking into account laterality, age and size (*sensu* White 1953; Reitz and Wing 2008). It does not reflect the real abundance

of an animal and is only a guide to the real number of individuals present in the death assemblage. Neither does this index imply that the animals were complete when the accumulation was formed (Reitz and Wing 2008).

5. *Minimum Anatomical Units* (MAU)*:* MAU is obtained by dividing the number of taxonomically identified elements (MNE) by the number of times this element appears in a complete skeleton. %MAU is the relativized scale obtained by dividing the MAU for each element by the greatest MAU and multiplying by 100. Subsequently, the %MAU was compared against the utility index proposed for white-tailed deer by Madrigal and Holt's (2002) modification of the index proposed by Binford (1984), and the simplified index of Metcalfe and Jones (1988). For this purpose, the MAU of the long bones was obtained by dividing by two, the phalanges by eight, the cervical vertebrae by five (excluding the atlas and the axis), the thoracic vertebrae by twelve and the lumbar vertebrae into seven (Madrigal and Holt 2002). Then a scatter graph was produced, on the X axis is the utility index and on the Y axis the %MAU and a correlation coefficient (Spearman's rho) was calculated between these variables.

The age at death of white-tailed deer was established by reference to epiphyseal fusion, tooth eruption sequence, and tooth wear. Two age categories were used: sub-adults (<24 months) and adults (>24 months) (Severinghaus 1949; Purdue 1983). This deer species exhibits sexual dimorphism, and María Fernanda Martínez-Polanco identified males when antlers were present (Smith 1991).

The differential destruction of bone may be influenced by its intrinsic characteristics, such as its density. Another influence is the intensity of external forces that act on the bone (Lyman 1994). In order to determine sample integrity, MAU and its frequencies were calculated (Lyman 2008) as well as the conservation differential in relation to bone density (VD). We used Lyman's (1994) averaged values following Reitz and Wing (2008). We plotted volume density (VD) against NISP and calculated a correlation coefficient (Spearman's rho) between these variables. In order to determine skeletal completeness, we compared archaeological bone frequencies with the expected frequencies if the deer skeleton were complete, applying the following equation:

$$d = \ln X - \ln Y$$

X is the percentage of each skeletal portion (% NISP) and Y is the percentage of the same portion in a complete skeleton; both are standardized by using the natural logarithm (ln). In this type of graphic, positive values imply that the skeletal portions are overrepresented and negative values indicate that the skeletal portions are underrepresented compared to the standard (Reitz and Wing 2008). The skeletal portions were organized as follows: Head (cranium, mandible, maxilla); Axial (Atlas, axis, lumbar, thoracic, cervical, and sacral vertebrae, sternum, ribs); Forequarter (scapula, humerus, ulna, radius); Hindquarter (acetabulum, ilium, ischium, femur, patella, tibia); Forefoot (scaphoid, trapezium, uncinated, lunate, metacarpal, rudimentary metacarpal); Hindfoot (metatarsal, astragalus, calcaneus, cuboid, cuneiform, intern cuneiform); and Foot (metapodials, proximal, medial, and distal phalanx) (Reitz and Wing 2008). To study long bone representation, we recorded the anatomical zone (proximal, medial, distal, whole) of the long bones.

The remains found in archaeological sites are characterized by the high degree of fragmentation, which could be caused by different taphonomical agents such as animal/human agents and/or physical processes. In order to distinguish the agent of the fragmentation (physical or animal/human) two different concepts could be used; fragmentation when the cause is a physical process, and fracture when an animal/human agent is responsible (Fernández-Jalvo and Andrews 2016).

The inherent characteristics of the bone produce different breakage patterns depending if the bone is green or dry (Bunn 1983; Villa and Mahieu 1991). Green bones have a high degree of plasticity, but they could break when the pressure is greater than their strength. In these cases, the fracture follows the natural lines in the structure of the bone. The fractures are produced by an animal/human agent when the bone is fresh, because their intention is to obtain the nutrients that are inside the bones (Bunn 1983; Villa and Mahieu 1991). A different case is the fragmentation of the dry bone. The physical characteristics of the bone change over time, losing moisture and other organic properties, and becoming fragile and brittle. As such, dry bones react differently under pressure, forming perpendicular cracks. This kind of fragmentation is produced by physical processes (natural processes) without any intentionality (Bunn 1983; Villa and Mahieu 1991).

For the purpose of identifying the an animal/human agent causing the bone breakage and the surface alteration we distinguished color changes in the outlines and also fracture angle for distinguishing an old breakage (occurring at or near the time of deposition) from a new breakage (occurring during or after the excavation) (Steadman, Plourde, and Burley 2002). Villa and Mahieu (1991) observed that the fractures are curved with oblique angles and smooth surfaces, while fragmentation is transversal with straight angles and smooth or irregular edges.

Butchering consists of a set or series of sets of human activities directed towards the extraction of consumable resources from a carcass (Lyman 1994). Preparing carcasses for consumption involves a series of activities that includes the extraction of external nutrients (skin, meat, and tendons) to obtaining internal resources (fat and marrow) (Binford 1981). Butchery marks can be identified in the archaeological record; they are known as cut marks. They are linear grooves, with a variable longitude and width. The transversal section of a cut mark has a “V” shape, and their walls and the bottom present microstriae (Potts and Shipman 1981; Shipman and Rose 1983a; 1983b). According to Binford (1981), cut marks can result from three activities: 1) skinning; 2) disarticulation; and 3) filleting (Binford 1981). Skinning is the activity that refers to the extraction of the animal’s skin, separating it from the rest of the body. This type of cut mark is produced in areas with little muscle mass, such as the skull, mandible, distal radius, and tibia, and on the metatarsals (Binford 1981). Disarticulation consists of dismembering the animal into smaller units. This type of activity is carried out to facilitate the transport of the animal and is done following the anatomy of the animal. The disarticulation marks are located at very specific points, on articular surfaces of the ends of long bones and on the surfaces of vertebrae or pelvic parts (Binford 1981). Defleshing (aka filleting) is the extraction activity for meat, which is attached to the bones. This process is one that leaves the greatest number of marks. Although they can be found on all the skeletal parts of the animal, they occur more frequently in the parts with less muscle mass. They are very frequent in the diaphysis of the long bones, but also in the metaphyses of the bones, particularly in areas of muscle insertions (Binford 1981).

The manufacturing process for bone tools involves a series of activities. Abrading is the reduction of the surface material using a grinding implement such as a sandstone abrader. Abrasion used in the manufacture of tools results in striations, a series of thin, parallel lines. Chopping is a percussive action where a relatively heavy tool cuts into the raw material resulting in a series of notches in the chopped surface. Cutting is produced with sharp tools which are pushed and pulled over the surface leaving incisions in the form of small channels. Grooves are generally larger, deeper versions of incisions. Incising and grooving are two actions that are performed during the cutting of the raw material. Scraping is an action aiming at reducing and shaping the surface of the raw material by pulling and pushing a scraping tool over the surface while applying pressure. The resulting debris is often dust-like pieces of material. Finally, polishing is an action which adds luster to the surface of osseous tools, achieved through abrasion with a very fine stone and often soft materials such as hide (Nagy 1990; Pérez Róldan 2005; Pérez Roldán 2013).

Surface alterations were identified macroscopically and microscopically. All skeletal specimens were examined using a stereomicroscope (Leica Wild M10, up to 120x). The analysis of cut marks took into account the number of striations, location on the anatomical element, distribution over the surface (isolated, clustered, and crossed), orientation with respect to the longitudinal axis of the bone (oblique, longitudinal, and transverse), and delineation (straight or curved). By studying the anatomical location and orientation of a cut mark and the function of a particular category of mark suggested by its location and orientation the cut mark could be assigned to a different activity (Binford 1981; Potts and Shipman 1981; Shipman and Rose 1983). The pictures of the cut marks were taken with a 3D digital microscope (HIROX KH-8700, MXG-2500REZ, 35-250x). Six degrees of thermal damage were identified from 0 (unburned) to 5 (calcined); degree #6 was used for specimens with two or more burning hues using the criteria of Stiner *et al.* (1995).

Tooth marks were analyzed and compared systematically in order to distinguish between human and non-human marks (*i.e.*, those made by carnivores and rodents). Human tooth marks were classified as pits (ovoid shape and shallowness) and scores (elongated shape and internal crushing) (Landt 2007). Carnivore and rodent marks were analyzed; carnivore marks were classified as pits, punctures, and scores (Binford 1981; Selvaggio 1994). Other damage produced during consumption, such as notches, crenulated edges or pitting, was recorded; these marks' distribution, orientation, and dimensions were all recorded. Finally, post-depositional modifications were also recorded, such as manganese, adhering concretions, root damage, and weathering probably commensurate with humidity (Grayson and Delpech 1998; López-González *et al.).*

Results

Zooarchaeological analysis

In Operation1/1B at Cerro Juan Díaz, 3379 remains of white-tailed deer were found in our samples; the MNE calculated for the assemblage is 604 (Table 1). A total of 11 individuals was identified and nine of them were adults, and two were subadults – at least seven males and one female.

Element	NISP	%NISP	MNE	%MNE
Occipital	3	0.09	2	0.33
Basioccipital	3	0.09	3	0.50
Exoccipital	8	0.24	7	1.16
Supraoccipital	1	0.03	1	0.17
Presphenoid	2	0.06	1	0.17
Parietal	1	0.03	1	0.17
Interparietal	1	0.03	1	0.17
Squamosal	5	0.15	3	0.50
Frontal	4	0.12	2	0.33
Antler	36	1.07	20	3.31
Zygomatic	5	0.15	4	0.66
Premaxilla	1	0.03	1	0.17
Maxilla	3	0.09	3	0.50
Tympanic bulla	16	0.47	14	2.32
Mandible	26	0.77	19	3.15
Incisor	2	0.06	2	0.33
Molar	35	1.04	35	5.79
Premolar	30	0.89	30	4.97
Atlas	6	0.18	5	0.83
Axis	1	0.03	1	0.17
Lumbar vertebrae	10	0.30	8	1.32
Thoracic vertebrae	15	0.44	15	2.48
Cervical vertebrae	13	0.38	7	1.16
Sacral vertebrae	3	0.09	3	0.50
Sternum	6	0.18	3	0.50
Ribs	40	1.18	20	3.31
Scapula	31	0.92	14	2.32
Humerus	35	1.04	17	2.81
Ulna	25	0.74	14	2.32
Radius	34	1.01	17	2.81
Scaphoid	8	0.24	8	1.32
Trapezium	9	0.27	9	1.49
Uncinate	8	0.24	8	1.32
Lunate	9	0.27	9	1.49
Metacarpal	23	0.68	12	1.99
Rudimentaary metacarpal	13	0.38	13	2.15
Acetabulum	2	0.06	2	0.33

Table 1. NISP (Number of Identified Specimens) and MNE (Minimal Number of Elements) of white-tailed deer in Operation 1/1B at Cerro Juan Díaz.

Element	NISP	%NISP	MNE	%MNE
Ilium	2	0.06	2	0.33
Ischium	2	0.06	2	0.33
Femur	51	1.51	28	4.64
Tibia	45	1.33	21	3.48
Patella	4	0.12	4	0.66
Metatarsal	39	1.15	16	2.65
Astragalus	18	0.53	18	2.98
Calcaneus	19	0.56	13	2.15
Cuboid	9	0.27	9	1.49
Cuneiform	6	0.18	6	0.99
Intern cuneiform	2	0.06	2	0.33
Metapodials	34	1.01	29	4.80
Phalanx prox.	54	1.60	51	8.44
Phalanx med.	49	1.45	44	7.28
Phalanx dist.	25	0.74	25	4.14
Phalanx unidentified	9	0.27		
Cranial fragment	7	0.21		
Vertebra fragment	29	0.86		
Long bone fragment >2 cm	640	18.94		
Long bone fragment <2 cm	1862	55.11		
TOTAL	3379	100.00	604	100

Table 1. continued.

Anatomical representation – MAU

The highest %MAU values were femur, followed by tibia and mandible (Table 2). At Operation 1/1B, it is observed that MAU is insignificantly correlated with meat gross yield ($r_s = 0.12$; $p = 0.75$) and significantly correlated with marrow gross yield ($r_s = 0.75$; $p = 0.02$) (Figure 2). There is no evidence of differential transport of high-yield meat bones to the site. In contrast, bones with higher marrow gross and return rates are more abundant and are more fragmented. Positive correlations between long-bone element abundances and marrow yields at Operation 1/1B may show evidence of processing marrow and/or bone artefact production after bones had been brought back to the site.

It is interesting to point out the relatively high number of isolated teeth (NR=67: incisor=2; molar=35; premolar=30) (Table 1). It is possible that they were selected for crafting activities.

Element	MNE	Occ.	MAU	%MAU
Mandible	19	2	9.50	67.86
Maxilla	3	2	1.50	10.71
Atlas	5	1	5.00	35.71
Axis	1	1	1.00	7.14
Lumbar vertebrae	8	7	1.14	8.16
Thoracic vertebrae	15	12	1.25	8.93
Cervical vertebrae	7	5	1.40	10.00
Ribs	20	26	0.77	5.49
Scapula	14	2	7.00	50.00
Humerus	17	2	8.50	60.71
Ulna	14	2	7.00	50.00
Radius	17	2	8.50	60.71
Trapezium	9	2	4.50	32.14
Uncinate	8	2	4.00	28.57
Lunate	9	2	4.50	32.14
Metacarpal	12	2	6.00	42.80
Acetabulum	2	2	1.00	7.14
Ilium	2	2	1.00	7.14
Ischium	2	2	1.00	7.14
Femur	28	2	14.00	100.00
Tibia	21	2	10.50	75.00
Patella	4	2	2.00	14.29
Metatarsal	16	2	8.00	57.14
Astragalus	18	2	9.00	64.29
Calcaneus	13	2	6.50	46.43
Cuboid	9	2	4.50	32.14
Cuneiform	6	2	3.00	21.43
Intern cuneiform	2	2	1.00	7.14
Phalanx prox.	51	8	6.38	45.54
Phalanx med.	44	8	5.50	39.29
Phalanx dist.	25	8	3.13	22.32

Table 2. MNE (Minimal Number of Elements), MAU (Minimal Animal Units), MAU% of white-tailed deer from Operation 1/1B Cerro Juan Díaz. Occ.: Occurrence (number of bones in skeleton).

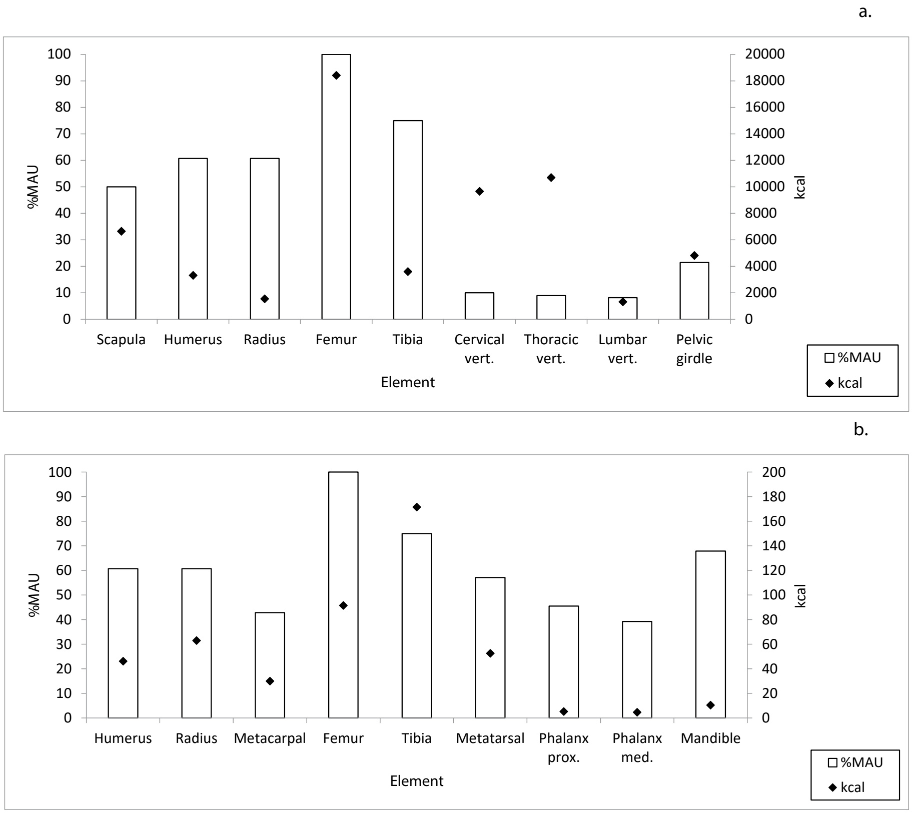

Figure 2. Scatter plots a. kcal meat and %MAU and b. kcal bone marrow %MAU.

Volume density (VD)

There is a statistically insignificant negative correlation between NISP and VD (r_s=-0.24, p=0.24) (Figure 3). These results suggest that density-mediated attrition was not responsible for the varying frequencies of skeletal parts.

Skeletal completeness

Forefoot, hindquarter, and hindfoot tend to be over-represented but not at the same level, as the forequarter and foot seems to be slightly under-represented but not as much as the axial skeleton (Figure 4). These results imply that the animal was brought complete to the settlement.

Long bone representation

Two hundred fifty-two remains belonged to long bones (7.45%); the best represented zone was the proximal, followed by distal, medial, and whole bone (Figure 5). All the long bones present shared the same pattern of zonal distribution except the ulna that only preserves the proximal portion.

The long bone fragments are the most abundant in the sample (74.05%), this group was divided into two categories, those that measured less than 2 cm (55.11%) and those that measured more than 2 cm and less than 4 cm (18.94%) (Table 1). The smallest could be considered as debitage. These fragments do not have a standardized

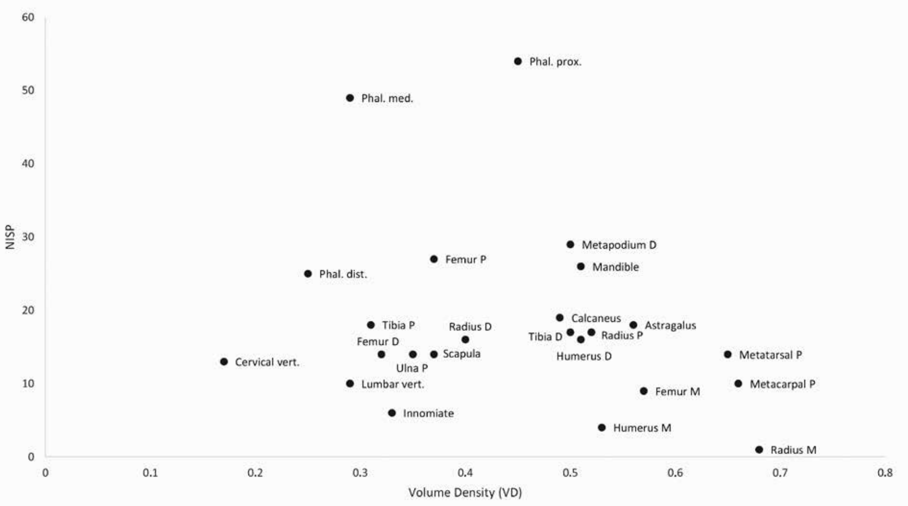

Figure 3. NISP (Number of Identified Specimens) against VD (Volume Density) values of white-tailed deer identified at Operation 1/1B Cerro Juan Díaz.

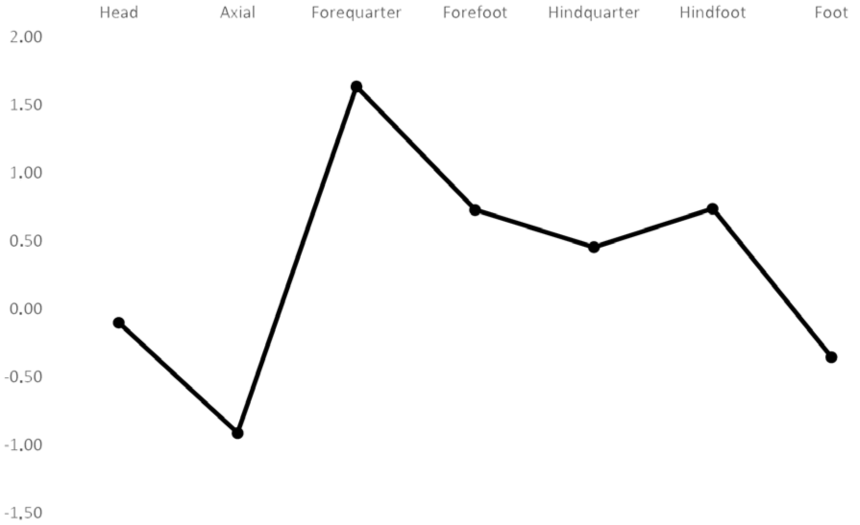

Figure 4. Ratio diagram of skeletal portions using NISP (Number of Identified Specimens) of white-tailed deer identified at Operation 1/1B Cerro Juan Díaz.

shape that would allow them to be classified as beads. Unfinished deer bone tubes were found in Operation 1/1B but the majority of specimens are proximal and distal portions of long bones that had been cut to make tubes (Section debitage; NISP=32; 0.94%) (Figure 5; Figure 6). The long bone > 2 cm category includes specimens that present evidence of anthropic fractures (NISP=63; 1.86%). All of these specimens are considered as craft production remains. However, finished deer bone tubes were not found in this operation (Table 3).

	NISP	%NISP	%NISP total sample
Section debitage	32	1.63	0.94
Debitage (long bones >2 cm) Fracture evidence	63	3.21	1.86
Debitage (long bones <2 cm)	1862	95.14	55.11
Finished deer bone tubes / artifacts	0	0	0
Total	1957	100.00	

Table 3. Percentages and frequencies of white-tailed deer bone reduction.

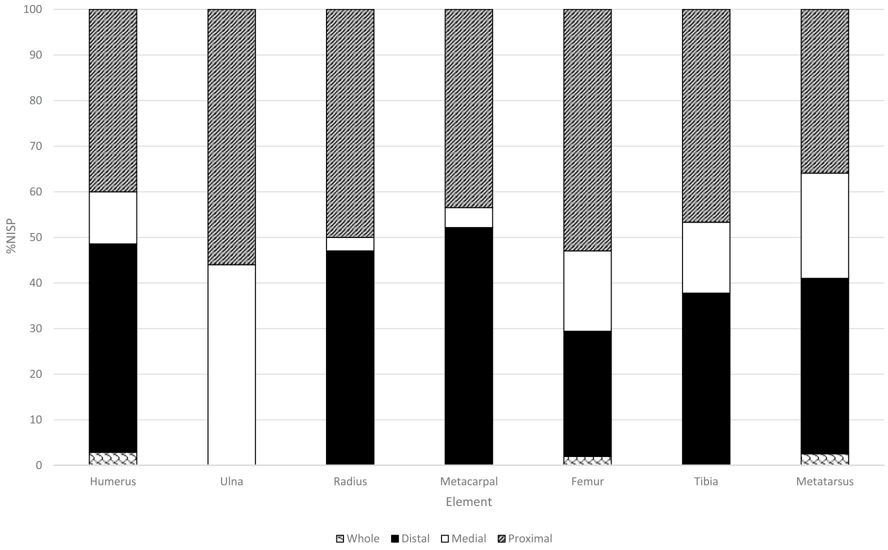

Figure 5. Long bone %NISP arranged by elements of white-tailed deer identified at Operation 1/1B Cerro Juan Díaz.

In Figure 6, it can be observed that the femur at different stages of fusion was used to produce bone tubes. It is important to mention that initial fusion of the proximal part begins at 20 months and finishes between 32 and 38 months of age. In the case of the distal end fusion, the timing is between 23 and 38 months (Purdue 1983). This implies that the Operation 1/1B crafters selected young adult deer bones to produce bone tubes. In only two cases were unfused distal humeri found; this part begins to fuse at 2 months, and it is completely fused between 12 and 20 months. This represents the two sub-adults of the sample. Figure 6 also illustrates the transversal clean cut both in the proximal (a, b, c, and d) and distal (f and g) sectors of the femur.

The only bone tube found at Cerro Juan Díaz can be seen in Figure 6e. The length of the tube is 106.5 mm, the width is 21.8 mm and the thickness is 2.54 mm. The proximal part of the tube has a series of fine horizontal grooves with a very shallow depth that may have been produced by abrasion when the thickness of the bone was being reduced. This tube is polished on all sides including the edges.

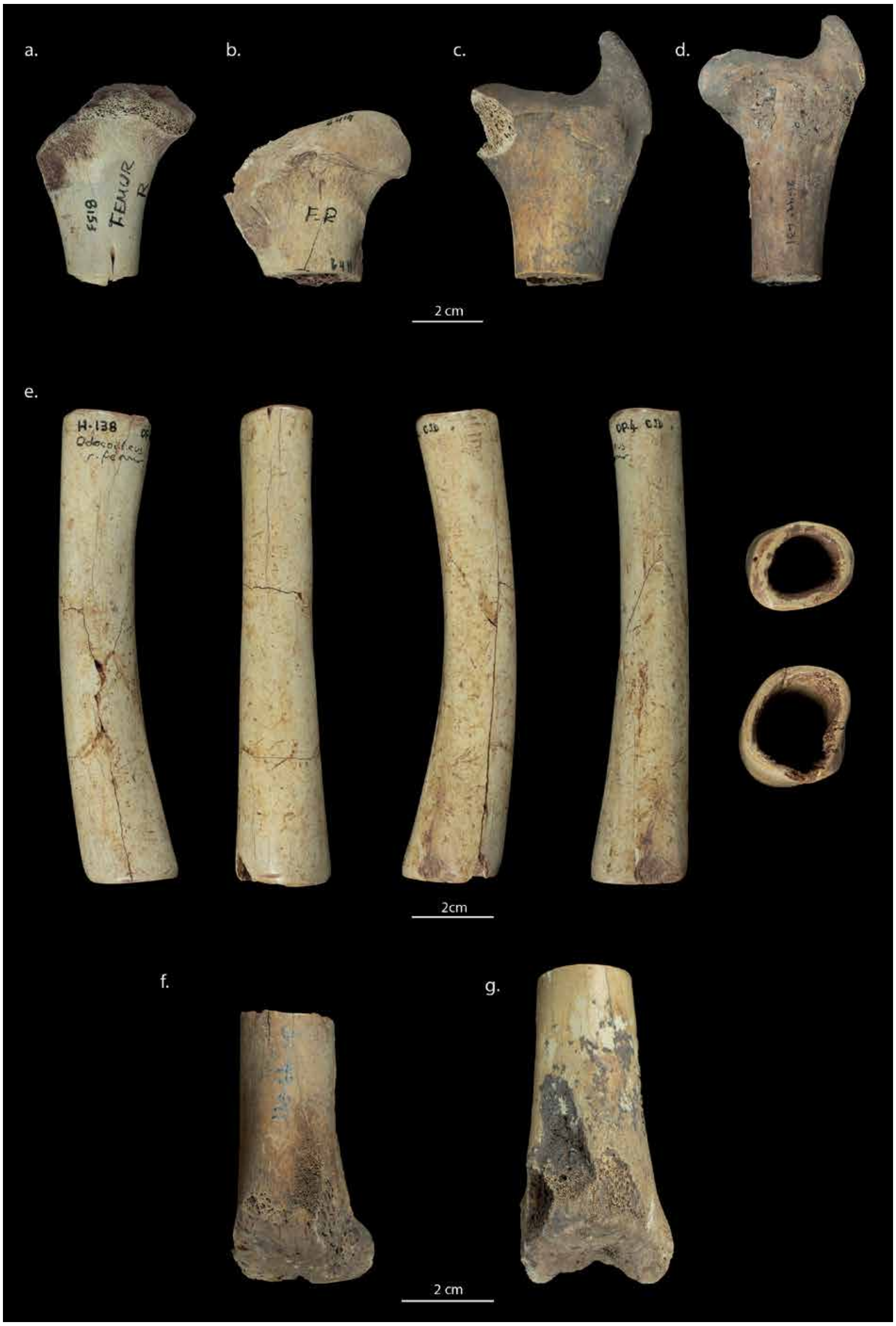

Figure 6. Stages of manufacture of long bone tubes made of white-tailed deer femur identified at Operation 1/1B Cerro Juan Díaz. a. Unfused right proximal femur; b. Fused right proximal femur; c. d. Fused left proximal femur; e. Bone tube from a right femur diaphysis; f. Unfused right distal femur; g. Unfused left distal femur. Scale is 2 cm.

Anthropic modifications				**Post-depositional modifications**			
	NISP	%NISP ant. mod.	%NISP total sample		NISP	%NISP post. mod.	%NISP total sample
Cut marks	45	23.44	1.33	Rodents	21	22.83	0.62
Burning damage	84	43.75	2.49	Concretion	44	47.83	1.30
Fractures	63	32.81	1.86	Roots	25	27.17	0.74
				Manganese	2	2.17	0.06
NR	192	100.00		NR	92	100.00	

Table 4. Anthropic modifications and post-depositional modifications on white-tailed deer bones at Operation 1/1B Cerro Juan Díaz.

Taphonomic analysis

Anthropic modifications

Anthropic modifications to deer bones were identified on 192 remains (5.6%), and most of them consisted of burning damage, fractures, and cut marks (Table 3, Figure 6-7).

Bone fracture patterns

Sixty-three (4.15%) deer remains in Operation 1/1B show percussion marks, cortical flake negatives and medullar flakes (Table 4).

Cut marks

One hundred ninety-five cut marks were identified on 45 elements representing 1.33% of the total sample. Cut marks are notable for being fairly deep straight incisions (61.53%). Superficial scraping (36.41%) and deeper hack marks (2.05%) were also observed. The position of the cut marks infers skinning (35.55%) more than other activities such as defleshing (33.33%) and disarticulation (17.77%) The remaining 13.33% are cut marks identified on antlers that could not be assigned to any of the former activities. Several cut proximal and distal portions of long bones were not only identified on the femur, but also on the radius, ulna, metacarpal, tibia, and metatarsal bones. Along the bone edges, cut marks were produced at the precise moment when the bones were cut (Figure 6).

Burning damage

Eighty-four elements show signs of thermal alteration, representing 1.30% of the sample (Table 4). The majority shows double color (40.48%) and color grade 3 (39.29%), which implies that meat was cooked and consumed. However, it is striking that 16 of the 84 elements were antlers. This may indicate that fire was also used in the production of bone artifacts.

Tooth marks

We did not identify human tooth marks in the sample from Operation 1/1B.

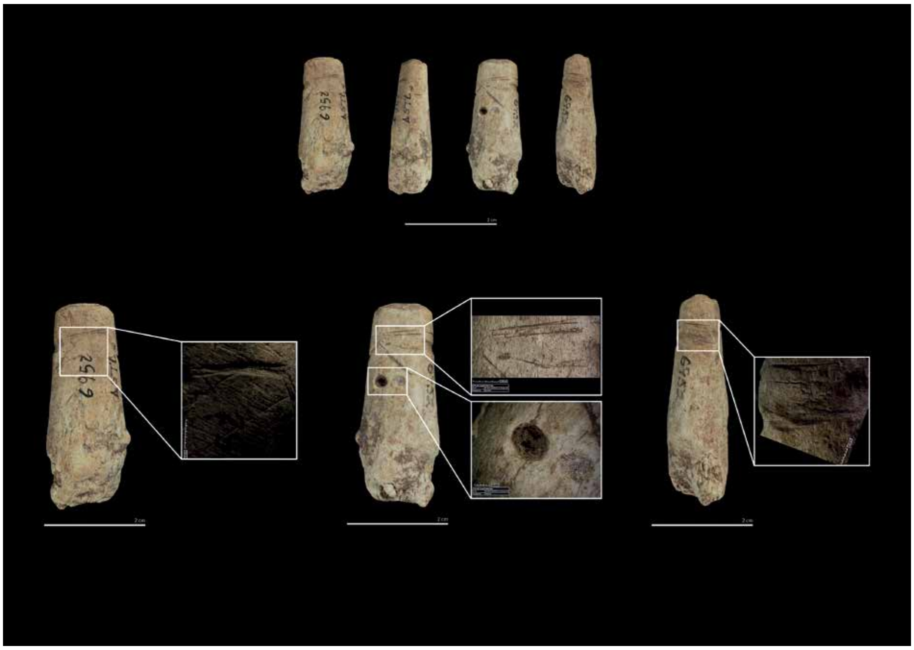

Figure 7. Details of white-tailed deer antler modifications (fairly deep straight incisions and small pit) recovered at Operation 1/1B Cerro Juan Díaz. Scale is 2 cm.

Post-depositional modifications

Post-depositional modifications were identified on 92 remains (2.72%). Concretions (47.83%), root damage (27.17%), rodent gnawing (22.83%), and manganese stains (2.17%) were the most prevalent (Table 4). Carnivore tooth marks were not identified in the assemblage.

Discussion

At Cerro Juan Díaz, a significant quantity of deer remains was found in Operation 1/1B, many of which show traces of human modifications, the most notable being traces of artifact manufacturing. These remains were deposited between 500 and 700 AD and were also placed there partly for nutritional purposes. This idea receives support from the deposition of bones with high meat values such as the femur and tibia, cut marks related to skinning, defleshing, and disarticulation, and signs of burning which points to cooking activities.

Nutrition was not the only goal as many of the cut marks on antlers in Operation 1/1B are clearly related to non-subsistence activities (Figure 7). The choice of materials for the crafting of tools was predicated upon availability, mechanics, the shape of the final product, and traditional practice. Long bones (humerus, radius, metacarpal, femur, tibia, and metatarsal) were selected to produce bone tubes (Figure 5).

Unfinished deer bone tubes were found in Operation 1/1B but the majority of specimens are the proximal and distal portions of long bones that had been cut to make tubes, and we consider these debitage (Figure 4, Figure 6) (*i.e.*, Cooke and Jiménez-Acosta 2010, Figure 3.6j). Small cut marks are visible along the edges of long bones prior to the final sectioning of the diaphysis from the proximal and distal ends. A complete tube made of a white-tailed deer femur shaft was found in a burial (Feature 10) in Operation 4, suggesting that deer bone artifacts produced in Operation 1/1B were used in other sectors of the settlement.

The transformation of long bones into tubes implies the selection of bones of young adults. The extraction of the proximal and the distal end of the bones occurs first. Next, abrasion is used in order to reduce the thickness of the element or to obtain more regular surfaces and finally the polishing of the tube (Figure 5). The large number of long bone fragments less than 2 cm may reflect the manufacturing of other artifacts, but since we do not have many finished objects in the deposit, it is difficult to establish the reduction sequence of any product. Although we did not find direct evidence of modifications in deer teeth, the relatively high number of isolated elements leads us to think about a selection or preselection of elements to produce pendants, such as those found in other operations (*i.e.,* Operation 4; Operation 1/1B stratum A).

The Sitio Conte elite burial ground is located 12 km inland from the present-day Parita Bay coastline and about 43 km linear distance from Cerro Juan Díaz across Parita Bay (Figure 1a). Most graves are now estimated to belong to the period cal 750-950 AD, with a few being slightly earlier or later (700-750 and 950-1000 AD) (Cooke, Sánchez Herrera, and Udagawa 2000). At this site, mortuary goods were deposited abundantly near human remains and can be classified into three groups: 1) costume items such as helmets, necklaces, shirts, belts, danglers, and ankle decorations, 2) ritual objects such as batons, and 3) weapons such as spears, probable arrow points, and spear-throwers. These objects were made of different raw materials such as gold, resin, and animal bones (summarized in: Briggs 1989; Cooke and Jiménez-Acosta 2010; Cooke 2004).

Bone and tooth ornaments and tools are diverse at Sitio Conte and often expertly crafted. The most remarkable item found is an exquisitely carved deer vertebra (see Lothrop (1937, Figures 192, 193) for the white-tailed species). Lothrop (1937, 215) proposed that a “robust and powerful male” wore a “shirt” decorated with bone tubes, which reached from his shoulders to the middle of the thighs. A smaller cluster of bone tubes was found near the feet suggesting that they formed ankle decoration. These appear to be white-tailed deer long bones. Hollow green bones arranged in a group tend to rattle and this fact undoubtedly increased their impact in ceremonies.

Pérez Roldán (2009) divides the usage of the artifacts in three groups, according to their function: 1) practical objects that had a tool function; 2) ornamental objects that have the function of decorating the human body, such as pendants, beads, and ear flares; and 3) votive objects made to be placed as offerings in burials and/or artifacts that were used by the individuals and were buried with them. The practical group includes tubes, defined by Valentín and Perez Roldán (2010), as pieces having an elongated morphology and an annular section by modifying straight long bones of bird or mammal. The function of these is unknown. These authors report the presence of one deer bone tube (H44a) in the bone artifact collection from the archaeological site of Monte Alban (Oaxaca, México). In the case of deer bone tubes found at Sitio Conte, their function is more related to the ornamental type, and in the case of the complete bone tube found at Cerro Juan Díaz also fits into this category.

Also part of the Sitio Conte mortuary attire were (1) large mammal teeth capped with gold (Lothrop 1937, Figure 166), (2) aprons of domestic dog teeth (Lothrop 1937, Figure 105),

(3) necklaces of peccary (Tayassuidae) tusks (Lothrop 1937, Figure 130), (4) garments made with avian long bones including booby (*Sula* spp.) (Lothrop 1937, Figures 103, 104; Cooke and Jiménez 2010, Figure 3.7), (5) carved manatee ribs (*Trichechus manatus*) (Lothrop 1937, 170 and *passim*), and (6) a delicate hair-comb (Lothrop 1937, Figure 72).

In comparison with high-ranked sites (*i.e.*, Sitio Conte), the bone mortuary goods found at Cerro Juan Díaz (LS-3) during the same period (750-950 AD) in Operation 3 (above ovens) and Operation 4 are strikingly sparse (Cooke and Jiménez 2010, Table 3.2). Only one white-tailed deer long bone tube from a young adult individual was found intact (in Operation 4, burial feature 10) (Cooke and Jiménez 2010, Figure 3.6h). In this context, 10 deer bone/antler artifacts and 20 perforated deer teeth probably used as pendants were found (Cooke and Jiménez-Acosta 2010, Table 3.2). One white-tailed deer bone artifact in Operation 1/1B (Stratum A) consists of a medial piece of a metatarsal, which seems to have been used as a spout perhaps for a gourd (Cooke and Jiménez 2010, Figure 3.6d). In addition, a perforated third right mandibular premolar was found (Cooke and Jiménez-Acosta 2010, Figure 3.8o).

The white-tailed deer was not the only vertebrate that was processed in Operation 1/1B for making artifacts. The proximal and distal ends of avian long bones belonging mostly to boobies (*Sula* spp.) were discarded in the bone pile and the shafts were most likely taken elsewhere (Cooke and Jiménez-Acosta 2010, Figure 3.7). In Operation 1/1B, at "Stratum A" several bird bones that had been cut for use as artifacts were identified. Eighteen cut bones belonged to boobies: one carpometacarpal, twelve ulnae, four humeri, and one radius. Apparently, a member of this community was deft at working fragile bird bone and may even have travelled to booby breeding colonies at Isla Villa, 12 km south east of Cerro Juan Diaz to procure them (Cooke *et al.* 2013, 523). As we shall see below, this idea is not far-fetched. At Sitio Conte, the cut booby bones were ulnae and humeri, cut into long pieces with perforations for passing a string at the proximal and distal ends and/or on shorter lengths of the diaphysis (*e.g.*, Lothrop 1937, Figures 103, 104). Boobies seem to have had great regional significance on a ritual plane: a blue-footed booby (*Sula nebouxii*) rostrum was reported in a pre-Columbian grave at Panamá Viejo (Mendizábal 2004, 149). These Parita Bay communities consumed large amounts of fish and it is understandable that boobies and ospreys were revered (Cooke and Jiménez-Acosta 2010).

Another workshop at Cerro Juan Díaz (LS-3)

A contemporaneous workshop was found at Operation 8 at Cerro Juan Díaz, located 15 meters from Operation 1/1B on the same small alluvial flat. Pottery found in the feature is largely from the Cubitá horizon. The primary activity of the feature was the preparation of marine shells for making ornaments and tools (Mayo 2004; Mayo and Cooke 2005; Mayo 2007). Ranked by weight (g) the species preferred for crafting were Pacific giant conch (*Lobatus galeatus*), thorny oyster (*Spondylus* spp.), Pacific crown conch (*Melongena patula*), giant mangrove cockle (*Larkinia grandis*), and pearl oyster (*Pinctada mazatlanica*). Cone shells (*Conus* spp.) were ranked above mangrove cockles by weight but Mayo (2004, 127) considered that the most common species, *C. patricius*, which frequent nearby beaches today (*i.e.*, Monagre), was collected primarily to make perforators out of the columellae.

Species- and genus-specific ornaments made in Operation 8 include elongated pendant-beads crafted from Pacific giant conch. They are known to archaeologists as "cuentas de bastón" (walking-stick pendants) (Mayo 2004; Mayo and Cooke 2005; Mayo 2007). They were used to make necklaces, which were frequently placed in burials of the period 500-850 AD (Lothrop, Foster, and Mahler 1957). *Spondylus* ornaments produced in Operation 8 consisted mostly of “chaquiras”–minute beads with an average diameter of 0.5 cm (Mayo 2004; Mayo and Cooke 2005; Mayo 2007). Operation 8 overlaps in time with Operation 1/1B. One hundred and fifty-eight “chaquira” beads of *Spondylus* were placed in Feature 16 in Operation 3 (Cooke and Sánchez Herrera 1997).

Deer bone-antler workshops and specialization

Cooke (2004) and Cooke and Ranere (1992) pointed out that “Gran Coclé” society may have been organized into ranked and named clans, which would have used animal and plant identifiers. Genealogy and ancestry were probable determinants of rank and the chiefs only came from certain social groups. It is possible that the same pattern occurred among crafters, that artisans belonged to a distinct social group. Cooke and Jimenez (2010) point out that the greatest number of carved bone artifacts occurs in grave 32 at Sitio Conte. Some objects, such as the carved vertebrae, the bone box, and the spear-thrower guards, exhibit unusual crafting skills. In this grave, three adult males were found and probably belonged to a lineage of specialist bone carvers. Taking this information into account, it is feasible that the deer bone and antler artisans who worked in Operation 1/1B in Cerro Juan Díaz belong to the same social group of specialists and the knowledge of bone and antler making techniques passed from one generation to another. Another support for the hypothesis of a specialization in the bone industry is related to the fact that all the evidence of manufacturing was found in the same place at Cerro Juan Diaz (southwest of the settlement), both the shell workshop (Operation 8) and the deer bone antler workshop (Operation 1/1B).

However, this is not the case for examples in the Iroquoian sites of Mailhot-Curran and McDonald where there are no concentration of remains that could be associated with bone workshops. At these sites, manufacturing debris are equally distributed in each family space of the longhouses. That implies the existence of the sharing of technical knowledge about bone tool production between families and also between households. It is possible that anyone in the household was able to make bone objects (Gates St-Pierre *et al.* 2016; Gates St-Pierre, Boisvert, and Chapdelaine 2016).

At La Montesita site (Aguascalientes, Mexico), approximately dating to the Epiclassic period (600-900 AD), a specialized area devoted to bone and antler work was identified. According to the authors, this area reflects an ideal working space, with access to light, comfortable space, tools, and raw materials (Blasco Martín *et al.* 2019).

The Classic Maya site of Aguateca (Guatemala) shows an interesting pattern of bone crafting production. In this site, there is evidence that all the members of Maya nobility were also artisans, and they produced bone artifacts. This site also shows that certain parts of the bone crafting process were carried out in certain households and in separate areas of each structure. The zooarchaeological evidence found in this site pointed out that the Maya women were directly involved in crafting activities, particularly in those related to food and textile areas (Emery and Aoyama 2007).

Conclusion

The study of deer bone and antler permits an understanding of different human behaviors related to social and economic organization, but it is also linked to a symbolic and ritual world. Along with white-tailed deer distribution, these patterns were different and responded to a distinctive need. The refuse feature in Operation 1/1B at Cerro Juan Díaz clearly represents the waste of a deer bone and antler workshop. In this operation, we did not find the kinds of final products that were used at the elite graveyards such as Sitio Conte, *i.e.*, awls, chisels, spear and/or arrowheads, spear-throwers, and hair-combs. This workshop appears only to have prepared tubes fashioned from white-tailed long bones. We identified evidence of the debitage produced during the manufacture of artisanal bone artifacts.

Knowledge of bone industry techniques and methods may have been passed down within families from generation to generation. Following the model proposed, the social status of the craftsman was inherited; birth within a certain family group determined the status of the new members of the group.

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Preliminary spatial analysis of the morphologically identifiable bone tools from an Early Bronze Age III domestic building in a residential neighborhood house at Tell eṣ-Ṣâfi/Gath (Stratum E5c)

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Abstract

Zooarchaeologists working in the Near East on early urban sites rarely have the opportunity to analyze the spatial distributions of bone tools since they are usually segregated as special finds by the field team and whisked off to museums. At Tell eṣ-Ṣâfi/Gath, all bone tools are analyzed along with the larger faunal assemblage. This paper explores the spatial distributions of the morphologically identifiable bone tools recovered from an early urban domestic building in a residential neighborhood at the site of Tell eṣ-Ṣâfi/Gath dated to the Early Bronze Age III (2850-2600 BC). The bone tool distributions are digitally analysed using ArcGIS for a single EB III stratum. These data provide insights into the unique economic behavior associated with tool production and deposition within the building of these remains. Activity areas related to tool production within a single building are also examined and help to highlight the similarities and differences between rooms and open spaces. The integration of spatial and architectural data provides a broader understanding of the behavior and range of activities associated with the inhabitants of the non-elite Early Bronze Age neighborhood of Tell eṣ-Ṣâfi/Gath.

Introduction

The examination of zooarchaeological assemblages from urban sites in the Near East have become more systematic in recent years (Early Bronze Age = EB 2850-2600 BC), particularly in the collection, identification, and analytical stage (*e.g.*, Allentuck 2004, 2015; Atici 2004; Berthon 2011; De Cupere *et al.* 2006; Greenfield and Allentuck 2011;

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Hesse and Perkins 1974; Horwitz 1997, 2003; Kansa 2004; Sasson 2010; Zeder 1988, 1990, 2003). However, faunal remains may represent a variety of other types of activities, as demonstrated here and throughout this volume. Osseous materials (*i.e.,* bones, horns, and teeth) may be used for a variety of functions beyond food, including tools, ornaments, and other worked bones. As such, the production, function, use, and discard of osseous materials are often misinterpreted post excavation unless they are analyzed along with the larger faunal assemblage.

While most studies of osseous materials from early urban households focus on architectural installations, pottery, and the few special finds, there is a wealth of other bioarchaeological data that receives less attention, during both the recovery and analytical phases (*e.g.,* Allentuck 2011; Choyke 1999). In general, certain faunal materials are, at times, neglected by many excavations; in particular, bones that have been culturally modified are generally designated as special finds and segregated from the larger faunal assemblage by the team in field at the time of excavation, since often they are not considered informative. Thus, the zooarchaeologists often never see, identify, or analyze these data, and are only occasionally included in the larger analyses (*e.g.*, Greenfield 2002; Greenfield and Allentuck 2011). This artificially segregates the bone tool data and often modified bones, identified in the general zooarchaeological analysis, are thus not incorporated into spatial analysis. This segregation provides only half of the picture when investigating spatial data to understand behavioural activities, particularly tool production and use at the household level. This paper illustrates the importance of documenting the spatial distribution of worked bone to study household level activities.

Worked bone material can provide information regarding their function in households (*e.g.,* as tools, ornaments, gaming pieces, *etc.*). Consequently, the spatial analysis of worked bone can provide an understanding of not only the economic behavior and associated activities within houses (and between rooms/spaces), but also inform on the use of organic goods as part of the production system of individual households.

To more fully understand the use of worked bones, a geographic information system (GIS) spatial analytic framework is implemented for intra-settlement analysis. This approach has proven successful elsewhere (*e.g.,* Samei and Alizadeh 2020) and allows for the identification of areas of manufacture, use, and discard. In addition, due to the ability to reconstruct areas or spaces within the house, there is the potential to determine area and even room function. Analyses of osseous material's spatial distribution can be suggestive of the way the space was used in an area.

In this paper, we utilize ArcGIS software to analyze the spatial distribution of 35 morphologically identifiable worked bone tools from an early urban building to explore the evidence of domestic activity areas. These data are derived from a domestic residential neighborhood house from Stratum E5c (late EB) at the site of Tell eṣ-Ṣâfi/Gath and are incorporated into a spatial analytic framework. The bone tool corpus (n=35) provides insights into the intensity of bone tool use and the types of associated activities within an individual house. The integration of spatial and architectural data provides a broader understanding of the behavior and range of activities associated with the inhabitants of the non-elite EB neighborhood of Tell eṣ-Ṣâfi/Gath.

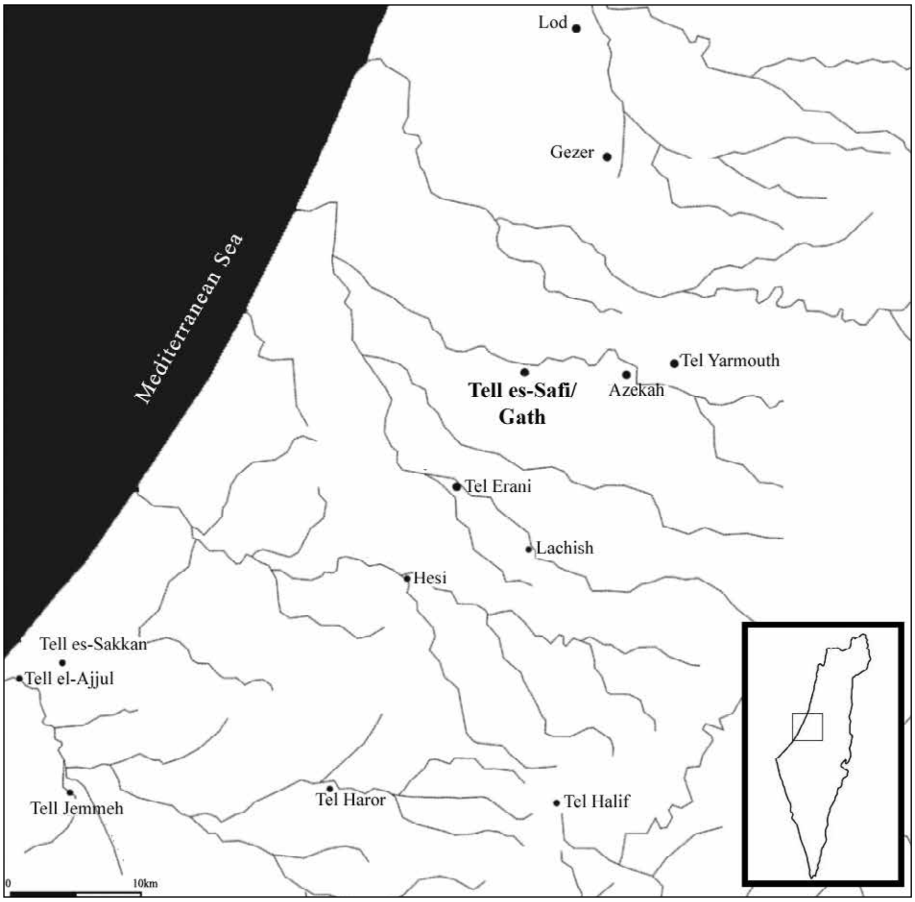

Figure 1. Map of the research area.

Context: Tell eṣ-Ṣâfi/Gath

The site of Tell eṣ-Ṣâfi/Gath is located on the border of the Judean foothills (*Shephelah)* and the southern coastal plain (Philistia) of modern Israel (see Figure 1) (Maeir 2012; Maeir 2017; Maeir and Uziel *in press*). Evidence for the EB III (2850-2600 BC) occupation extends across the tell and is based on excavated occupational deposits, surface scatters of pottery sherds, and the extensive stone-foundation of the fortification system. It is one of the largest sites in the region during this period (*c.* 24 ha) (Uziel and Maeir 2012; Shai *et al.* 2014).

On the eastern end of the tell, in Area E, part of an EB domestic neighborhood was excavated between 2004 and 2017 (Greenfield, Shai and Maeir 2016, 481; Greenfield *et al.* 2017; Greenfield *et al.* 2018; Shai *et al.* 2016). The excavations revealed several buildings that compose a non-elite domestic quarter separated by an alleyway. These buildings likely represent separate houses as there is no evidence for doorways between them. The structures were built on terraces descending in elevation from northwest to southeast with the sloping ground. In contrast, the alleyway follows the natural slope of the terrain. Given the nature of the associated architecture and artifactual remains, this appears to be a non-elite domestic residential quarter.

The EB III occupation of the site ranges from *c.* 2850-2550 BC (Regev 2013; Shai *et al.* 2014; Shai *et al.* 2016). There is occupational continuity in this part of the site throughout the EB III. Given our understanding of the stratigraphy and chronology, Stratum E5 from which our data derive probably is the last *c.* 100-150 years of the period. Stratum E5 is divided into three phases, the most recent of which is E5a. The E5a and E5b phases were heavily damaged by pits and intrusions from the later E4 (Late Bronze) and E3 (Iron I) strata. The best-preserved phase is the earliest, E5c, and our analysis focuses on it. All the worked bone items discussed below are only from the E5c phase.

In each of the phases of E5 occupation, every domestic building appears to consist of a central courtyard and a single auxiliary room. This is a common theme throughout the EB III of the southern Levant (Greenfield *et al.* 2018, 203; Maeir 2012; de Miroschedji 2014; 2018; Sebag 2005). The auxiliary rooms were likely used for storage, sleeping, food preparation, and consumption. The courtyards possess various installations, including storage facilities (*e.g.,* silos, platforms, and hearths). The architectural units each share outer walls (seen in Figure 3 and 4) as part of what is likely an organized urban pattern.

Zooarchaeologists were in the field during each excavation season and were able to ensure that the culturally modified bones (*e.g.,* tools, ornaments, *etc.*) were analyzed with the rest of the faunal assemblage. In contrast to other sites, they did not disappear into the storage system of the antiquity service or museum, as is often the case with other projects (*e.g.,* Titriş Höyük – Greenfield and Allentuck 2011). This allows the modified bone to be analyzed within the context of the wider faunal assemblage.

This analysis is focused on the distribution of bone tools from Building 134307. There is a total NISP of 1289 faunal specimens from the floor and ashy accumulation in this building. Of these, 35 (2.7% NISP) of these are morphologically identifiable tools which are discussed in greater detail below. Only the bone tools found on the floors or in the ashy matrix that builds up from activities on these surfaces are included in the analysis since these are primary depositional contexts where presumably they were used or stored in antiquity. As a result, the specimens found in the collapse of the walls and upper stories are excluded from this analysis.

This building is the center structure within a row of dwellings along the eastern side of the alleyway in Area E and is 5.53 meters (north-south) by 6.79 meters (east-west) in its entirety (approximately 37.54 m^2 including the interior wall) (Figures 3 and 4). The earliest phase (E5c), appears to consist of a large walled courtyard without any evidence of auxiliary rooms, though through this analysis we argue that there is an interior division. In both subsequent phases (E5b and E5a), the space is clearly subdivided with a small auxiliary room at its western end between the main room and the alleyway (L20E83A02). While there are no physical indications of an intervening wall that divided the space, the western quarter of the room was likely divided from the courtyard in some manner as with the rest of the dwellings in the area. The division is delineated by a dotted line in each of the distribution maps below. This reconstruction is supported by the fact that the pebble stone floor covering a sizable portion (L18E83C09) of the western portion of the building stops at where a wall would have been located. The subsequent dimensions of the two areas are 5.53 meters (north-south) by 4.42 meters (east-west) for the courtyard and 5.43 meters (north-south) by 2.03 meters (east-west) for the auxiliary room.

E5c phase bone tools from Tell eṣ-Ṣâfi/Gath

The bones selected for this study are those from the building that are clearly morphologically identifiable as culturally modified. They are identifiable as tools based on their shape and manufacture. They are not only purposefully shaped, but also polished as a result of use. This study includes only the tools, not the ornaments, since it explores activity areas related to production and storage within a building. The vast majority of worked bone specimens were too fragmentary to be identified to a type and/or function (Greenfield *et al*. 2018). The significance of their distribution will be explored elsewhere.

Initially, a typological analysis of the bone tools is based on the identification to taxon and/or size of animal (*e.g.*, sheep (*Ovis aries)*, goat (*Capra aegagrus hircus*), medium mammal), the type of osteological element (*e.g.*, radius, tibia), or if the element is not known, the type of bone (*e.g.*, long bone shaft, flat bone distal shaft, *etc.*), the part of the bone (*e.g.*, distal end, proximal end, or midshaft), the location and morphology of the modified end of the bone (*e.g.*, chisel shaped, rounded, scalloped) and finally, any associated perforations (*e.g.*, needle), and the location and nature of usewear (*e.g.*, polish, scratches) that may hint at its potential function or range of functions. These are criteria that have long been used in research that investigates culturally modified bone, and more specifically tools (*e.g.*, Choyke 1983; Choyke and Schibler 2007, 52-53; Horwitz and Garfinkel 1988; Semenov 1964).

The objects identified as worked bone items are assigned a potential general function based upon the above combination of variables. Tool morphology is generally limited by the relationship between the shape of the original bone element (*e.g.*, metapodium) and the desired tool shape (*e.g.*, awl; *e.g.*, Allentuck 2011). While morphology is not always an indicator of use, it can be used as a general guide as to its function since the shape to some extent determines the range of possible uses (Horwitz and Garfinkel 1988). Unfortunately, as with stone tools, function can change over the course of the lifespan of the object. In addition, changes to the tool can occur during the *chaîne opératoire* of manufacturing and use (Maeir *et al*. 2009; Poplin 1974). Hence, it is difficult to definitively identify all possible functions within the lifespan of the bone artifact. Usewear marks can include edge wear and usewear striations indicating the most intense area of use and possibly function and are in addition to production or shaping which may also be indicative of purpose (*e.g.*, for a handle). The intensity and location of polish suggests the locus and nature of use (*e.g.*, where it was held or rubbed), and its intensity of use (González-Urquijo and Ibáñez-Estévez 2003).

Eleven categories of tools and ornaments are identified in the analysis of Building 134307 and are named by their presumed function. There is no standardized typology for bone tools from this region or period. Hence, presumed function is often based upon analogies with later periods in the region when bone tool production was much more systematic (*e.g.*, Ayalon and Sorek 1999; Shatil and Behar 2013). Included among these tools are awls, spatulae, shovels/dust pans, scoops, and points. Since items may be multi-purposed and can have a change in function through their life history, these categories may not necessarily correspond with their entire range of possible functions. The analysis presented below focuses on the 35 fragments of tools identifiable to a potential function. More detail for each is provided in Table 1.

Three awls are identified by their shape, usewear, and polish. Generally, these tool fragments are long, narrow, and come to a definite point. The tip of the end of the awl is more highly polished and shaped than the rest of the bone (see Figures 2.1 and 2.2).

Locus	Basket	Bone #	Taxon	Element	Element part	Tool sub-type	Whole? (%)
114502	1145012	6	*Ovis/Capra/ Gazella*	Humerus	Proximal and distal shaft	Handle	50
114502	1145046	6	*Ovis/Capra*	Scapula	Proximal and distal shaft	Handle	Fragment
114503	1145013	1	*Ovis/Capra*	Tibia	Distal shaft and end	Handle	50
114503	1145013	3	*Ovis/Capra*	Vertebra	Dorsal half	Awl	50
114503	1145013	5	*Capra hircus*	Scapula	Distal shaft and end	Shovel	30
114503	1145013	8	*Ovis/Capra*	Rib	Distal shaft	Point	60
114503	1145026	1	*Gazella gazella*	Rib	Proximal shaft	Handle	Fragment
114503	1145026	4	*Ovis/Capra*	Tibia	Proximal shaft	Spatula	Fragment
114503	1145026	11	*Bos taurus*	Rib	Proximal shaft	Scoop	Fragment
114503	1145026	18	*Gazella gazella*	Rib	Distal shaft	Spatula	Fragment
114503	1145026	19	*Bos taurus*	Rib	Proximal shaft	Spatula	Fragment
114503	1145033	1	*Ovis/Capra*	Rib	Shaft	Spatula	10
114503	1145033	5	*Ovis/Capra*	Rib	Distal shaft	Spatula	Fragment
114503	1145033	15	*Ovis/Capra*	Rib	Proximal and distal shaft	Spatula	50
114503	1145033	16	*Ovis/Capra/ Gazella*	Rib	Proximal shaft	Spatula	Fragment
114503	1145033	22	*Ovis aries*	Tibia	Distal shaft	Spatula	Fragment
114503	1145037	15	*Ovis/Capra*	Tibia	Distal end and shaft	Handle	90
114503	1145037	16	*Equus asinus*	Metacarpus	Distal shaft	Handle	50
114503	1145039	13	Mammal – large	Long bone	Proximal end and shaft	Awl	Fragment
114503	1145039	30	Mammal – medium	Flat bone	Shaft	Handle	20
114503	1145039	78	*Ovis/Capra*	Metacarpus	Shaft	Spatula	Fragment
114602	1146004	7	*Ovis/Capra*	Rib	Proximal shaft	Scoop	50
114602	1146018	9	Mammal – medium	Rib	Distal shaft	Spatula	Fragment
114602	1146018	10	*Ovis/Capra*	Rib	Distal shaft	Spatula	10
114602	1146023	2	*Ovis/Capra*	Rib	Shaft	Spatula	Fragment
114602	1146047	2	*Ovis/Capra*	Rib	Distal shaft	Spatula	10
114602	1146047	11	*Ovis/Capra*	Rib	Proximal and distal shaft	Spatula	Fragment
134307	1343023	1	*Ovis/Capra*	Rib	Proximal and distal	Spatula	50
134307	1343055	13	Mammal – large	Femur	Midshaft	Handle	10
134307	1343131	9	*Ovis/Capra*	Long bone	Shaft	Spatula	10
19E83C03	19E83C129	9	Mammal – medium	Long bone	Shaft	Awl	20
19E83C03	19E83C129	10	Mammal – medium	Long bone	Shaft	Handle	10
19E83C03	19E83C129	12	Mammal – medium	Long bone	Shaft	Handle	10
19E83C04	19E83C084	1	Mammal – large	Rib	Shaft	Spatula	Fragment
20E83C07	20E83C064	2	*Ovis/Capra*	Humerus	Distal end and shaft	Handle	80

Table 1. Detailed listing of each of the worked bone artifacts discussed.

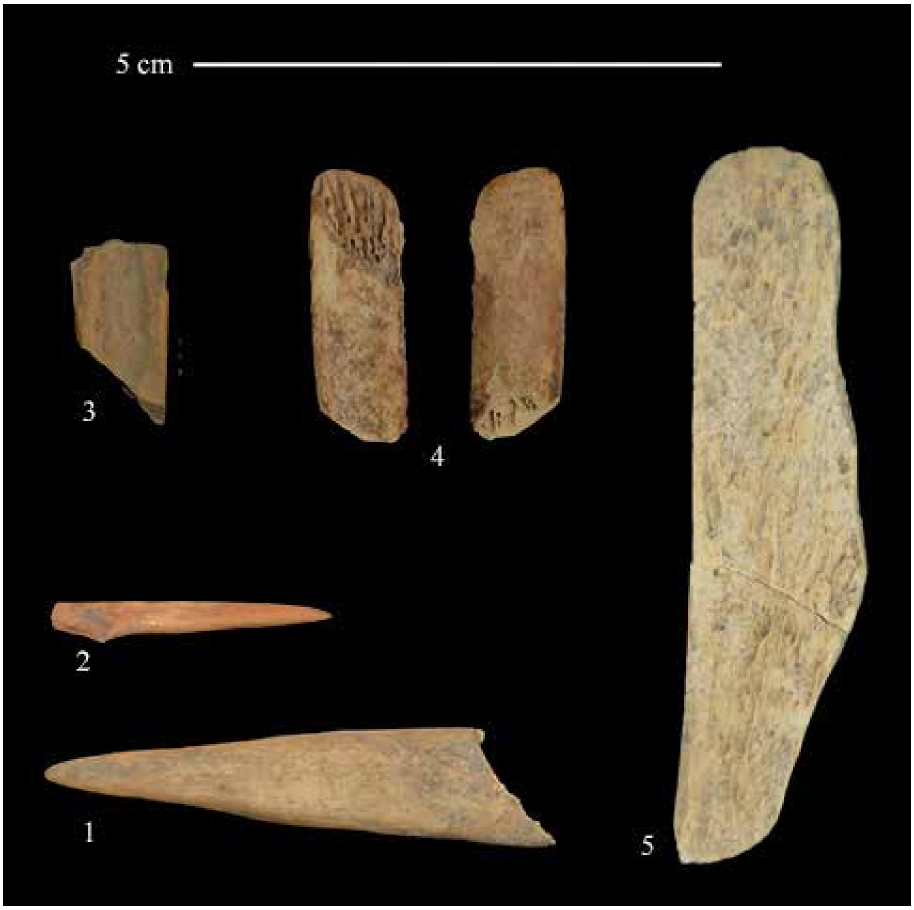

Figure 2. Bone tools from the assemblage: (1) awl; (2) point; (3) handle fragment; (4) spatula; and (5) spatula.

They tend to be made from straight long bones, such as metapodia and tibiae, but in this case are only identifiable as long bone fragments. One fragment, however, derives from the spinous process of a sheep/goat vertebra. Both medium (*e.g.*, sheep/goat) and large mammal bones are exploited. It has been hypothesized that tools such as these were used with textiles, leathers, or weaving (Amiran *et al.* 1978, 56; Legrand-Pineau and Christidou 2005; Peyronel 2014).

One bone point is identified and differentiated from awls by its shape. The morphology of this tool is wider and flatter than that of the awls. It is made from a flatter distal end of a sheep/goat rib that is split, shaped, and polished.

Eleven handle fragments are identified by their unique shaping toward the midshaft of the elements they are created from. The shaping of the handle is indicated by beveling, rounding, and/or smoothing of the chopped end of the shaft to allow a tool to be inserted. There is also often differential polish toward the far end of the shaft where the hand would have been held during use (see Figure 2.3). They are made from a variety of long and flat bone elements, including the humerus, metacarpus, rib, scapula, and tibia. Gazelle, sheep/goat, and donkey taxa are exploited for this type of tool.

Seventeen spatula-like specimens are identified by polish and shaping. These fragments are often created from either whole (medial and lateral faces intact) or split ribs, but, there are also several examples of other osteological elements, such as femur, metacarpus, and tibia. Several taxa are exploited for this tool type, such as gazelle, sheep, sheep/goat, and large mammal. These tools are likely used for manufacturing purposes rather than for application of cosmetics as understood from their morphology. They are identified by the rounding of the split edge and end of the shaft as well as the flattening of the interior section of bone (see Figures 2.4 and 2.5). A small number of these tools are highly polished and display usewear marks suggesting that they are well used, whereas many are more *ad-hoc* in shape or in early stages of their production (*e.g.*, Choyke and Schibler 2007; see also Ariel 1990; Shatil and Behar 2013). Some also display a high level of polish, even though they are only rudimentarily shaped. The latter group of tools either were used in an ad-hoc fashion or broke early in their life history and were discarded before the production process was completed. The more complete fragments that were found in this assemblage are made of quite thick and rigid ribs which suggests their use as a spatula or scraper potentially used in hide processing (Legrand-Pineau and Christidou 2005; Schibler 2001) rather than a weaving or ceramic implement as has been identified in other assemblages (*e.g.*, Greenberg and Paz 2014; Paz 2014).

One specimen is identified as a potential shovel/dustpan or scapular scraper (Gilbert 1979). It is made from goat. It is identified by the unique shaping (often rounding) of the proximal (widest) end of the bone and polish on the neck where the tool would likely have been held. Given the size, shape, and usewear, it is unlikely to have been used for any kind of heavy work, such as earth-working (contrary to Xie and Stiner 2018). Two specimens have been identified as scoops. One is made from sheep/goat and one from cattle (*Bos taurus)* rib. They are identified by their distinctive polish and morphology.

The spatial analysis

Method

The worked bone specimens included in this analysis of Building 134307 (n=35) were identified entirely through the analysis of the larger faunal assemblage by two authors (Haskel and Tina Greenfield, with the help of Annie Brown). During the zooarchaeological stage of analysis, each specimen was assigned a specialized identification number that included its locus, basket within the locus, and bone number within the basket. The locus is the analytical behavioral unit (*e.g.*, floor, material on a specific floor, installation, *etc.*) from a room in the building, whereas the baskets are specific finds from within a specific locus (Maeir and Zukerman 2012). By using the baskets excavated on different days, these data can be spatially mapped to monitor changes in the distribution of remains across a locus: it is a substitute for spatial gridding across a locus. The basket boundaries from the excavation are digitally recorded (traced) into a GIS framework by the senior author (SR).

The spatial analysis is based upon the centroid, or center points for each basket of remains. As all of the tools discussed here were not identified in the field, point data cannot be used for each individual tool fragment. Some specimens were only identified in the larger basket of faunal remains. Hence, there is less potential bias in this approach rather than the usual approach that relies on the few special finds recorded in the field. The frequency of the remains within a basket were spatially plotted across the locus. These 35 specimens are represented by the points portrayed in the figures below as a frequency distribution of remains across Building 134307.

Figure 3. Distribution of (1) spatula; (2) handle; and (3) awl fragments within Building 134307.

This analysis highlights where the concentrations of material are found, and the frequencies of tool types (and fragments) are the most common in each of these locations. As noted above, this analysis focuses on the morphologically identifiable remains found within the buildings in the accumulation on and just above the floors as a means for understanding household behavior.

Results

The distribution within Building 134307 varies for each tool type and each type is separately discussed. There are clear concentrations for some tool types and no apparent concentration for others. The tools (Figure 3 and Figure 4) are more concentrated in certain areas of the courtyard and associated with two loci (L114503 and L134307).

The spatulae (n=17) are mostly located in the courtyard (L114503), aside from one in the western auxiliary room (L19E83C03) (Figure 3.1). The spatulae in the courtyard (L114503) are concentrated around the installations (114607, 17E83B07, and 94606) to the north, east, and west.

Handles (n=11) are the most spatially dispersed of the modified bone types (Figure 3.2). Three are found in or near to the installations in the center of the courtyard (Inst. 114607, 17E83B07, and 94606), three on the pebbled surface, Inst. 18E83C09, in the western room area, and three are found to the south of the pebbled surface in the western room (L114502). One is also found along the center of the southern wall of the courtyard (W74611).

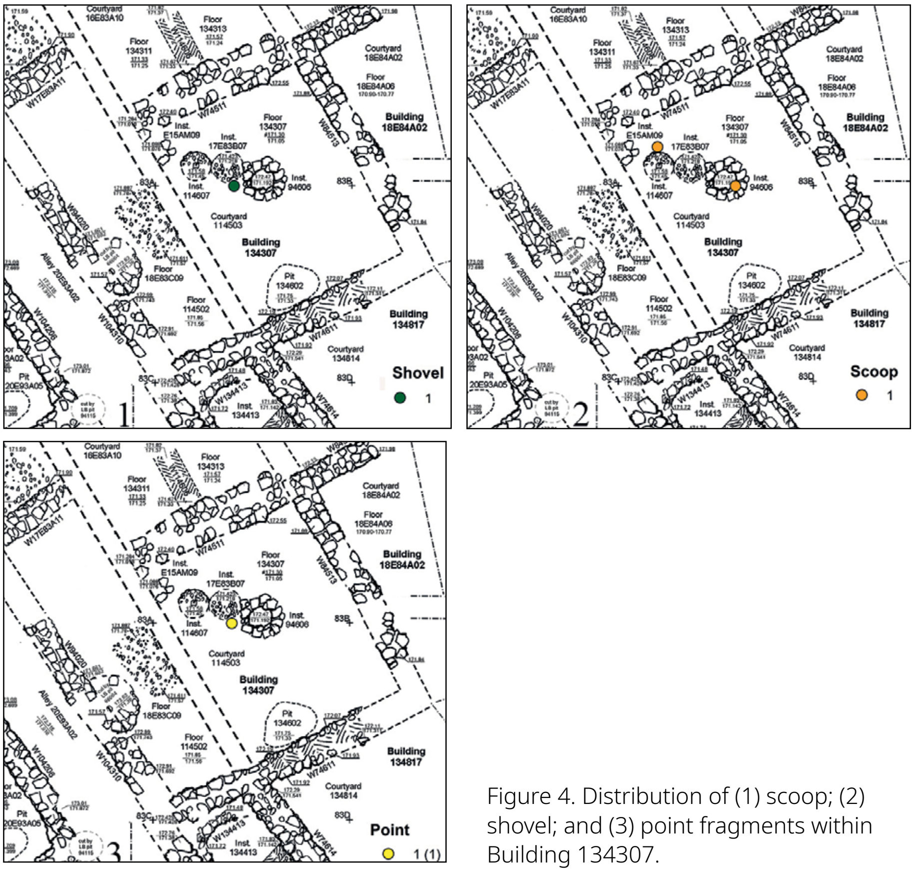

Figure 4. Distribution of (1) scoop; (2) shovel; and (3) point fragments within Building 134307.

There are three awls. One of the awls is located between two installations: Inst. 17E83B07 and 9466 (Figure 3.3). Two awls are found in areas away from the installations. One is found along the southern wall (W74611) of the courtyard (L114503), and the other is on the pebbled surface in the western auxiliary room of the building (L18E83C09) in the vicinity of three handles.

The shovel fragment (n=1) (Figure 4.1) is found on the southern side of the installations between 17E83B07 and 9466 of the courtyard (L114503). It is found in the vicinity of an awl and a point.

Two scoops were found. The scoops (Figure 4.2) are found in the courtyard (L114503) surrounding the installations (114607, 17E83B07, and 94606), one to the north of Inst. 114607 and another to the east of 94606.

A single bone point (Figure 4.3) is located between Installations 94606 and 17E83B07 in the center of the courtyard (L114503) near one of the awls and the scoop.

Conclusions: What does it all mean?

The distribution maps of the morphologically identifiable bone tool fragments from Building 134307 of Stratum E5c at Tell es-Safi/Gath provide detailed information on the spatial distribution of domestic activities specifically related to tool production. The concentrations of these tools inform us of the importance of courtyards within a domestic quarter as public spaces with multifunctional areas for cooking, gathering, and household level production.

Once these data are combined with the other spatially analyzed materials, the final picture will provide a fuller understanding of the way that early urban societies spatially organize their activities. The spatial analysis presented here is unique in that it incorporates a larger number of worked bone items than in previous studies (*e.g.,* Genz 2016; Maeir *et al*. 2009) and reflects a more complete picture of the location of working areas in a building within a domestic quarter from the southern Levant during the late EB III.

The distribution maps show that the worked bone materials in question are largely located in the eastern two-thirds of Building 134307, in what is presumed to be the courtyard (L114503). This pattern is consistent with the above assertion that the courtyards are the functional areas of the prehistoric house used for gathering, cooking, and working. The materials found in the western room are secluded which suggests that either these tools are involved in processes that are not conducted in the public eye, or more likely that this space is a storage area for tools or materials that were not in use.

The spatial analysis of the morphologically identifiable bone tools recovered in association with the analyzed faunal remains provides insight into the designation of space in the non-elite domestic quarter of Tell eṣ-Ṣâfi/Gath during the EB. These analyses can dramatically enhance interpretations of the use of space and associated material remains. However, such analyses are only one part of a larger picture. There are a wealth of other artifacts and ecofacts (*i.e.,* ground stone, chipped stone, ceramic, carbonized plant remains, *etc.*) that need to be integrated into the spatial model presented here, that will enrich our understanding of the socio-economic behavior the inhabitants of Area E, at Tell eṣ-Ṣâfi/Gath. In addition, this analysis demonstrates the need to ensure that future excavations do not allow the worked bone to simply disappear into the registry of finds within excavations and become inaccessible to the zooarchaeologist.

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A Woodland-period bone tool industry on the northern Gulf of Mexico coastal plain

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Abstract

Study of 686 bone tools and debitage from a Late Woodland site in coastal Alabama has led to recognition of a distinctive bone technology practiced in coastal regions of the northern Gulf of Mexico during the Middle and Late Woodland periods (350-1100 AD). Virtually the entire assemblage was manufactured from metapodials of white-tailed deer (*Odocoileus virginianus*). Replication experiments show that many of the deer metapodials were split longitudinally and transversely, into anterior and posterior halves, by direct percussion on an anvil, a technique reported from few other areas of the world. Preliminary carbon, nitrogen, and strontium isotope analyses indicate primarily local raw material acquisition, although deer element ratios suggest some metapodials must have been obtained elsewhere. The presence of bitumen on similar well-preserved tools from the Texas coast raises the possibility of chemically identifying its use in other places and in documenting trade in bitumen from the Gulf of Mexico, where it occurs naturally, washed ashore as tar balls from offshore oil seeps. This study exemplifies the benefits of integrating zooarchaeological, archaeometric, and worked bone analyses, which in this case has enhanced our understanding of the worked bone assemblage, while also hinting at broader social interactions between the coast and hinterland of southeastern North American during the Woodland period.

Zusammenfassung

Die Untersuchungen von 686 Knochenwerkzeugen und Abschlagmaterial aus einer Fundstelle der späten Woodland-Periode an der Küste Alabamas (USA) führte zur Erkenntnis einer charakteristischen Knochentechnologie, die in Küstenregionen des nördlichen Golfs von Mexiko während der mittleren und späten Woodland-Periode praktiziert wurde (*c.* 350-1100 n. Chr.). Nahezu die gesamte Sammlung wurde aus Metapodien von Weißwedelhirschen (*Odocoileus virginianus*) hergestellt. Replikationsexperimente zeigen, dass viele der Hirsch-Metapodien in Längs- wie auch

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Querrichtung durch direktes Aufschlagen auf einem Amboss in vordere und hintere Hälften geteilt wurden – eine Technik, über die auch von einigen anderen Regionen der Welt berichtet wurde. Vorläufige Kohlenstoff-, Stickstoff- und Strontiumisotopenanalysen weisen hauptsächlich auf eine lokale Rohstoffaufnahme hin, obwohl die Verhältnisse der Elemente in den Hirschknochen darauf hindeuten, dass einige Metapodien doch von anderswoher stammen müssen. Das Vorkommen von Bitumen auf ähnlichen, gut erhaltenen, Werkzeugen an der texanischen Küste eröffnet die Möglichkeit die Verwendung von Bitumen auch an anderen Orten chemisch zu bestimmen und den Handel mit Bitumen in der Region am Golf von Mexiko zu dokumentieren, wo Bitumen auf natürliche Weise in Form von Teerkugeln (von Offshore-Ölsickerungen) an Land gespült wird. Diese Studie veranschaulicht die Vorteile der Integration von zooarchäologischen, archäometrischen und techno-funktionalen Analysen von Knochenwerkzeugen, was in diesem Fall unser Verständnis dieser Knochenartefaktsammlungen verbessert hat. Gleichzeitig deuten diese Studien auch auf breitere soziale Interaktionen zwischen der Küste und dem Hinterland im Südosten Nordamerikas während der späten Woodland-Periode hin.

Keywords: southeastern North America, northern Gulf of Mexico, Woodland period, white-tailed deer, metapodials

Introduction

Excavations in 2004 and 2006 at the Bayou St. John site (1BA21), on the Alabama coast of the northern Gulf of Mexico, recovered a large assemblage of worked bone artifacts. A single-phase model of 31 AMS radiocarbon assays (Table 1) suggests occupation of this site began *c.* 460-530 calAD and ended *c.* 1020-1060 calAD (both boundaries estimated at 68.2% probability; A_{model} = 91.3).[1] However, peak occupation occurred during the Late Woodland period (*c.* 700-1000 calAD), with much smaller Middle Woodland and Mississippian occupations. The Late Woodland-period worked bone assemblage, the focus of this study, is extraordinary for the sheer number of artifacts recovered, for their generally good state of preservation, and for the diversity of formal tool types. A paucity of lithic resources in the Gulf coastal zone likely partially explains the abundance of bone artifacts at Bayou St. John, since bone was readily available as a byproduct of hunting and could have substituted for stone for some purposes. Unfortunately, this presumption is difficult to test because preservation issues have biased much of the archaeological record in this region of acidic soils not conducive to bone preservation. In coastal Alabama ancient bones tend to survive only at shell middens such as Bayou St. John, where decomposition of alkaline shells buffers soil acidity. Consequently, this unusually large, diverse, and well-preserved worked bone assemblage offers a rare opportunity to document a bone tool technology that must have once been in common use throughout the region.

Table 1 (right). Radiocarbon dates and carbon and nitrogen isotope data from Bayou St. John site (1BA21) samples and comparative specimens (from Hadden *et al.* 2019; Price 2009, 86-92; Reitz *et al.* 2013).

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[1] Calibrations derived using OxCal v. 4.4 (Bronk Ramsey 2009) from the IntCal13 database (Reimer *et al.* 2013; Talma and Vogel 1993).

Lab ID	**Context**	**^{14}C BP**	**±**	**Material**	**δ^{13}C, ‰**	**δ^{13}N, ‰**	**Atomic C/N Ratio**
BETA-208097	1BA21, Feat 82	1650	40	Wood charcoal	-26.0		
BETA-208095	1BA21, Feat 8 Zone B	1580	40	Wood charcoal	-25.8		
BETA-208100	1BA21, Feat 106 Zone II	1570	40	Wood charcoal	-24.6		
BETA-251722	1BA21, Feat 215 Zone B	1310	40	Charred hickory (*Carya* sp.) nutshell	-25.1		
UGAMS-13927	1BA21, Feat 106	1300	20	Collagen, bear (*U. americanus*), ulna	-19.6	4.3	3.0
BETA-208098	1BA21, Feat 147	1300	40	Wood charcoal	-26.0		
BETA-208101	1BA21, Feat 106 Zone IV	1260	40	Charred hickory (*Carya* sp.) nutshell	-26.3		
BETA-208102	1BA21, Feat 106 Zone V	1250	40	Charred hickory (*Carya* sp.) nutshell	-26.3		
UGAMS-13929	1BA21, Feat 106, *worked*	1230	20	Collagen, deer (*O. virginianus*), metatarsal	-21.6	6.7	2.9
BETA-251729	1BA21, Trench 7 II/3	1230	40	Charred hickory (*Carya* sp.) nutshell			
UGAMS-13930	1BA21, Feat 23, *worked*	1220	20	Collagen, deer (*O. virginianus*), metatarsal	-21.2	4.8	3.0
UGAMS-13928	1BA21, Feat 96, *worked*	1220	20	Collagen, deer (*O. virginianus*), metapodial	-21.4	7.0	3.1
BETA-208099	1BA21, Feat 106 Zone I	1210	40	Wood charcoal	-25.6		
UGAMS-8557	1BA21, Feat 96	1210	25	Collagen, deer (*O. virginianus*), calcaneus	-21.2	6.4	3.0
BETA-251724	1BA21, Trench 2 II/2	1200	40	Charred hickory (*Carya* sp.) nutshell			
UGAMS-34035	1BA21, Feat 96	1200	30	Conchiolin (*L. irrorata*)	-17.3	–	–
BETA-251731	1BA21, Trench 8 II/3	1190	40	Charred hickory (*Carya* sp.) nutshell			
UGAMS-13924	1BA21, Feat 31	1190	20	Collagen, deer (*O. virginianus*), tarsal	-21.5	4.5	2.9
BETA-208103	1BA21, Feat 159 Zone A	1170	40	Wood charcoal	-24.5		
UGAMS-13932	1BA21, Feat 359	1160	25	Collagen, deer (*O. virginianus*), vertebra	-21.2	7.7	2.9
BETA-208096	1BA21, Feat 35	1150	40	Charred hickory (*Carya* sp.) nutshell	-23.7		
BETA-251725	1BA21, Trench 3 IIB	1150	40	Charred hickory (*Carya* sp.) nutshell			
BETA-208094	1BA21, Feat 1	1130	40	Wood charcoal	-25.0		
UGAMS-13925	1BA21, Feat 89	1130	20	Collagen, deer (*O. virginianus*), scapula	-21.3	7.5	2.9
BETA-251730	1BA21, Feat 378	1120	40	Charred hickory (*Carya* sp.) nutshell			
UGAMS-10140	1BA21, Feat 347	1120	25	Collagen, deer (*O. virginianus*), metapodial	-21.6	8.0	2.9
BETA-251728	1BA21, Trench 3 II/4	1100	40	Charred hickory (*Carya* sp.) nutshell			
BETA-251727	1BA21, Feat 347	1100	40	Charred hickory (*Carya* sp.) nutshell			
BETA-251726	1BA21, Trench 3 II/3	1070	40	Charred hickory (*Carya* sp.) nutshell			
BETA-251723	1BA21, Feat 233 Zone C	1030	40	Charred hickory (*Carya* sp.) nutshell			
UGAMS-13926	1BA21, Feat 317	980	20	Collagen, deer (*O. virginianus*), antler	-19.7	5.2	–
UGAMS -13921	1BA134 (Plash Island site)	1550	20	Collagen, deer (*O. virginianus*), humerus	-21.6	5.9	2.9
UGAMS-13923	1BA134 (Plash Island site)	1450	20	Collagen, deer (*O. virginianus*), tibia	-22.0	4.7	2.9
UGAMS-13922	1BA134 (Plash Island site)	1420	20	Collagen, deer (*O. virginianus*), humerus	-21.9	5.7	2.9
UGAMS-13931	1BA134 (Plash Island site)	590	25	Collagen, deer (*O. virginianus*), astragalus	-22.4	6.5	3.1
UGAMS-13916	Washington Co. AL	Modern		Collagen, deer (*O. virginianus*), 2nd phalanx	-23.4	6.1	2.8
UGAMS-13917	Franklin Co., FL	Modern		Collagen, deer (*O. virginianus*), 2nd phalanx	-23.9	3.1	2.9
UGAMS-13918	Clarke Co., AL	Modern		Collagen, deer (*O. virginianus*), tarsal	-24.2	2.3	2.9
UGAMS-13919	Clarke Co., AL	Modern		Collagen, deer (*O. virginianus*), tarsal	-24.0	3.5	2.8
UGAMS-13920	Franklin Co., FL	Modern		Collagen, deer (*O. virginianus*), 2nd phalanx	-22.9	5.1	2.9

Taxa	Count	Percentage
Unidentified Bird, Aves	24	3.5
Crane, *Grus* sp.	9	1.3
Swan, *Cygnus* sp.	1	0.1
Wild turkey, *Meleagris gallopavo*	4	0.6
Unidentified mammal, Mammalia	82	12.0
Bobcat, *Lynx rufus*	1	0.1
Gray fox, *Urocyon cinereoargenteus*	1	0.1
Raccoon, *Procyon lotor*	2	0.3
White-tailed deer, *Odocoileus virginianus*	562	81.9
Total	686	100.0

Table 2 (above). Bayou St. John site worked bone, by species.

Table 3 (right). Bayou St. John site worked bones, by tool and debitage form.

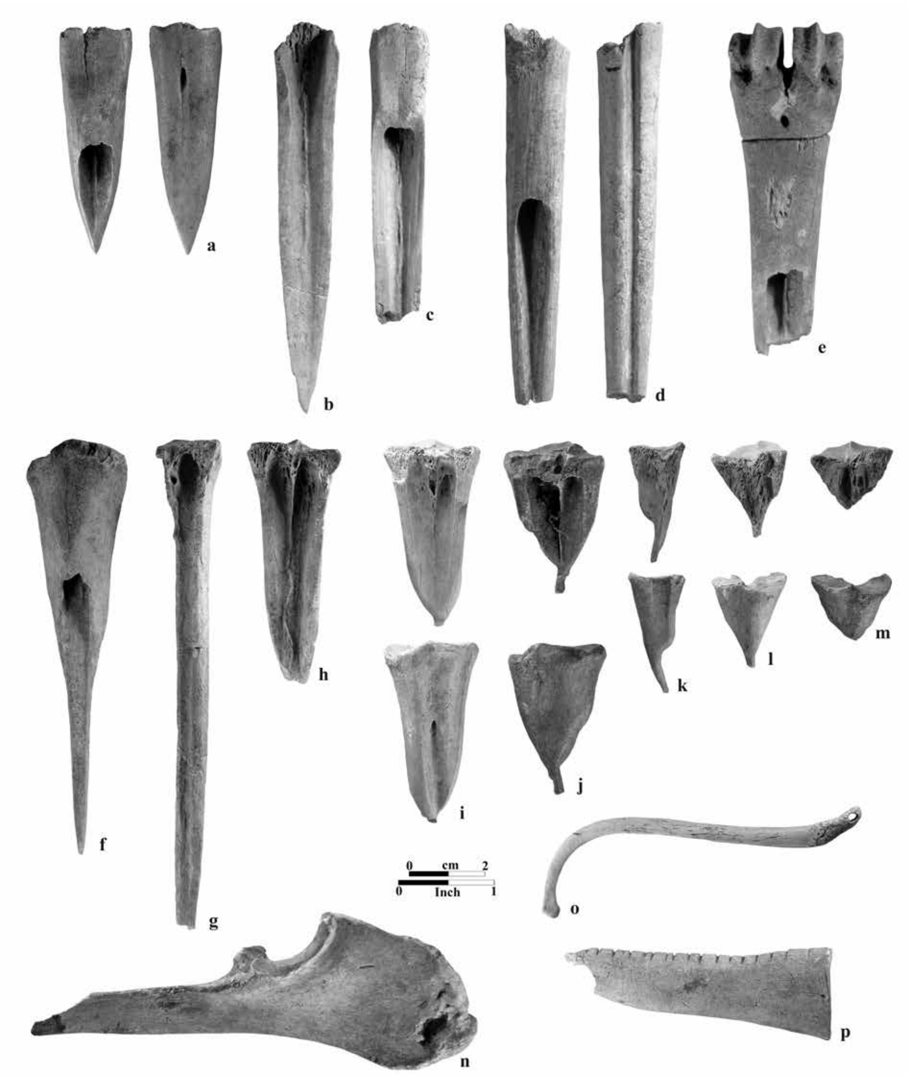
Worked bone assemblage

The assemblage of 686 worked bone specimens consists overwhelmingly of mammal bones (Table 2), with worked bird bones comprising just 5.5% of the assemblage. Most of the worked mammal bones, 562 specimens or almost 82% of the tool assemblage, are attributable to white-tailed deer (*Odocoileus virginianus*), and most of those come from deer metapodials. We have identified thirty-two distinct forms of worked bone tools and debitage (Table 3), briefly summarized here.

The first six categories derive from the distal ends of deer metapodials. All, with the exception of unfinished and debitage specimens, exhibit polish on their working ends.

Figure 1 (right). Deer metapodial short socketed projectile point (a: FS 412a); deer metapodial long socketed point, flat blade (b: FS 667d; c: FS 750a); deer metapodial long socketed points, rounded blade (d: FS 701a); deer metapodial long socketed point, unfinished (e: FS 389a); deer metapodial long awl (f: FS 222c); deer metapodial quartered long awl (g: FS 405d); deer metapodial medium-sized awl (h: FS 1422a); deer metapodial stylus awls (i: FS 606a; j: FS 742h; k: FS 359f; l: FS 643e; m: FS 714e); deer ulna awl (n: FS 602g); raccoon baculum pendant (o: FS 667b); deer tibia rasp fragment (p: FS 717a).

Tool Form	Count
White-Tailed Deer	
Distal Metapodial	
Short Socketed Points	43
Long Socketed Points (flat blade)	15
Long Socketed Points (rounded blade)	21
Long Socketed Points, unfinished	7
Socketed Points, incomplete	25
Production Debitage, Distal Condyles	47
Proximal Metapodial	
Long Awls	31
Quartered Long Awls	14
Medium-Sized Awls	21
Stylus Awls	69
Awls, Incomplete	26
Spatulas	219
Distal Radius	
Awl	1
Proximal Ulna	
Awls	10
Proximal Tibia	
Incised Rasp	1
Antler	
Socketed Tines	12
Bobcat, Distal Humerus	
Production Debitage, Distal Condyle	1
Gray Fox, Distal Tibia	
Indeterminate, Worked	1
Raccoon, Baculum	
Perforated Pendants	2
Unidentified Mammal	
Beads	2
Fishhook Debitage	1
Indeterminate, Worked	79
Crane	
Production Debitage, Proximal Humerus	1
Spatulas, Shaft Tarsometatarsus	7
Worked Tube, Distal Ulna	1
Swan	
Awl, Distal Tibiotarsus	1
Wild Turkey	
Awl, Distal Tibiotarsus	1
Awls, Proximal Tibiotarsus	3
Unidentified Bird	
Indeterminate, Worked	2
Production Debitage	1
Socketed Points, Indeterminate Element	6
Worked Tubes, Indeterminate Element	15



1. Short socketed points (n=43; Figure 1a)

These conical, hafted, sharp-pointed implements are generally interpreted in the regional literature as projectile points (*e.g.*, Ford 1951, Figure 49; Fuller and Silvia Fuller 1987; Kennedy and Arthur 2015, 56-57). They were manufactured from the distal ends of deer metacarpals and metatarsals. The distal articular end of the metapodial was removed by scoring around the shaft near the vascular foramen, snapping off the condyles, and removing the cancellous bone inside the shaft to make a socket-like end for handle or shaft attachment. The posterior (ventral) surface was then ground to a finely tapered point. Lengths of eight intact specimens range from 4.1 to 7.6 cm. Most of the remainder (n=29) are broken at the socket or down the anterior midline; in other words, the points failed while hafted from stresses imposed by use. Interestingly, the sharpened ends of these tools are off center of the anterior groove, perhaps to relieve the significant stress placed on that weakest part of the tool during use.

2. Long socketed points, with flat blade (n=15, Figure 1b-c)

This category consists of elongated, heavier versions of the short, socketed points. Distal condyles of deer metacarpals were removed by scoring and snapping, and the remaining distal shaft ends were whittled and hollowed for hafting. The working edges were finely tapered on their posterior surface and ground to a flattened or V-shaped point. The longest specimen measures 9.4 cm in length. With two exceptions, these tools failed at the haft, where the small posterior portion of the socket is gone, as if it popped off cleanly while in use.

3. Long socketed points, with rounded blade (n=21; Figure 1d)

These tools resemble the previous form in overall morphology, except that the elongated, pointed working end is rounded, rather than flat or V-shaped, in cross section. Each was made from the distal end of a deer metapodial, with distal condyles removed by scoring and snapping. The remaining shaft end was whittled and hollowed to a socket, and the posterior surface tapered and ground to form the working point. From the thinned, whittled edge of the socket (on this and the previous tool form), we infer that something was fitted or lashed over the tool edge to more securely attach the inserted handle or shaft. Three nearly complete specimens range in length from 7.6 to 11.2 cm. While archaeologists working on the northern Gulf coast generally agree that the short, socketed points functioned as projectile (spear) points, the long forms of socketed tools have not previously been so defined. While we presume there must have been some differences in function between the three forms, we group them together based on their similar means of hafting at the distal ends of the same bones. This rounded-blade form appears to have failed (with one exception) along the shaft, not at the haft, which is much sturdier than in the flat-bladed type.

4. Long socketed points, unfinished (n=7; Figure 1e)

These specimens resemble the previous two forms, but retain their distal condyles and lack finished working ends. From every indication, these are early or mid-stage production failures. All are distal ends of deer metacarpals with worked posterior surfaces. Scoring around the shaft of one specimen indicates the distal condyles were to be removed, presumably so the shaft end could be modified with a socket for hafting. None have a complete measurable length, and all were likely discarded before completion.

5. Socketed points, incomplete (n=25)

These fragmentary specimens all appear to derive from socketed points but lack diagnostic features that would permit attribution to one form or another. Eighteen are portions of deer metapodials and six are only identifiable as large mammal.

6. Socketed point production debitage (n=47; Figure 2a)

Recognizable refuse from production of socketed bone points consists entirely of deer metapodial distal condyles, still bearing the scoring lines along which they were snapped from the long bone shafts. This debitage accounts for the creation of only about half of the distal metapodial tools recovered at the Bayou St. John site, which suggests that some tool production occurred elsewhere.

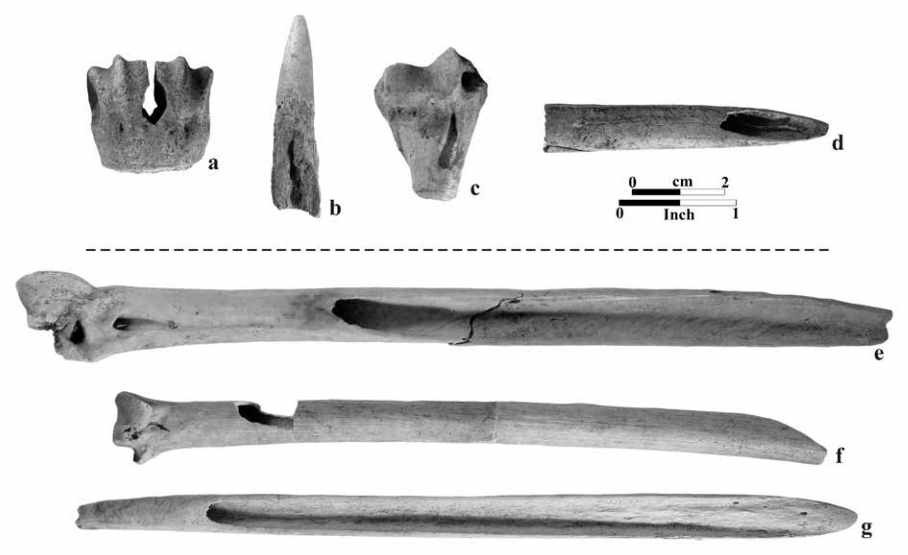


Figure 2. Deer metapodial socketed point, production debitage (a: FS 706); deer antler tine socketed point (b: FS 184); bobcat humerus debitage (c: FS 401); bird bone socketed point (d: FS 643j); swan tibiotarsus awl (e: FS 773a); worked crane ulna (f: FS 184n); crane tarsometatarsus spatula (g: FS 543a).

The next six tool forms are made from the proximal ends of deer metapodials, and they all lack the hollowed end socket for hafting seen in the previously described tools.

7. Long awls (n=31; Figure 1f)

These long, pointed tools made from the proximal ends of deer metacarpals and metatarsals are crudely tapered on the anterior surface, leaving ragged edges, with an intact articular end. One complete specimen measures 10.6 cm long.

8. Quartered long awls (n=14; Figure 1g)

These long, narrow, pointed tools consist of one-quarter of the proximal end of a deer metapodial, with the corresponding portion of the proximal articular end intact.

9. Medium-sized awls (n=21, Figure 1h)

These tools are short, transversely split metapodials with a very thin working end. The anterior portion of the proximal end of the bone was retained, and all are modified on the posterior surface. Four complete examples range in length from 5.4 to 6.6 cm. The tips of most specimens have broken away, so we are uncertain whether the working ends were narrow or broad.

10. Stylus awls (n=69; Figure 1i-m)

These tools were manufactured from the split proximal ends of deer metapodials (evenly divided between metacarpals and metatarsals). Each one is now very short, although they originally had a long, slender, pointed stylus-like projection. The posterior surface was removed by splitting the bone in half transversely, while the anterior portion of the articular end was left unaltered. There are no complete specimens (although FS 359

Figure 3. Deer metapodial spatulas (interior and exterior views of each specimen; a: FS 405; b: FS 1372a; c: FS 664a); lateral views of the same tools (a’-c’).

[Figure 1k] may be nearly intact); the stylus-like projections are all broken, with most snapped off at the stylus base. Twenty specimens that retain some part of the stylus range in length from 2.0 to 5.3 cm, with a mean length of 3.3 cm. Despite the vestigial remnants of most of the projecting tips, the more intact specimens suggest the stylus comprised about one-third of the total tool length. These tools do not appear to have been hafted. They are exceedingly small tools of a form that has not, to our knowledge, been previously reported. All appear to have been resharpened repeatedly during their use-life, which helps account for the short average length of this category. In fact, they may be recycled alterations of larger tool forms. The unusual nature of the stylus, which is invariably somewhat angled, suggests a specialized function. In the absence of complete tools with intact styluses, we can only speculate about their use. The nature of the stylus suggests that perhaps they could have functioned as winkle pins, to probe and extract meat from gastropods. These tools bear deep parallel striations or grooves on their back (the bone’s anterior surface), extending from the stylus base, apparently resulting from use with a vigorous pushing motion.

11. Awls, incomplete (n=26)

These awl fragments are proximal end portions of deer metapodials, although lacking diagnostic features for any of the four preceding forms.

12. Spatulas (n=219; Figure 3)

These most abundant of bone tools are transversely split proximal ends of deer metapodials with broad, flat, thin, spatula-like working ends. The worked portion of the original bone is predominantly the anterior surface, although five specimens (2%) were worked on the posterior surface. The more complete specimens have distinctive percussion notches on one or both sides just below the articular end, evidence of splitting by direct percussion on an anvil. Thirty-three complete specimens range in length from 5.2 to 13.4 cm, with a mean length of 9.8 cm. Those specimens identifiable to element include 32 metacarpals and 50 metatarsals. Those for which side could be determined skew somewhat between left (33) and right (41).

This tool category exhibits extensive reworking of the metapodial shaft, and most specimens show heavy wear with deep longitudinal use grooves on the sides and posterior surface. There are many broken shaft fragments, most of which show extreme wear that resulted in thin, brittle tool edges. Such bone spatulas may have been used for shellfish processing; as early as 1944, Gordon Ekholm speculated that this form of bone tool “could have been used in opening oysters” (Ekholm 1944, 484-485, Figure 53b). Griffitts and Bonsall (2001, 215) demonstrated experimentally that bevel-edged bone tools could be used to harvest limpets by scraping them from their rocky habitats and then to scoop the meat from limpet shells. The Bayou St. John environment lacks both a rocky shoreline and limpets, but oysters and other bivalves abound. Most pre-industrial shellfish gatherers opened bivalves by roasting, which causes the shells to gape slightly (Waselkov 1987, 100-103). They then must be pried apart, and the adductor muscle severed to extract the meat. In our own experiment, we successfully used replica metapodial spatulas to open and remove meat from roasted oysters, although the spatula’s cutting edge dulled quickly, which would necessitate periodic sharpening by abrasion. But the spatulas did perform adequately. The force required to pry apart the shells left gouges and striations on the tool’s surfaces that resemble those seen on the archaeological specimens.

13. Other deer bone awls (n=11)

One awl is made from a deer distal radius and ten are made from deer ulnas (Figure 1n). The narrow distal ends of the ulnas were originally ground to a point, which probably tended to snap off during use, since no specimens remain intact. Deer ulna awls are represented in most ancient North American bone tool assemblages and were widely observed in use ethnographically in the same region for weaving and basketmaking (Stein 2000, 88-91).

14. Socketed antler tines (n=12; Figure 2b)

Short segments of deer antler tines have the cut ends slightly hollowed or socketed. Examination under a microscope did not reveal use-wear marks that would indicate function as pressure flakers or other tool types. They presumably were used as another form of hafted projectile point.

15. Other worked mammal bone (n=87)

Two raccoon baculum pendants (Figure 1o), a worked distal tibia of a gray fox, a scored and snapped distal humerus of a bobcat (Figure 2c), and a variety of worked unidentified mammal bones (see Table 3) were recovered from the Bayou St. John site. A possible rasp (Figure 1p), probably manufactured from a white-tailed deer proximal tibia, has a series of 18 short incised notches. It resembles rasps recovered from the early historic Hopi site of Awatovi in Arizona (Wheeler 1978, 61). The bobcat humerus debitage is the only one of its type, and no additional bobcat bones were recovered from the faunal assemblage. One possible fishhook blank was made from an indeterminate mammal bone; no finished bone fishhooks were recovered.

Four tool types are made of bird bones. Forms include awls, spatulas, socketed points, and tubes. The first three are more delicate than their mammal bone counterparts, by virtue of the structural nature of the raw materials, and consequently were presumably used for tasks requiring less application of force.

16. Bird tibiotarsus awls (n=5)

Awls were made from swan (n=1; Figure 2e) and turkey (n=4) tibiotarsals, each sharpened on one end, distal or proximal, with the opposite articular end left intact. One complete specimen measures over 8 cm in length, which, considering the nature of the bone, indicates these awls were used for relatively delicate tasks.

17. Worked bird bone tubes (n=16)

All show longitudinal striations from shaping or use, and one was scored and snapped at one end. Only one, of unknown function, could be identified to species, element, and portion, a very long left distal ulna of a crane (Figure. 2f). We are not sure if these fragmentary specimens are parts of awls, spatulas, or gouges, and in truth some may be bead blanks.

18. Crane tarsometatarsus spatulas (n=7; Figure 2g)

This class of delicate spatula-like tools consists exclusively of the shafts of crane tarsometatarsals. One virtually complete specimen has a very short, closed, hollow haft end, a very long flat medial section, and a blunt tip, with an overall length exceeding 8 cm. Only this specimen, a left distal tarsometatarsus, could be identified to bone portion and side. For all specimens the anterior surface of the bone was modified. Because the diagnostic articular ends were removed from these tools, species could not be determined, but visible features indicate either sandhill crane or whooping crane. Van Gijn (2007, Figure 16) described a similarly delicate split swan ulna tool with similar wear polish that had been used on plant materials, probably for plaiting or weaving textiles, nets, or baskets.

19. Bird bone socketed points (n=6; Figure 2d)

These narrow, socketed points made from the long bones of indeterminate bird species, are similar in tool morphology to the deer metapodial socketed points, although much smaller.

Deer metapodial tool manufacture by direct percussion

The reduction sequence used to create tools from deer metapodial bones at the coastal Woodland Bayou St. John site evidently differs from that which led to the creation of most other metapodial bone assemblages around the world. In other regions, the most commonly inferred production method involved splitting metapodials lengthwise, midway between lateral and medial sides, to take advantage of a natural weak plane in the cortical bone corresponding with the midline vascular groove. In many cases, repeated scoring preceded splitting, permitting better control of the split. Once split in two, the proximal end of each half could be worked into an awl point or spatula tip, with a distal condyle usually retained to serve as a handle (*e.g.*, Adán Álvarez 1997, 42; Arrighi *et al.* 2016, 148-151; Choyke and Tóth 2012, 340-349, Figure 3; David 2007; Gooding 1980, 111; Inomata and Emery 2014, 130; Kidder 1947, 58, Figure 82c; Legrand and Sidéra 2007; Maigrot 2004, 68-69, Figure 3, 2005, 117-120; Vitezović 2016, 128, Figure 1; Vitezović and Bulatović 2013, 284, Figure 5).

In contrast, the Bayou St. John metapodials were also split lengthwise but *transversely*, perpendicular to the more commonly used splitting plane, dividing anterior from posterior faces. Splitting was accomplished by direct percussion, which leaves telltale impact fractures on the lateral and medial margins near the proximal bone end. Several experimental studies have demonstrated how impact points and flake scar notches are created by direct percussion, and opposing notches by bipolar percussion using an anvil (David 2005, 69; Galán *et al.* 2009; Gifford-Gonzalez 2018, 293-296; Peréz Roldán 2005, 45-46; Pickering and Egeland 2006; Stavrova *et al.* 2019). We were able to replicate this percussion procedure experimentally (Figure 4) and found the method to be effective and a much quicker way to split metapodial bones than the scoring method. Indeed, flake scars at the direct percussion impact points and corresponding flake scars on the opposite (anvil) sides of experimentally split bones correspond to conchoidal fractures observed on many of the Bayou St. John archaeological specimens.

Our experimental method involved placing the lateral or medial margin of the proximal end of a deer metapodial on a raised spot on an anvil stone, then striking the upward side of the bone sharply at the top of the shaft with a small hammerstone. Once a longitudinal crack forms through the proximal end and on each side of the bone, the metapodial can be pried apart into two unequal-sized blanks (see Figure 4). The smaller fragment (usually the posterior face), which retains half of the proximal end of the metapodial, could be used as a spatula tool after minor flattening and sharpening of the tip end by abrasion, with little or no further shaping or reduction. Alternatively, that same piece could be worked, mainly by abrasion, into the long awl or quartered long awl tool forms. The larger fragment of the metapodial bone, which typically includes an intact distal end and the split anterior face of the proximal end, would then be worked into a choice of tools. The distal end could be fashioned into any of the three socketed point forms, once the distal condyles were removed. The other half, with the anterior portion of the proximal bone end, could be worked into a medium-sized awl or a stylus awl. Considering that bone working is a reductive process (Christidou 2005, 93-95; Olsen 1984, 53), it is perhaps likely that a short socketed point would have resulted from recycling and reworking a worn or broken long socketed point, and similarly that a worn or broken medium-sized awl could have been converted to a stylus awl.

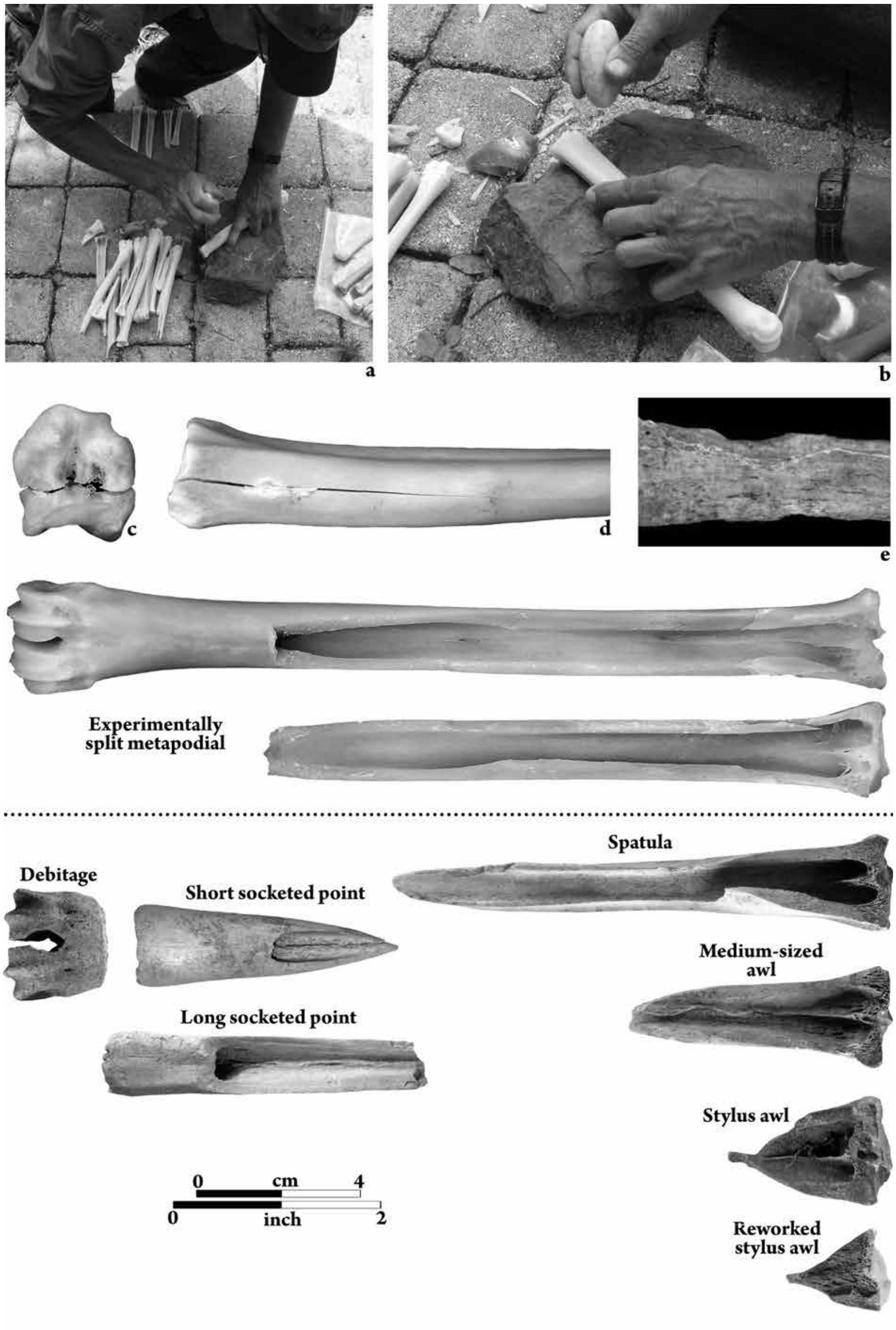


Figure 4. Experimentally splitting a deer metatarsal transversely by direct percussion on a stone anvil (a-b). Note percussion impact damage on modern experimental specimen (c-d), and resultant direct and bipolar percussion flake scars and notches in archaeological metapodial (e). Tool production from transversely split deer metapodials, archaeological tools and debitage.

In sum, splitting metapodials transversely permitted a bone worker to create up to eight different tool forms, yielding three separate tools from the start, each with a distinct function, and another five tools through further modification or refurbishing of worn or broken implements. This was a remarkably adaptable *chaîne opératoire*, a production sequence that utilized a scarce commodity very efficiently. While the deer element data (reviewed below) suggest that some deer metapodials may have been imported to the site from elsewhere to supplement the local supply of these most coveted of deer bones, the efficiency in tool variety and number achieved by this metapodial splitting method probably lessened the need for extralocal bones.

While we initially thought this method of splitting deer metapodials was unique to Woodland Gulf coastal technology, we learned at the 2019 Worked Bone Research Group meeting in Montréal that a similar application of this technique was also employed at St. Lawrence Iroquoian sites, where Boisvert and colleagues have recognized identical impact fractures and percussion flakes created by this reduction method (Boisvert *et al.*, this volume; Boisvert and Gates St-Pierre 2019, 283-285; Gates St-Pierre and Boisvert 2015, 262-269; Gates St-Pierre *et al.* 2014, 99; Gates St-Pierre *et al.* 2016, 58-60). This hammer-and-anvil approach to splitting metapodials, in fact, has been used elsewhere. Our literature review found several published descriptions and illustrations of tools evidently created in this manner (cf. Christensen and Tejero 2015, 81, Figure 2; Feinman *et al.* 2018, 38; Lewis and Kneberg Lewis 1961, 78, Plate 35a-b; Ricklis 1994, 84; Ricklis *et al.* 2012, 230-234, Figure 7-39i-m; Stahl and Athens 2001, 172-173, Figure 13a-b, g; Webb 1946, 282, Figures 42a, 44d).

Bone procurement for tool production

Archaeologists have long assumed that acquiring raw material to produce bone tools was a task, by and large, embedded in subsistence activities. This, despite abundant evidence that human decisions to exploit animal species involve far more than simple perceptions of nutrient needs. The recent “ontological turn” in anthropology encourages us to consider how indigenous peoples have treated animal species as “other-than-human” persons (*e.g.*, Hill 2011, 2013). The relationship between a human society and an animal species is reflected in archaeological distributions of an animal’s remains, their contexts of deposition, and the specific ways that an animal’s parts are used. Of the 148,045 faunal remains from the Bayou St. John site analyzed by zooarchaeologists (Baker and Klippel 2009; Orr 2009), the lone bone of a bobcat is a scored and snapped distal humerus discarded during creation of what must have been a special object. Likewise, all the bones of cranes from this site are worked, including seven tarsometatarsals intriguingly fashioned into long, delicate spatulas. Five of them were found in an enormous pit thought to have been associated with an earthen mound. Such highly selective patterns must signal special relationships between the Late Woodland occupants of the Bayou St. John site and the bobcats and cranes that populated their world.

Some species, on the other hand, do seem to have served principally as food sources, with little archaeological evidence that their remains were accorded special treatment. Such seems to be largely the case with white-tailed deer, even though at this coastal site fish and shellfish provided far more meat to site inhabitants. In the zooarchaeologically analyzed portions of the vertebrate faunal assemblage, deer specimens account for an

NISP (number of individual specimens) of 89, representing an MNI (minimum number of individuals) of just 15 deer (Baker and Klippel 2009, 255; Orr 2009, 215-216).

Because deer bones feature so prominently in the worked bone assemblage, but are relatively uncommon in the overall subsistence remains (and, specifically, in the analyzed faunal samples), we decided to expand our sample of deer remains to include every excavated site context. All white-tailed deer bones, worked or not, were retrieved from previously unanalyzed faunal samples. We also re-examined deer remains from samples already analyzed by zooarchaeologists. Here, as in many other parts of the world, archaeologists traditionally divide vertebrate assemblages into worked and unworked components, for separate specialized analyses. However, as Boisvert and colleagues have noted (this volume; Gates St-Pierre *et al.* 2016, 55), collaborative research on vertebrate assemblages involving both a zooarchaeologist and a worked bone specialist is best able to provide both analysts with the full range of evidence for vertebrate subsistence and bone technology. Close examination of a vertebrate assemblage often reveals specimens unrecognized by zooarchaeologists as worked, especially less formal expedient tools and production debris essential for understanding tool manufacturing sequences. In our case, the zooarchaeologists had identified some worked specimens, but missed others, as anticipated.

Our assemblage-wide search yielded 2,093 unworked deer specimens. We were particularly interested in determining whether the deer acquired during subsistence hunting to feed the occupants of the Bayou St. John site were likely to have furnished enough raw material to produce the 562 worked tools and debitage made from deer bone. Could animals acquired locally for subsistence have provided enough suitable raw material for one out of every five deer bones to be turned into tools or toolmaking debris? Or were additional metapodials, the bones most in demand for tool production, obtained from extralocal sources?

Table 4, which presents frequency data on a cross section of white-tailed deer elements, helps us answer this question. Our sample of elements includes representatives of each of the major portions of a white-tailed deer: head, forequarter, axial skeleton, hindquarter, forefoot and hindfoot (*i.e.,* metapodials), and foot. The most abundant element in the Bayou St. John unworked deer assemblage is the astragalus (MNE=113), which provides an MNI of 57 deer. Other unworked elements were recovered in numbers far lower than expected. For instance, 57 deer should yield 114 distal tibiae, compared to just 33 recovered from excavations. Similarly, only 76 unworked distal metapodials, instead of the 228 expected, were found during excavation, just 33% of the expected frequency. However, when worked deer bones are added to unworked elements, the count of distal metapodials jumps to 187, 82% of the expected number, and a total of 316 proximal metapodials exceeds expectations at 138% (equivalent to an MNI of 79).

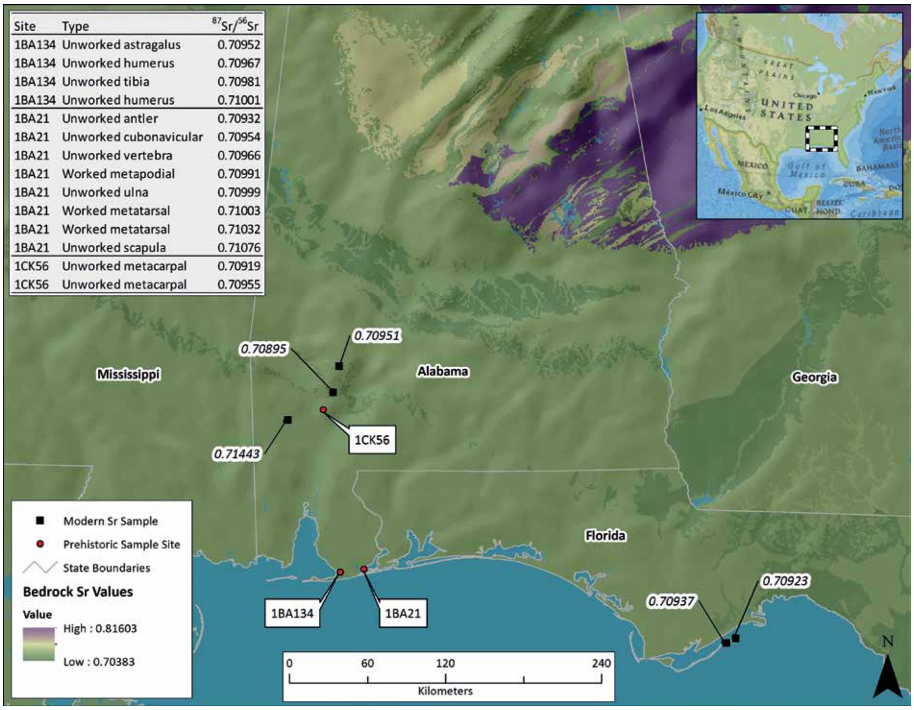
Taphonomy certainly accounts for some of the low element frequencies. Relatively fragile bones such as vertebrae are typically not well preserved in archaeological contexts. But distal tibiae and distal radii, which are structurally comparable to proximal metapodials, are similarly underrepresented in this assemblage, so non-taphonomic factors must be responsible for these discrepancies. We postulate that metapodials were collected specifically for tool manufacture from deer killed and butchered elsewhere, to supplement the specimens obtained during subsistence hunting in the immediate site vicinity. Furthermore, the unusually high number of astragali, which were not used for tools here, may be due to their incidental

Skeletal Element	Observed Unworked MNE	Frequency in Skeleton	Observed/ Expected Unworked MNE	Observed Worked and Unworked MNE	Observed/ Expected Worked and Unworked MNE
Upper 1st Molar	24	2	0.21	24	0.21
Scapula	23	2	0.20	23	0.20
Humerus, distal	29	2	0.25	29	0.25
Ulna, proximal	13	2	0.11	22	0.19
Radius, distal	22	2	0.19	23	0.20
Atlas	5	1	0.09	5	0.09
Thoracic Vertebra	35	13	0.05	35	0.05
Lumbar Vertebra	36	6	0.11	36	0.11
Acetabulum	25	2	0.22	25	0.22
Femur, distal	13	2	0.11	13	0.11
Patella	18	2	0.16	18	0.16
Tibia, proximal	22	2	0.19	23	0.20
Tibia, distal	33	2	0.29	33	0.29
Metapodial, proximal	52	4	0.23	316	1.38
Metapodial, distal	76	4	0.33	187	0.82
Astragalus	113	2	0.99	113	0.99
First Phalanx	105	8	0.23	105	0.23

Table 4. Ratios of observed to expected white-tailed deer Minimum Number of Elements (MNE) from the Bayou St. John site, with expected frequencies based on Minimum Number of Individuals (MNI=57) calculated from astragalus recovery.

inclusion in articulated forefeet and hindfeet brought to Bayou St. John from elsewhere. Since the high astragalus count provides the basis for our deer MNI calculation at Bayou St. John, if their numbers, too, are inflated due to acquisition elsewhere, then the MNI for deer taken locally may be closer to 17, as indicated by distal tibiae.

An overabundance of deer metapodials and their preferential use for tools at Classic and Postclassic Maya sites (Carr 1996, 255; Emery 2008, 208; Masson and Peraza Lope 2008, 181; Thornton 2011) has prompted stable isotope studies to determine if bones recovered at Bayou St. John were traded, either as raw material or finished product. In terrestrial herbivore species such as deer, individuals from different habitats can frequently be distinguished from one another based on carbon and nitrogen isotope values, which fluctuate in response to isotopic variations in the plants at the base of the food web (Cormie and Schwarcz 1994; Darr and Hewitt 2008; Land *et al.* 1980). For our region of the northern Gulf coast we hypothesized that bone collagen ratios of carbon isotopes ^{12}C to ^{13}C (δ^{13}C) and nitrogen isotopes ^{14}N and ^{15}N (δ^{15}N) would reveal ^{13}C depletion and ^{15}N enrichment in bones of deer from inland areas compared to those of coastal deer. In tested specimens of worked and unworked deer bones from Bayou St. John and from the nearby Middle Woodland Plash Island site, δ^{13}C values range from -19.7 to -22.4‰, and δ^{15}N values range from 4.5 to 7.7‰ (see Table 1). Occupation of both sites preceded adoption of maize agriculture; deer browsing even occasionally on fields of maize, a C_4 plant, would typically result in higher δ^{13}C values than seen here.



Site	Type	$^{87}Sr/^{56}Sr$
1BA134	Unworked astragalus	0.70952
1BA134	Unworked humerus	0.70967
1BA134	Unworked tibia	0.70981
1BA134	Unworked humerus	0.71001
1BA21	Unworked antler	0.70932
1BA21	Unworked cubonavicular	0.70954
1BA21	Unworked vertebra	0.70966
1BA21	Worked metapodial	0.70991
1BA21	Unworked ulna	0.70999
1BA21	Worked metatarsal	0.71003
1BA21	Worked metatarsal	0.71032
1BA21	Unworked scapula	0.71076
1CK56	Unworked metacarpal	0.70919
1CK56	Unworked metacarpal	0.70955

Figure 5. Strontium isotope ratio ($^{87}Sr/^{86}Sr$) variations in bedrock and water (from Bataille and Bowen 2012; Bowen 2020) and in modern and archaeological deer samples in the north-central Gulf of Mexico coast.

While the ranges of variation in deer bone collagen $\delta^{13}C$ values are similar for the two sites, $\delta^{15}N$ values are somewhat higher and more diverse at Bayou St. John. In herbivores variability in $\delta^{15}N$ is likely to represent metabolic variations from weaning (*e.g.*, Fogel *et al.* 1989), drought stress (Chritz *et al.* 2009; Cormie and Schwarcz 1996), or micro-environmental conditions. None of the deer in either assemblage were juveniles and freshwater sources are common in this low-lying coastal region. Plants growing in saline and waterlogged environments tend to have higher $\delta^{15}N$ values (*e.g.*, Atahan *et al.* 2011; Britton *et al.* 2008), which suggests deer were hunted in locations with soils of different $\delta^{15}N$ values (Cormie and Schwarcz 1994, 234-237). Either hunters from Bayou St. John exploited a wider range of habitats than their predecessors at Plash Island, or Bayou St. John occupants acquired deer bones from elsewhere through exchange (Price and Waselkov 2009, 166; Waselkov 2012).

Analysis of strontium isotopes ($^{87}Sr/^{86}Sr$) has also been used to identify extralocal sources of deer bones at Maya archaeological sites (Hodell *et al.* 2004; Price *et al.* 1985, 2008; Sharpe *et al.* 2018, 3606). In southeastern North America, Christine Mikeska (2020) has employed strontium isotope analysis of deer teeth to map colonial-era changes in deer-hunting territories across geologically distinct river valleys in Piedmont North Carolina. Strontium isotope ratios in bone collagen of terrestrial fauna are known to correlate with strontium isotope ratios found in surface waters, sediments, and bedrock of an animal's home range, with minimal biological fractionation. Along the northern Gulf coast, strontium isotope ratios vary across a narrow range throughout much of the coastal plain (Figure 5), where they reflect a fairly homogeneous underlying geology (Bataille and Bowen 2012; Chesson *et al.* 2012; Grimstead *et al.* 2016). Using thermal ionization spectrometry, we analyzed strontium isotope ratios in the mineral (bioapatite) fraction of fourteen archaeological specimens – three worked deer metapodials and eleven unworked deer elements of various sorts – from three Woodland sites in southwest Alabama, including Bayou St. John (1BA21), Plash Island (1BA134), and the Corps site (1CK56). We also obtained data on five modern deer foot bones, three from Clarke and Washington counties, Alabama in the vicinity of the Corps site, and two from St. Vincent Island National Wildlife Refuge, a barrier island in Franklin County, Florida (modern deer isotope ratios plotted on Figure 5).

The strontium isotope ratios from archaeological deer bones, worked and unworked, cluster tightly between 0.709 and 0.711 ($\delta^{87}Sr/^{86}Sr$). One modern Washington County deer, with a ratio of 0.714, falls outside that narrow range, which suggests to us that a higher resolution mapping of the modern strontium isoscape (isotopic landscape) could reveal more complexity than is presently apparent from the available generalized geological data. Strontium isotope ratios of the three worked metapodials from Bayou St. John fall well within our unworked bone data cluster and the remaining modern deer data cluster, indicating local origins for the deer exploited for those three tools. Perhaps more (destructive) analysis of additional worked metapodials, particularly the very numerous proximal metapodials, would reveal some to have an extralocal origin. We present our data to encourage others to expand the modern background database for this coastal region and to explore other archaeological applications of this promising method in southeastern North America (also see Hedman *et al.* 2009, 2018).

Socketed bone points and bitumen

The Bayou St. John worked bone assemblage is notable for the high proportion of socketed projectile points made of bone and antler – 129 specimens, one-fifth of the total bone tool assemblage. We presume this is largely due to the absence of stone suitable for knapping into hafted bifaces in the immediate region. Figure 6 shows locations of surface or near-surface geological sources of workable stone on or close to the northern coast of the Gulf of Mexico. Sources near the coast in Mississippi and Louisiana consist mainly of Citronelle gravels; larger pieces of flakeable stone could only be obtained from Tallahatta formation outcrops, or sources even further afield, well inland from Bayou St. John. Archaeological excavation there recovered only thirty hafted stone bifaces. Ferruginous sandstone and coarse ochre, on the other hand, are locally available in abundance and were put to use as abraders and anvil stones, which were both essential for production of the bone tool forms found at Bayou St. John (Price 2009, 118-148)

Socketed bone and antler points are found throughout the stone-poor northwestern and north-central Gulf coast, from Texas (Aten 1983, 258-270, 302-305; Ricklis 1994, 157-158, 223, Figures 6.6E, 8.5b-f, 2004, 186, 192-193; Ricklis and Weinstein 2005, 120; Ring 1994, 269-271; Scott 2002, 561-563) to Louisiana (Bogucki 2015, 109; Ford 1951, 122-123, Figures 49m-n; Ford *et al.* 1945, 42-45, Figure 12; Fuller and Silvia Fuller 1987, 68-73; Gagliano 1963, 116-117, Figure 9p-r; Kidder and Barondess 1981, 90-92; Miller *et al.* 2000, 369-377; Phillips *et al.* 1951, 430), Alabama (Kennedy and Arthur 2015, 85-86), and northwest Florida (Willey 1949, 393, pl. 24b). Although the majority of Bayou St. John socketed points are deer distal metapodials (n=111), elsewhere bones of raccoon, alligator, bobcat, and various birds also provided raw material.

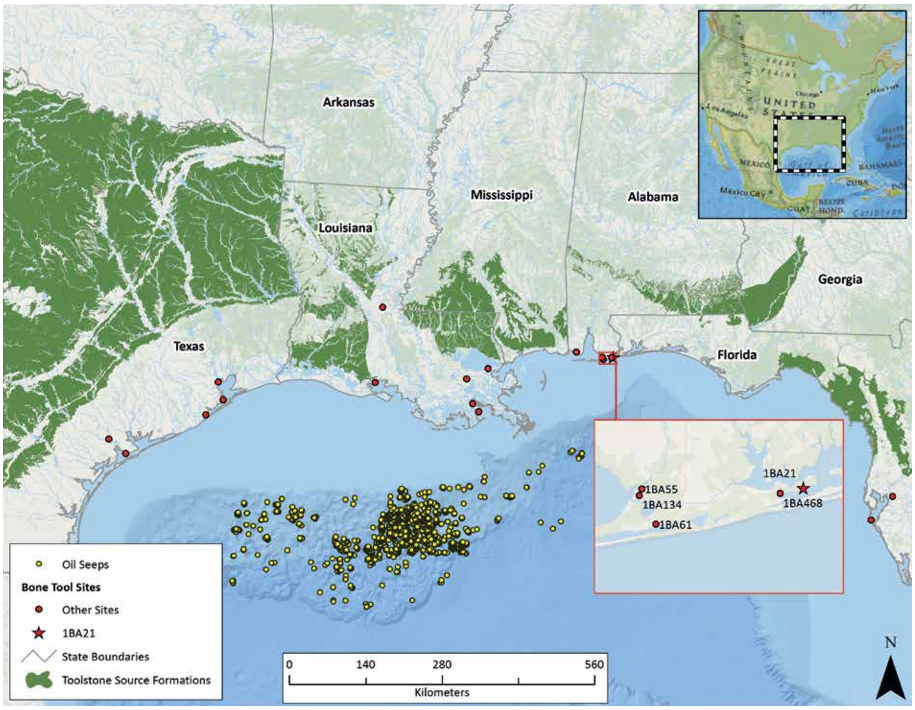


Figure 6. Accessible sources of workable stone (dark green); natural offshore oil seeps (yellow: Bureau of Ocean Energy Management 2020); and archaeological sites (red) with transversely split deer metapodial tool technology (Texas sites: 41BO35, 41CL2, 41GV66, 41HR70, 41VT98; Louisiana sites: 16AV2, 16LF17, 16LF66, 16OR7, 16SC2, 16VM9; Alabama sites: 1MB1 and six in the callout box; Florida sites: 8HI2, 8MA6).

In all instances where deer metapodials served the purpose, the distal condyles had been removed using the score-and-snap method, and the cancellous bone inside the distal shaft had been scraped out to form a socket. Dozens of specimens found at coastal sites in Texas and Louisiana have bitumen (also known as asphaltum) adhering to the inner walls of the sockets (Aten 1983, 262; Bogucki 2015, 107; Ford *et al.* 1945, 42-45, Figure 12; Fuller and Silvia Fuller 1987, 69; Heller 2000, 383; Miller *et al.* 2000, 369-377, 383; Phillips *et al.* 1951, 430; Ricklis 1994, 223; Ricklis and Weinstein 2005, Figure 5.11; Ring 1994, 290-291). As several archaeologists have noted, the presence of bitumen adhesive inside the sockets of these bone artifacts "indicates that the shafts to which these points were adhered did, in fact, fit into the base and, incidentally, confirms the fact that these tools did function as [projectile] points rather than awls" (Bogucki 2015, 107; also Ricklis 1994, 223).

Use of natural bitumen and other tarry organic substances as adhesives, sealants, and for waterproofing is now well documented archaeologically across the ancient world since the Middle Paleolithic (*e.g.*, Boëda *et al.* 1996; Brown 2016; Brown *et al.* 2014; Cnut *et al.* 2018; Degano *et al.* 2019; Fauvelle *et al.* 2012; Hodgskiss 2005; Niekus *et al.* 2019; Smith and Fauvelle 2015; Wendt 2009; Wendt and Cyphers 2008; Wendt and Lu 2006). Indigenous peoples in the Olmec and Huastec regions of Mexico and the Native peoples of southern California could obtain bitumen from either submarine seeps or terrestrial tar pits. On the northern coast of the Gulf of Mexico, bitumen originated as tar balls that formed at underwater oil seeps and drifted to shore. In 1722 the English colonist Daniel Coxe wrote this account of tar balls washing ashore around the mouth of the Mississippi River:

> *"There is found in great Quantities upon the same Coast on the Shores to the East and West of the Meschacebe, especially after high South Winds, a Sort of Stone Pitch by the Spaniards call'd Copec, which they likewise find in the South-Sea upon the Coast of Peru. They mix it with Greese to make it more liquid, and use it as Pitch for their Vessels, and affirm it to be better in hot Countries, not being apt to melt with the Heat of the Sun or Weather."* (Coxe 1722, 87-88)

By the early twentieth century, geologists had begun to map the locations of oil seeps in the Gulf (Soley 1910). In the wake of the catastrophic Deepwater Horizon oil spill in 2010, researchers have mapped 914 major natural seeps in the Gulf, mostly offshore of Louisiana, Mississippi, and Alabama, and analyzed the oil from each for its distinctive geochemical signature (see Figure 6) (MacDonald *et al.* 2015, 8369-8370).

Considering the widespread availability of naturally occurring bitumen, in the form of tar balls that wash ashore in the northern Gulf of Mexico, and the presence of bitumen in socketed bone points at Woodland-period sites along the Texas-Louisiana coast, we consider it likely that similar socketed bone points from Bayou St. John on the Alabama Gulf coast were once hafted with bitumen, as well. To test the proposition that socketed bone points with no visible bitumen once had bitumen for hafting, we selected two short socketed points for chemical residue analysis.

We used gas chromatography mass spectrometry (GCMS) to investigate if traces of bitumen remain in socketed bone points without visual indication of bitumen. Gas chromatography (GC) converts mixtures of analytes (like crude oil and its subcomponent bitumen) into a gas through heat, then separates the components based on chemical differences (which often trace closely with boiling point). For less complex mixtures with only a few analytes, each mixture component exits the gas chromatograph at a different time. For complicated mixtures like crude oil and bitumen, separation in GC is not complete; therefore, a detector is needed that can further disperse analytes and provide information that helps identify them. In the mass spectrometry portion of GCMS, molecules exiting the GC column are bombarded with highly energetic electrons, which removes (knocks out) one electron from analyte molecules. By losing an electron, molecules are turned into positively charged ions. Ions of differing mass-to-charge ratio can be steered on different paths through electrostatic potentials. In this way, the mass spectrometer disperses analyte ions and provides a snapshot of the mass of each analyte exiting the GC column at any given point in time. In addition, being bombarded with highly energetic electrons causes bonds in molecules to break. The weakest bonds break most often; stronger bonds break less often. Positively charged fragment ions are also pulled into the mass spectrometer. The result is a mass spectrum that reveals the mass (strictly speaking the ratio of mass to charge [m/z], but here all ions carry a single charge) of each molecule that entered the mass spectrometer and the mass of the fragments they broke into. Because weaker bonds break preferentially, the pattern of fragments created (their masses and relative heights) is characteristic of the types of bonds holding each analyte molecule together.

Previous research on crude oil and bitumen (as reviewed by Ashton *et al.* (2000), for example) indicates that some compound classes within crude oil tend to survive well over time. This is particularly important for archaeological bitumen from tar balls, which have undergone moderate to severe weathering, including evaporation of aromatic hydrocarbons, photochemical degradation, and biodegradation. Among the compound classes most resistant to weathering, and consequently among those most frequently employed as biomarkers for identification of crude oil sources, are the terpanes and steranes. Terpanes tend to break into fragments at m/z 191; steranes into fragments at m/z 217 or 218. Therefore, the GCMS can be set to record specifically when those target ions – ions with those ratios of mass to charge – arrive at the detector.

Adapting methods from Boëda *et al.* (1996) and Wang *et al.* (2006), we sampled two socketed bone points, one of which had split in two, each portion treated separately; a Native-made pottery sherd, from the early eighteenth-century site of colonial Mobile (1MB94), exhibiting visual traces of bitumen, which served as a positive control; and unworked deer phalanges from the Bayou St. John site as negative controls. Samples were extracted with warm chloroform under sonication for an hour and allowed to sit in the chloroform extract at least overnight. Samples and controls were extracted and decanted at the same time. Extracts were cleaned through flash column chromatography on high purity silica gel. Thin layer chromatography revealed that Fraction 3 contained the most material. Where possible, Fractions 2-4 were combined and allowed to evaporate to dryness under atmospheric pressure. Otherwise, fractions were evaporated to dryness separately, under vacuum, at 30˚C. Finally, samples were reconstituted in chloroform and injected on the GCMS instrument (Shimadzu GCMS-QP5000). The chromatography column (Restek Rxi-XLB) was 30 meters long, had an inner diameter of 0.25 mm, and a stationary phase thickness of 0.25 μm. The GC gradient started at 150˚C, stayed there for 5 minutes, then increased linearly to 330˚C at 3.5˚C per minute, then stayed at 330˚C for a final 5 minutes. The mass spectrometer was set to monitor for analytes that create fragments indicative of crude oil and bitumen (Wang *et al.* 2006, 108): m/z 191, 218, and 217. The results are displayed in Figure 7.

Comparing the samples (socketed bone points) to the negative controls (unworked deer bone of the same age and buried context at the Bayou St. John site) and positive control (archaeological bitumen), the data indicate that the presence of bitumen cannot be ruled out for one of the socketed bone points (Sample 2). However, given the minute traces of analyte recovered and the few samples tested, the data are inconclusive in proving bitumen presence. Still, the method appears promising. This analysis ended with the COVID-19 shutdown of our lab facility, but future analysis of more samples, pooling of extracts from several samples, and improvements to the extraction and cleaning methods to specifically target bitumen analytes may provide more conclusive results.

Today it is technically possible to trace ancient bitumen back to its source seep. Archaeologists have begun to document ancient trade in bitumen emanating from terrestrial and submarine seeps in southern California into southwestern North America, but the potential for documenting pre-modern trade in bitumen from the Gulf coast into the interior Southeast remains unexplored. Recognizing that socketed bone points which lack visible bitumen, such as the specimens from Bayou St. John, are essentially identical to socketed points with bitumen found at sites in Louisiana and Texas, offers a future avenue of research to begin to understand the extent of trade in bitumen across ancient eastern North America.

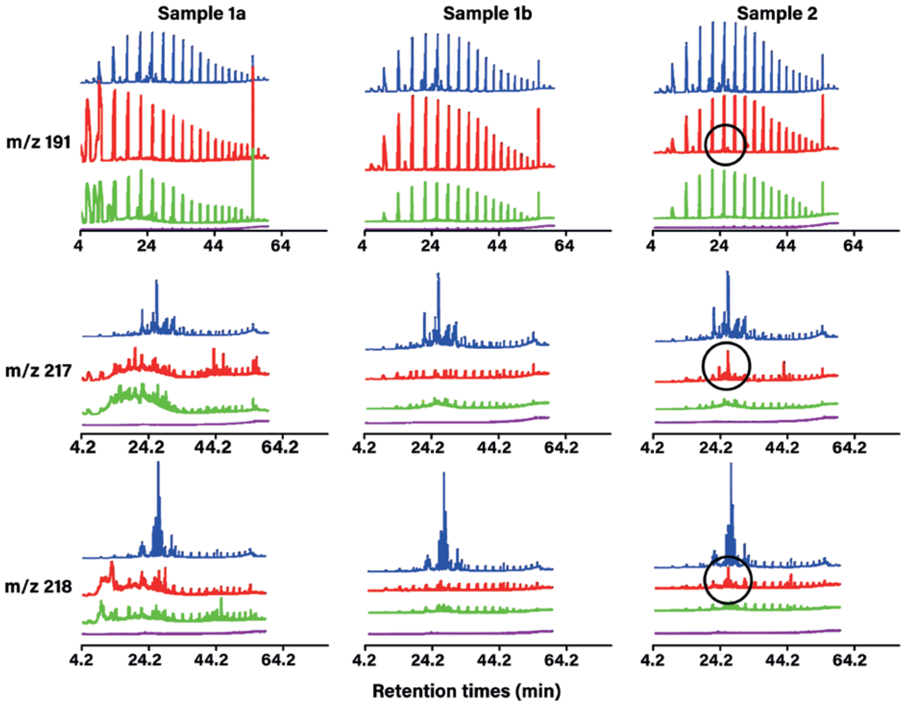


Figure 7. Results of the GCMS bitumen analysis of short socketed points made of distal deer metapodials from the Bayou St. John site, 1BA21. Samples 1a and 1b are two fragments of a single point from Trench A, Level 2 (FS 400a), and Sample 2 is a fragmentary point from Feature 31 (FS 217a). Rows indicate bitumen compound analytes detected (terpanes at m/z 191, steranes at m/z 217 or 218). Blue traces: positive controls provided by a bitumen-coated Native American-made sherd from the early eighteenth-century French colonial site of Mobile, 1MB94 (Structure 5 Vessel 67, FS 1889). Red traces: socketed point samples, with possible analyte presences circled for Sample 2; three purification fractions combined for Sample 1a; middle fraction only for Samples 1b and 2. Green traces: negative controls provided by unworked deer phalanges from Bayou St. John site, 1BA21 (Sample 1a control phalanx from Feature 233, FS 1096; Samples 1b and 2 control phalanx from Feature 236, FS 1076). Purple traces: solvent blank (chloroform).

Conclusions

While studying the large assemblage of worked bone from the Woodland period Bayou St. John site, we realized that a seemingly unusual bone toolmaking technique, which involved direct percussion to split deer metapodials transversely, was, in fact, a method employed by Woodland peoples along nearly the entire coastline of the northern Gulf of Mexico. Although evidence is still sparse for this bone-working method in Florida and Mississippi, we have identified metapodial tools of the types described here for Bayou St. John at nineteen other sites. On that basis, we conclude that the Bayou St. John assemblage represents a widespread and long-lived bone working tradition, evidently one well adapted to Woodland lifeways in the coastal zone. The efficiency of splitting metapodials transversely to make at least seven distinct forms of tools enabled fisher-gatherers to cope with a paucity of workable stone near the coast and produce tools needed to process shellfish and other coastal subsistence activities. Contemporaneous sites located in areas with workable stone inland from the coast have bone tools, but those sites lack these metapodial forms, presumably because subsistence activities away from the coast required different toolkits.

We initially suspected that this unusual bone technology might be a circum-Gulf coast phenomenon, but diligent searching in the Mesoamerican literature has not turned up any examples of these metapodial tools at Mexican sites. However, the use of bitumen for bone tool hafting (as well as for other purposes) did extend around the entire Gulf, which is hardly surprising given the easy availability of bitumen in the form of tar balls throughout the region, as well as the accessibility of terrestrial oil seeps from east Texas southward to Tamaulipas, Veracruz, and Tabasco. Gordon Willey mentioned the prominence of bitumen in Woodland sites in his pioneering study of Florida Gulf coast archaeology (Willey 1949, 205, 266, 309, 319), but few other archaeologists studying the Native peoples of southeastern North America have realized the importance of bitumen as an adhesive, sealant, and paint. We hope our small-scale effort to identify bitumen residue on bone artifacts with no visible bitumen will spur others to consider a resource that has been largely overlooked in discussions of ancient trade to and from the northern coast of the Gulf of Mexico.

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The many dimensions of a bone

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Abstract

This chapter introduces a global perspective on the analysis of faunal and worked bone assemblages through the adoption of an integrative approach. Using a series of Pre-Contact Iroquoian sites from southern Quebec (Canada) as a case study, it illustrates the benefits resulting from a sustained and integrated collaboration between faunal and bone tool specialists. An archaeological bone has many dimensions, and the integrative approach promoted here allows researchers to combine these into a coherent conceptual framework that provides a more accurate and holistic understanding of faunal exploitation by human societies in the past. This can be accomplished without overriding the complexity and specificities of faunal and technological analyses by simply taking advantage of their natural, yet underrated interplay.

Résumé

Ce chapitre présente une perspective globale de l'analyse de collections de restes fauniques et d'ossements ouvragés en adoptant une approche intégrative. Pour illustrer les avantages d'une collaboration soutenue et intégrée entre les spécialistes de la faune et des outils osseux, les résultats issus de l'analyse de sites iroquoiens pré-contact du sud du Québec (Canada) seront présentés. L'approche intégrative promue ici encourage les chercheurs à considérer les multiples dimensions des ossements archéologiques dans un cadre conceptuel cohérent, fournissant ainsi une compréhension plus précise et holistique de l'exploitation de la faune par les sociétés humaines dans le passé. Cet objectif peut être atteint sans négliger la complexité et les spécificités des analyses fauniques et technologiques, en tirant simplement parti de leur interaction naturelle, bien qu'à ce jour encore sous-estimée.

Keywords: bone technology, zooarchaeology, archaeometry, integrative approach, Iroquoians

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Introduction

Archaeologists have made several calls in recent years to foster the integration of zooarchaeological methods and data with those from other disciplines or from archaeological subdisciplines. Examples include pleas for the integration of zooarchaeology with archaeology in general (Maltby 2002; O'Connor 1996; Reitz and Wing 1999; Thomas 1996), with archaeobotany and palaeoethnobotany (Crane and Carr 1994; Foreman 2011; Smith and Miller 2009; VanDerwarker and Peres 2010); isotopic (Boethius 2018; Makarewicz 2016; Pilaar Birch 2013; Zangrando *et al.* 2014) and lithic analyses (Real *et al.* 2020; Seetah and Gravina 2012); historical (Albarella 1999; MacKinnon 2004, 2017; Thomas 2005), environmental (Choyke and Schibler 2007) or bioarchaeological data (Outram *et al.* 2005); and modelling (Boone 2012), as well as biology, zoology, and wildlife management (Broughton and Miller 2016; Fossile *et al.* 2020; Lyman 1996; Stahl 2008; Wolverton *et al.* 2016), to name just a few. Similar calls for the integration of zooarchaeology with one of its most closely related specializations, the study of worked bone, were frequently heard in France during the past decade (Bignon-Lau *et al.* 2018; Christensen and Tejero 2015; Leduc and Burnouf 2011; Soulier 2013; Soulier *et al.* 2014; Tolmie 2013), but less so elsewhere (see Acosta and Buc 2010; Buc and Loponte 2012; Wild 2020). Indeed, faunal analysts and worked bone specialists often work in isolation, even when they analyze collections from the same site, despite their use of common or similar methods and concepts, not to mention an absolutely identical base material: animal hard tissues (*i.e.*, bone, antler, tooth, and shell). This naturally impedes a more comprehensive, holistic understanding of faunal exploitation informed by these two sister domains.

This chapter builds on a previous, similar call to highlight the benefits of developing and applying an integrated approach to the archaeological study of the multiple dimensions of animal use in the past (Gates St-Pierre, St-Germain, *et al.* 2016). The integrative approach overcomes the subsistence-technology dichotomy, which too often prompts faunal and bone tool specialists to work separately. As pointed out by Letourneux (2003, 39), the entanglement of subsistence with bone technology highlights the conceptual aberration of the traditional, commonly made divide between these two dimensions of faunal exploitation. In bringing together the expertise of zooarchaeologists and bone tool specialists, this approach provides a set of simple guidelines for the integration of zooarchaeological data into technological research on osseous industries, and *vice versa*. It preserves the complexity and specificities of faunal and technological analyses, while taking advantage of their natural, yet under-exploited complementarity. More importantly, we demonstrate how the integrative approach enhances the understanding of the activities that have taken place on a site and the interplay between economic and technological choices in the exploitation and treatment of animal species, including the *chaîne opératoire* (Creswell 1976; Leroi-Gourhan 1965). The series of logical steps in processing animal carcasses to obtain food and raw materials does not have to be either economic or technological, but can be both at the same time, constituting technoeconomic *chaînes opératoires.* Studying this series of intermingled technological and economic choices and decisions without considering one of these two primary dimensions entails a risk of missing or misunderstanding the rationale behind choices and decisions that were taken while processing animal carcasses and selecting skeletal parts for bone working.

Finally, this approach also opens up new possibilities of addressing the social and symbolic dimensions of worked and unworked faunal remains, as will also be illustrated later in this chapter. Animals can be sources of food and raw materials and sources of social practices and symbolic expressions all at the same time, as revealed through the integrated analysis of their remains using the appropriate set of methods and techniques. Hence the value of the integrative approach promoted here, which makes it easier to access and combine the multiple dimensions of a bone. This is somehow related to, although not an extension of, the conceptual approaches developed in the archaeological and anthropological studies of technological choices and technological styles in the 1970s and 1980s by such people as H. Lechtman, A. Steinberg, P. Lemonnier, and B. Pfaffenberger (Lechtman 1977; Lechtman and Steinberg 1979; Lemonnier 1983, 1986, 1992, 1993; Pfaffenberger 1988, 1992; Steinberg 1977), and later adopted by a vast array of archaeologists and anthropologists. Instead of using purely functional or performance considerations, their approaches bring cultural criteria and decision-making to the forefront of their endeavours to understand ancient or traditional techniques, illustrating in their own way that any technology has many dimensions to be considered (see van der Leeuw and Pritchard 1984).

Simple and straightforward, the integrative approach was applied to the case of the St. Lawrence Iroquoians, one the Iroquoian tribes inhabiting north-eastern North America before European contact. The sites and collections analyzed are presented below, followed by a description of the methods and protocols established and used within the integrative approach. Since most of the results have already been published elsewhere, they will be summarized here simply to illustrate how effective this approach has been for this specific case study.

Sites and collections

The assemblages of faunal remains from three sites were considered in this study: McDonald, Droulers, and Mailhot-Curran (Figure 1). They are part of a cluster of village sites located in the St. Anicet area, in southern Quebec, and were occupied by St. Lawrence Iroquoians during the Late Woodland period (*c.* 1000 to 1600 CE). The historical territory of that nation extends along the St. Lawrence river lowlands, between Lake Ontario and the Quebec City area, and can be divided into cultural or archaeological provinces (Chapdelaine 1989, 1990; Tremblay 2006). Like all Pre-Contact Iroquoian tribes, St. Lawrence Iroquoians were sedentary communities inhabiting semi-permanent villages containing several longhouses of various sizes. They had a mixed economy that was based on the polyculture of maize (*Zea mays*), squash (*Cucurbita* sp.), and beans (*Phaseolus vulgaris*)–also called the Three Sisters – combined with the products of fishing, hunting and gathering. One of the most distinctive characteristics of the St. Lawrence Iroquoians' material culture was the preference for bone over stone as a raw material in the production of their tools, including projectile points (Engelbrecht and Jamieson 2016a, 2016b; Gates St-Pierre 2010, 2014; Jamieson 1990, 1993, 2016). Indeed, St. Lawrence Iroquoians are known for their skilled, sophisticated and diversified osseous industry (Figure 2). As a result, bone objects of all kinds are to be found in St. Lawrence Iroquoian assemblages. They are associated with crafting (awls, chisels, flakers, handles, needles, punches, scrapers, spatulas), subsistence (barbs, fish hooks, harpoon heads, husking pins, projectile points), warfare (daggers, projectile points), leisure or ceremonial activities (cup-and-pin game, pipes, rattles, shamanic tubes, tokens), as well as body or clothing adornment (beads, hair pins, pendants, tattooing needles, toggles).

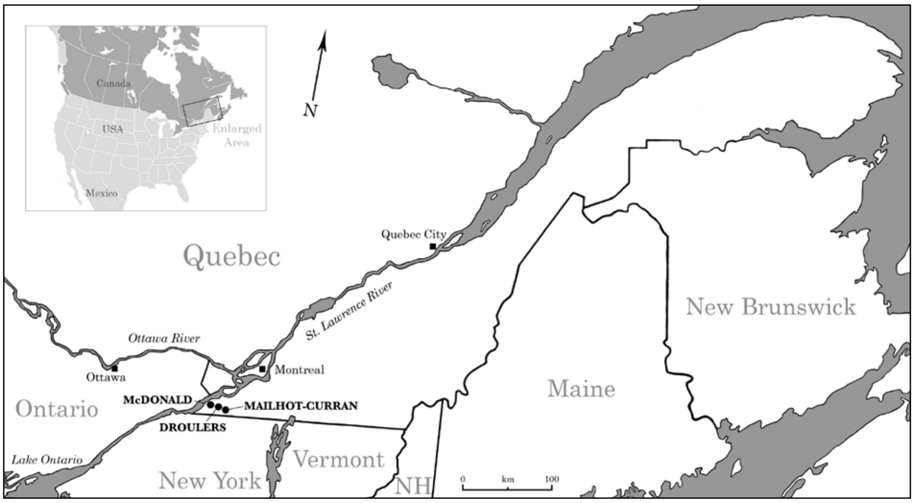

Figure 1. Location of the McDonald, Droulers, and Mailhot-Curran sites in southern Quebec, Canada.

Figure 2. Various functional categories of bone objects from the St. Anicet Cluster, Quebec: beaver incisor chisels (1), awls (2), awl or hair pin (3), sewing needles (4), tattooing needles (5), awls/points/daggers (6), bone sucking tubes (7), spatulas (8), harpoon heads (9), projectile points (10), cup-and-pin gaming pieces or tinkling cones (11), discoidal beads (12), tubular beads (13), and pendant (14).

Site	Approximate date AD	Debris	Blanks	Preforms	Tools	Total worked bone	Total faunal remains	Total
McDonald	1335-1380	590	0	38	438	1066	22,878	23,944
Droulers	1490-1515	720	5	47	1451	2223	378,777	381,186
Mailhot-Curran	1530-1550	443	23	12	403	881	26,508	27,389

Table 1. Content of the bone assemblages from the McDonald, Droulers, and Mailhot-Curran sites.

The three sites were discovered and partly excavated in the 1990s and early 2000s (Clermont and Gagné 2004) and were further investigated during the summer field schools of the Université de Montréal, from 2010 to 2017 (Chapdelaine 2015, 2018, 2019a). Based on the stylistic analysis of the ceramics, radiocarbon dates and Bayesian statistics, the sites are considered to represent a single community's succession of semi-permanent villages from the middle of the fourteenth century to the middle of the sixteenth century AD (Chapdelaine 2019c; Méhault 2019). The Berry and Isings sites are also part of this sequence of farming settlements, but the former has not been analyzed and published in detail (Pendergast 1966), while the latter is currently being investigated (Gates St-Pierre and Ouellet 2020). Consequently, neither of these sites have been included in this study.

The oldest site, McDonald, consists of a minimum of three longhouses and three middens, yielding a total of 438 bone tools and 628 items of production waste (Gates St-Pierre and Boisvert 2018) (Table 1). This village has the smallest assemblage of faunal remains (M. Chapdelaine *et al.* 2018), which may be due to the use of less effective recovery methods compared with the other two sites. However, the sorting method that we have established as part of our protocol allowed the identification of additional tools and production debris among the faunal assemblage recovered, providing an assemblage of worked bones comparable in size to the one from the Mailhot-Curran site.

Droulers is the largest of the three villages and may represent an aggregation of smaller, regional settlements for defensive purposes. It could have contained up to fifteen longhouses, although only seven have been found and excavated so far, along with two middens (Chapdelaine 2019b). A total of 2223 worked bone objects were recovered from this site, including 772 items of manufacturing waste (Boisvert and Gates St-Pierre 2019). This is the largest of the three collections of worked bone analyzed. The faunal assemblage is also the largest one, with nearly 380,000 remains, although only a quarter of that total has been analyzed (Courtemanche and St-Germain 2019). Finally, the Mailhot-Curran site has the smallest collection of worked bone, containing 403 artifacts and 478 pieces of manufacturing waste (Gates St-Pierre and Boisvert 2015), and a modest assemblage of faunal remains as well (St-Germain and Courtemanche 2015). However, this is in line with the Mailhot-Curran collections in general, where the number of stone and ceramic artifacts is also low.

As mentioned above, bone tools are varied in function and are characterized by a lack of standardization (Boisvert and Gates St-Pierre 2019; Gates St-Pierre 2010), although one regular type of bone point has been defined (Gates St-Pierre 2014) (Figure 3). The manufacturing waste includes blanks (also termed supports); preforms (also termed rough-outs); flakes; and other production debris that has been described in more detail elsewhere (Boisvert 2018). The bone artifacts analyzed are well preserved, and evidence of taphonomic processes is rare,

Figure 3. Bevelled, conical bone projectile points made by St. Lawrence Iroquoians.

except for the high degree of fragmentation of the worked bone. Modifications induced by the transformation of animal bones into functional objects are numerous, but they form a class apart and will be presented and discussed later. Overall, the richness of these assemblages of worked bone has made it possible to build a solid database, one of the most significant in northeastern North America in terms of volume and research attention. Indeed, the data presented here are the results of many years, and types, of analysis.

Methodology

The methodology applied to the bone assemblages from St. Anicet consists in five steps: 1) visually sort all the faunal remains to separate the worked from the unworked bone material; 2) classify the worked bone; 3) proceed to the zoological (taxonomic) and anatomical/skeletal identification of the bone remains, worked and unworked; 4) proceed to the technological analysis of the worked bone; and 5) proceed to additional, complementary analyses (microwear, biomolecular, *etc.*) as necessary. Since the main objective of this article is to present the advantages of the collaborative approach between faunal and bone tool specialists, a focus is here placed on the first three steps.

Sorting the faunal remains

Sorting the faunal remains consists in visually examining every single bone in a faunal assemblage, allowing the identification and putting aside of small fragments of bone tools, preforms, blanks, and waste that were not identified in the field. Although time-consuming, this is worth the investment, as it significantly increases the ability to identify worked bone, which in turn improves the quality and reliability of the technological analyses that can then be conducted using larger sets of modified bone. Needless to mention, relying on a bone tool specialist can only enhance the identification results.

While we were initially expecting to find only a few additional bone tools and pieces of bones manufacturing waste during the sorting process, we actually ended up counting them by the hundreds. This is illustrated in Table 2, where the total number of worked bones identified before and after sorting is indicated. The differences can be explained by the high level of fragmentation of the bone tools, the tiny size of most bone manufacturing waste, and the expertise needed to identify bone manufacturing traces and waste. This is especially true in the context of fieldwork, where the identification of worked bone is often impeded by large quantities of faunal remains to be processed on site, and by a

Sites	Waste		Blanks		Preforms		Tools		Total	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
McDonald	0	590	0	0	0	38	116	438	116	1066
Droulers	90	720	1	5	6	47	190	1451	280	2223
Mailhot-Curran	21	443	0	23	0	12	177	403	198	881

Table 2. Total numbers of worked bone by technological category, pre and post sorting of the faunal remains.

lack of time, appropriate lab equipment, and experience among the field workers, most of them students not trained in bone technology. Indeed, courses on the analysis of osseous industries are usually less prevalent than ceramic, lithic, or even zooarchaeology courses, for example, in North America at least. Moreover, only a small part of most zooarchaeology courses can be devoted to bone technology, if at all.

The results obtained from the St. Anicet bone assemblage clearly demonstrate the value and the necessity of sorting worked from unworked bone before proceeding to any further analysis, including standard zooarchaeological analyses. Sorting the worked bone gives access to a significant amount of data that would have gone unnoticed without this procedure. In the present case study, only 10% to 20% of the worked bone (including bone tools and production waste) was identified in the field, before hand-sorting by a specialist. Bone modifications can be very subtle and may escape the attention of zooarchaeologists who are not trained in the identification of worked bone and related manufacturing waste. Most of the time, the bone tool specialist is also a zooarchaeologist *de facto* (*i.e.*, trained in both fields, since bone technology is often considered a subdiscipline of zooarchaeology), but the reverse is not necessarily true. Thus, while some zooarchaeologists have a deep knowledge of and experience in bone technology, others at the other end of the continuum have almost none. They may be quite familiar with butchery marks, but less acquainted with traces of worked bone. This should not be interpreted as a questioning of the zooarchaeologist's capabilities or qualifications, but, rather, as an illustration of the complementarity and synergy of the zooarchaeologist's and the bone technologist's respective skills and knowledge.

Classifying the worked bone

After sorting the worked bone, each piece is classified according to its morphotechnological characteristics, including modification marks, such as macro-traces of grooving, scraping, percussion, or abrasion, as well as microwear, in the form of striations, polish, chippings, *etc*. As pointed out by Averbouh (2001), this characterization allows a technological reading of the subsets of worked bone, which in turn makes it possible to establish connections between these complementary subsets. The general idea is

> *"to separate materials by the way they function in the different levels they belong to: categories and types of products; schemes; techniques and transformation procedures and, to finally, categorize and type the raw materials."* (Averbouh 2001, 114)

Worked bone collected during post-excavation sorting was not always easy to identify, as will be emphasized below. Moreover, it should be noted that the criteria used to identify

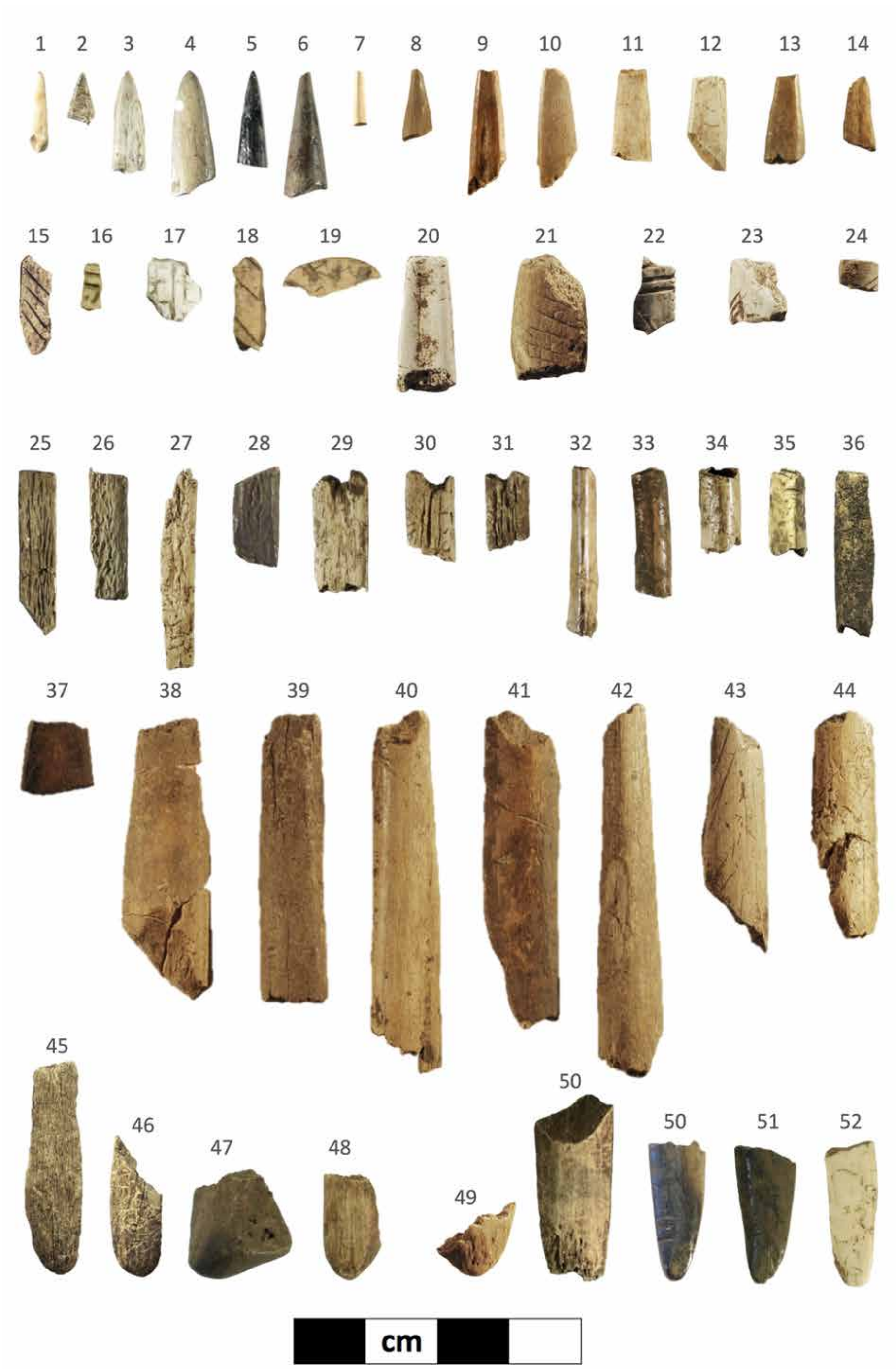

Figure 4. Distal (1-14), mid- (15-44) and proximal (45-52) sections of bone objects from the St. Anicet assemblages. Their functions are unknown, with the exception of needles (25-31; note the partial eyes in 29-31) and bead preforms (32-36). Some are decorated with abstract motifs (15-24) that are similar to those found on Iroquoian pottery vessels.

by-products (or waste and debris), blanks (or supports), preforms (or rough-outs), and, to a lesser extent, finished objects remain rare, unclear, and variable among scholars, especially in North America (see Bonnichsen and Sorg 1989; Johnson *et al.* 2012; Karr 2015; Lyman 1984; Morlan 1984; Sadek-Kooros 1972, 1975; Yesner and Bonichsen 1979). This is especially true for by-products, since they usually receive little attention from researchers. However, the past two decades have seen interesting developments in technological approaches applied to the study of bone production waste, especially in Europe (see Averbouh 2001; Averbouh and Pétillon 2011; Baumann and Maury 2013; Beldiman 2005; Buc *et al.* 2014; Chauvière 2003; Christensen and Goutas 2018; Christensen and Tejero 2015; Christensen and Valentin 2004; David 2017; David and Sorensen 2016; Lang 2010; Moreno-García *et al.* 2010; Rosen and Roux 2009; Sidéra 2005; Soulier *et al.* 2014; Tartar 2003; Treuillot 2016; Wild 2020). Although most of these studies are focused on worked antler, they still represent a significant advance in our understanding of osseous industries. It should also be noted that such categories of by-products sometimes overlap in definition and would need to be redefined and standardized eventually. Moreover, some bone waste may present very distinctive morphotechnological characteristics, while other items carry very few, if any, traces of modification. The latter are therefore more difficult to connect with a particular step in the reduction sequence, or *chaîne opératoire*.

The waste products, blanks, preforms, and finished objects from the St. Anicet sites were characterized in light of these considerations. Examples of the small fragments of finished bone artifacts that are regularly found when sorting faunal remains are illustrated in Figure 4. Examining the faunal remains in detail made it possible to isolate, among other things, fragments of needles made from deer ribs (likely from white-tailed deer) (25-31); distal tips (1-14) and proximal ends (45-52) of various slender tools; fragments of tubular beads made from the diaphyses of bird bones (32-36); small sections of decorated bone objects (15-24); and many mid-sections of indeterminate tools (15-44).

The first specimens (1-9) shown in Figure 5 are examples of preforms or rough-outs. Since the preform is an intermediate stage between the production of a blank (or support) and the finished object, it usually shows minimal evidence of initial shaping and does not bear any traces of the finishing steps, nor any sign of use (Averbouh 2001, 114). For this reason, they rank among the most difficult worked bones to identify and they may go unrecognized by field archaeologists and zooarchaeologists untrained in bone technology. In the present case, the preforms are generally elongated and rectilinear. They constitute a perfect canvas – one that offers a large variety of possibilities for the tool maker. The preforms are also characterized by a series of removals along the edges, resulting from percussion flaking undertaken to regularize the shape of the edges. The collections from St. Anicet contain many dozens of these percussion flakes (Figure 6: 1). They are all thin, wide and short, and often have a striking platform and a bulb of percussion, just like a typical stone flake. The latter feature is the result of conchoidal fracture and is very distinctive and rather easy to identify (Goutas and Christensen 2018, 59). Percussion flakes were one of the most frequent waste items in the worked bone assemblages from St. Anicet. The flakes serve as direct evidence for the use of direct percussion or retouching[1] on bone, and the scars that they leave on the objects help to determine their position in the reduction

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[1] The terminology used here refers to the techniques presented in Goutas and Christensen (2018, 62) and Wild (2020, 79).

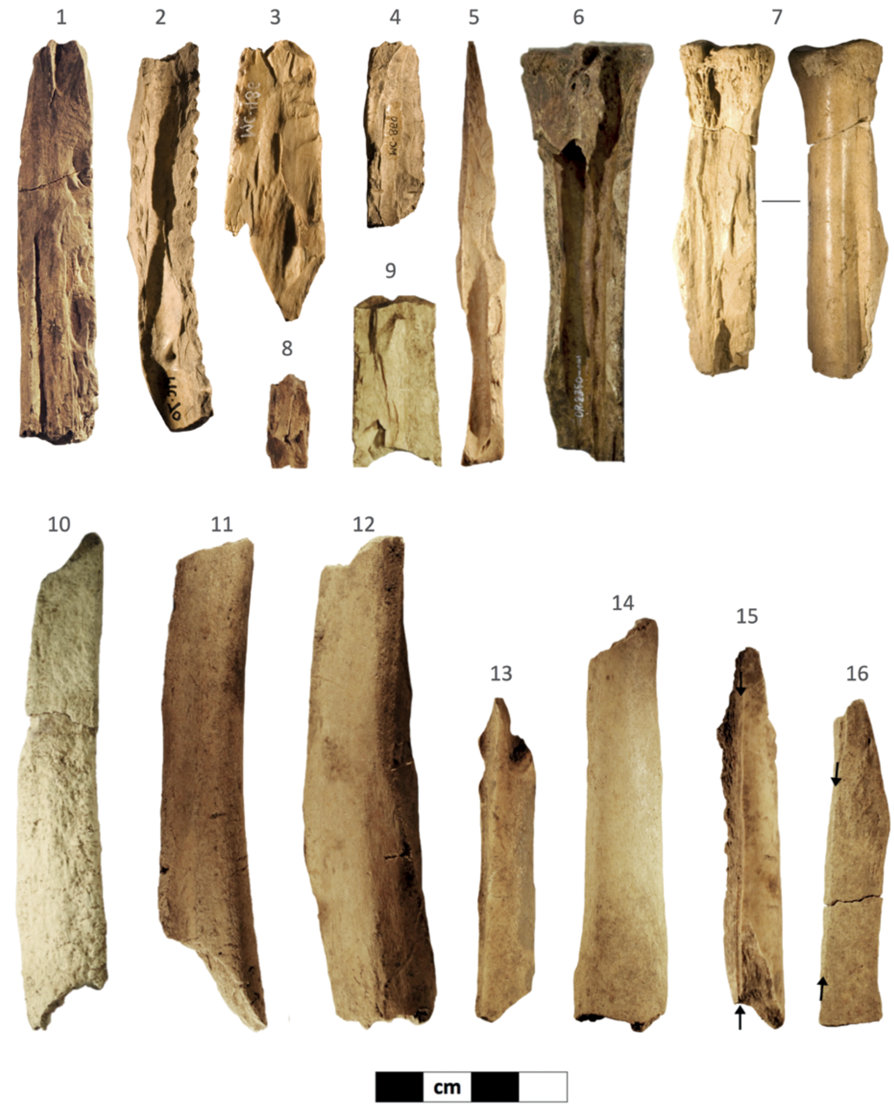


Figure 5. Bone preforms (1-9) and blanks (10-16) from the St. Anicet assemblages.
Note the flaking on nos. 1-9 and the grooves on nos. 15 and 16 (indicated by arrows).

sequence. One could refit the bone flakes on a bone preform in order to reconstruct the reduction sequence, just as one would do with stone flakes put back on a stone core or preform. Each of the collections from St. Anicet also contains unretouched, rectangular bone fragments that could have been used as blanks or supports (Figure 5: 10-16). In two cases (Figure 5: 15-16), the grooves produced to facilitate the sectioning of the diaphysis through snapping are still visible.

St. Lawrence Iroquoians made great use of white-tailed deer metapodial bones in their production of bone tools. Metapodial bones were especially coveted due to their morphology (long bones with straight edges) and their hardness, which are highly valued technological properties (Christensen and Tejero 2015, 75). The manufacturing waste associated with

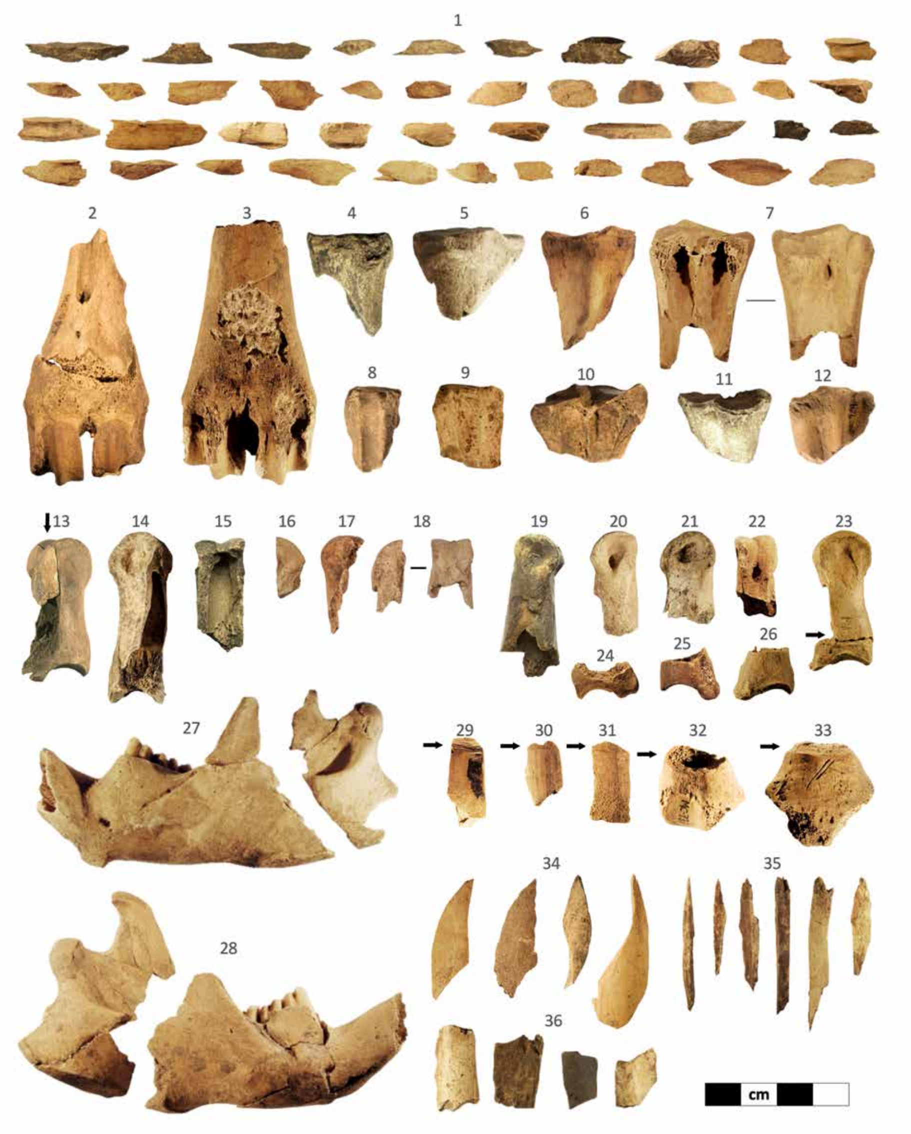


Figure 6. Bone tool manufacturing waste from the St. Anicet assemblages. Percussion flakes (1), cervid metapodial bones with hammering marks (2-3), proximal ends of cervid metapodial bones (4-12), fragments of deer phalanges (13-26; the arrow above no. 13 indicates where indirect percussion blow was hit, whereas the arrow beside no. 23 indicates grooves), broken beaver mandibles (27-28), bone debris with grooves (29-33, indicated by arrows) and scraping marks (30) , spiral flakes (34), elongated flakes (35), and angular flakes (36).

their transformation mainly consists of distal and proximal ends (epiphyses, essentially), supporting the idea that irregular shapes were not desired and needed to be removed. As shown in Figure 6: 2-12, the distal and proximal ends of metapodial bones were detached using direct percussion, hitting the bone at the fusion line. Byrd (2011) believes this is the "sweetspot" for removing epiphyses, resulting in an appreciable length of the diaphysis to serve as blanks, while also allowing the extraction of the marrow from the medullary cavity: "trapped marrow is not only lost as food, it delays bone drying. Cutting too far from the distal end wastes shaft length" (Byrd 2011, 104). For these reasons, the epiphyses must have been removed at the very beginning of the transformation process.

Manufacturing waste resulting from the working of white-tailed deer phalanges is also abundant in the collections from St. Anicet. To date, two categories of debris have been identified and associated with a specific reduction sequence. The first category is composed of phalanges that were split longitudinally to produce rectangular bone toggles or gaming pieces (Figure 6: 13-18). They were probably obtained using indirect percussion with a stone wedge and a hammer, as there is no evidence of grooving. While such debris was present in each of the collections from St. Anicet, not a single finished object was found in any of them. In this case, the manufacturing waste demonstrated that phalanges from cervids were indeed transformed into utilitarian objects, whether toggles or gaming pieces, even though such finished objects were totally absent from the collections analyzed. The second category is composed of proximal fragments (articular surfaces) of phalanges associated with the manufacture of cup-and-pin game pieces, although some may rather represent tinkling cones (Figure 6: 19-23; see also Figure 2: 11). They were probably split using the groove-and-snap technique described by McCullough (1978), although chopping or breaking off the articular surface with a stone axe or a stone hammer also appears to have occurred in some cases. However, we must consider that this also represents a marrow extraction technique that has nothing to do with bone technology (see Binford 1978; Jin and Mills 2011; Jones and Metcalfe 1988). Grooves (Figure 6: 28-33) and traces of scraping (Figure 6: 29) were also noted on a few items of phalange waste; they could not be linked to any specific *chaîne opératoire*, nor was it possible to identify the function of the object that was being produced.

Peculiar fragments of beaver mandibles were identified during the sorting, all showing fractures on the ramus (Figure 6: 27-28). According to our current understanding, these fractures appear to be systematically located at that spot where the incisor takes root. The blow applied through direct percussion on the ramus of the mandible broke that thin section of bone in fragments and facilitated the extraction of the incisor, a technique that has been used for millennia in this part of the world (see Clermont and Chapdelaine 1998). Given the possibility that the mandibles may have been used as natural handles, the fracturing could also be explained as an intent to remove the uncomfortable condyle and coronoid process (Gates St-Pierre and Boisvert 2015).

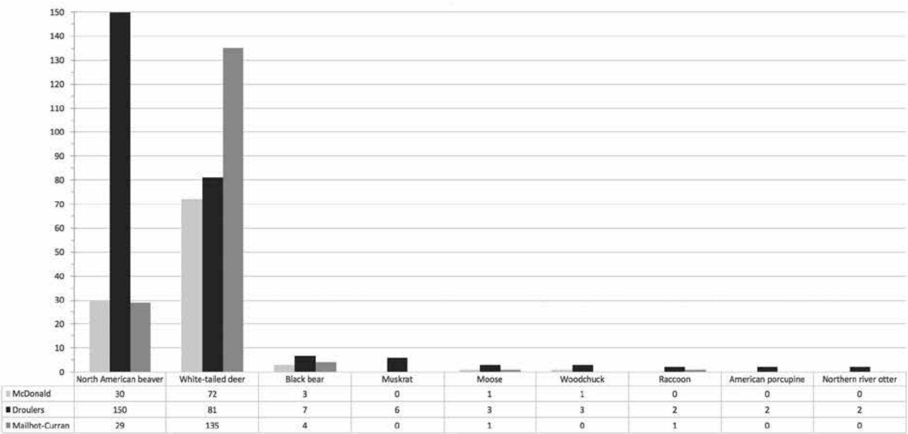
Finally, some categories of bone waste are more difficult to analyze and understand, but they deserve our attention nonetheless: flakes with spiral fractures, elongated flakes and angular flakes (Figure 6: 34-36). These simple and standardized categories are largely based on the shape of the fracture(s) and the general shape of the flake, following Clark (1993). Simply put, spiral flakes are characterized by helical fractures resulting in curved (concave or convex) edges (Figure 6: 34). Angular flakes have various angles and straight edges (Figure 6: 36), whereas elongated flakes are thin and long, with various types of fractures at their extremities (Figure 6: 35). Variable in size, the flakes from each of these categories are also characterized by the presence of the inner (medullary) and outer (cortical) surfaces, as most were detached from the diaphysis of long bones. Usually they do not show any other trace of technological modification or butchering, however, and the causes of the fractures are not fully understood.

These flakes are problematic. As pointed out by Yesner and Bonnichsen (1979, 305): "A central problem in isolating bone tool product patterns in assemblages of bones is the isolation of identifiable morphological criteria that can be used to separate marrow processing practices from tool making patterns." However, fractures induced by marrow extraction may also create straight and slender fragments or supports that are suitable for the manufacture of bone objects (Goutas and Christensen 2018, 63; Griffitts 2006, 357). In this regard, Byrd (2011, 97) states that "Cutting and snapping for marrow exposure and tool-making are not necessarily mutually exclusive. Combining the two actions would have saved time and effort." We certainly concur with this assertion.

Despite there being an abundant literature on the subject, there are no conclusive criteria that can be used to differentiate natural from anthropogenic fractures on bone, let alone to differentiate fractures resulting from the making of bone tools from those created during food processing (especially butchering), as they may constitute examples of equifinality (Behrensmeyer 1978; Blumenschine 1973, 1995; Blumenschine, Marean, and Capaldo 1996; Bonnichsen 1973; Bonnichsen and Will 1980; Haynes, 1982, 1988; Johnson 1985; Karr and Outram 2012a, 2012b, 2012c; Kyoman 2004; Lyman 1984, 2004; Masset *et al.* 2016; Maté-González *et al.* 2019; Morlan 1984; Myers, Voorhies, and Corner 1980; Outram 2002; Parmenter and Outram 2016; Sadek-Kooros 1975; Saint-Germain 1997, 2005; Vettese *et al.* 2020; Wheatley 2008; and many more). Therefore, the criteria currently used to define and identify spiral, angular, and elongated flakes need to be clarified and better documented. Experimental studies could certainly contribute to this objective. In addition, we will need to standardize our terminology in order to reduce the current disparity, following recent efforts by Goutas and Christensen (2018) in this regard.

Performing zooarchaeological analysis

Most of the worked bone just described could not have been identified without an integrative approach, since a large proportion of these items would probably have ended up in an "indeterminate" category in a more standard faunal analysis. As mentioned above, zooarchaeologists and bone tool specialists usually work separately and in isolation, even when studying collections from a single site. Thus, the faunal specialist may not have access to the collections of worked bone, since bone tools are considered artifacts, not ecofacts. The faunal analyst is then deprived of a crucial part of the total faunal assemblage, which may result in incomplete results and biased or plain wrong interpretations. On the other hand, the bone tool specialist needs to have access to precise and reliable anatomical and taxonomic identifications; if that specialist is not trained in traditional faunal analysis (as in the case of the first author of this paper), the collaboration with the zooarchaeologist becomes even more necessary. Likewise, most zooarchaeologists (such as the second author of this paper) are not trained in the identification of manufacturing traces on bone fragments, but only in the analysis of complete, finished objects. Moreover, the constant collaboration and mutual sharing of knowledge and expertise between the zooarchaeologist and the bone tool specialist can make it easier to differentiate bone modifications caused by natural processes from those resulting from bone working, thereby helping to clarify the criteria to be used in the identification of taphonomic processes. As pointed out by Christensen and Tejero (2015, 77), the technological analyst would benefit from collaborating with



	North American beaver	White-tailed deer	Black bear	Muskrat	Moose	Woodchuck	Raccoon	American porcupine	Northern river otter
▨ McDonald	30	72	3	0	1	1	0	0	0
■ Droulers	150	81	7	6	3	3	2	2	2
▨ Mailhot-Curran	29	135	4	0	1	0	1	0	0

Figure 7. Mammal species used for tool manufacturing at the McDonald, Droulers, and Mailhot-Curran sites (number of identified specimens per taxon): North American beaver, white-tailed deer, black bear (*Ursus americanus*), muskrat (*Ondatra zibethicus*), moose (*Alces americanus*), woodchuck (*Marmota monax*), raccoon (*Procyon lotor*), American porcupine (*Erethizon dorsatum*), and Northern river otter (*Lontra canadensis*).

the zooarchaeologist, not only to share information, but also to avoid pitfalls and misinterpretations of all sorts (see also Acosta and Buc 2010; Buc and Loponte 2012).

Knowing that the selection of skeletal elements from particular species never seems to be the result of pure chance, there is a whole range of emic choices and etic interpretations that needs to be evaluated from a combined technological and zooarchaeological perspective. This would provide a better understanding of raw material procurement strategies in the past. Since the St. Lawrence Iroquoians favoured bone over stone to make most of their tools, the lack of a collaborative, integrative approach to the study of faunal remains deprives us of precious information, knowing that there are always a minimum of planning, knowledge, and cultural preferences in the production of any bone object.

In order to achieve an integrated collaboration as promoted here, the entire collections of faunal remains and worked bone from the three sites selected for analysis were examined by both specialists: Marie-Ève Boisvert, the bone technologist (with the help of Christian Gates St-Pierre, a bone technologist and zooarchaeologist), and Claire St-Germain, the faunal analyst. The reference collections at Ostéothèque de Montréal were used for anatomical and taxonomic identifications. Of the utmost importance was the reciprocal integration of datasets: data from the worked bone assemblage were included in the faunal analysis, while zooarchaeological identifications were considered during the worked bone analysis, especially in trying to understand technological choices.

The faunal assemblages from the McDonald, Droulers, and Mailhot-Curran sites contain a large variety of taxa. White-tailed deer always ranks first, closely followed by the North American beaver (*Castor canadensis*) and other rodents, whereas carnivores usually rank third (Chapdelaine *et al.* 2018; Courtemanche and St-Germain 2019; St-Germain and Courtemanche 2015). Deer and beaver were also widely favoured for the production of bone objects, although beaver incisors were much more abundant at the Droulers site, whereas deer bones were slightly more popular among the crafters of the Mailhot-Curran site (Figure 7). Between 99% and 100% of the worked bone from each assemblage came from mammals, while a very few

White-tailed deer

Skeletal part	N and % faunal	N and % tool	N total
Cranium	14 (82%)	3 (18%)	17
Post-cranial skeleton (axial)	1 (100%)	0 (0%)	1
Forelimb	6 (24%)	19 (76%)	25
Hindlimb	10 (22%)	35 (78%)	45
Indeterminate limb	14 (21%)	52 (79%)	66
TOTAL	45 (29%)	109 (71%)	154

North American beaver

Skeletal part	N and % faunal	N and % tool	N total
Cranium	222 (63%)	133 (37%)	355
Post-cranial skeleton (axial)	82 (99%)	1 (1%)	83
Forelimb	55 (92%)	5 (8%)	60
Hindlimb	158 (93%)	11 (7%)	169
Indeterminate limb	10 (100%)	0 (0%)	10
TOTAL	527 (78%)	150 (22%)	677

Table 3. White-tailed deer and North American beaver skeletal parts from the Droulers faunal assemblage. Numbers for white-tailed deer include indeterminate cervid bones the size of white-tailed deer that are most probably from that species.

bone objects were made out of bird bones (essentially beads made from the long bones of ducks [*anatinae*] and grouse [*tetraoninae*]) or fish bones (mostly channel catfish [*Ictalurus punctatus*] spines transformed into awls).

It seems fair to say that the most important species in St. Lawrence Iroquoian assemblages were subject to a "mixed exploitation." for both subsistence and technological purposes. The McDonald site offers a good example of this. The osseous remains of four beavers – three adults and one juvenile (perhaps members of a single family captured together) – were found in a pit located inside a longhouse. Although most body parts were present, all the mandibles were missing. However, three pairs of adult mandibles and a section of a juvenile mandible were found a few metres away, most probably the ones that had been removed from the carcasses in the pit (Chapdelaine *et al.* 2018). Moreover, each mandible had its lower incisor extracted following the procedure described above. This suggests that the mandibles were removed and carried away to extract the incisors, which were used to make bone tools shortly thereafter, while the rest of the bodies were stored in a pit for later consumption, but were ultimately forgotten. The acquisition of osseous raw materials is often considered as a secondary activity, as a by-product of butchering. In the present case, however, the need to obtain osseous raw materials may have been equally, if not more urgent than the need to obtain protein (Gates St-Pierre, St-Germain, *et al.* 2016). This should serve as a reminder that hunters often make complex decisions involving multiple needs – needs that can vary in terms or priorities. This is a lesson that can be relevant to situations and contexts beyond the ones illustrated in our case study.

Moose is another case worth mentioning. Under different circumstances, this species could have remained completely unknown in the faunal analysis of the Droulers assemblage, since the only three bones (MNI=1) identified to this species were worked and thus were dropped into the worked bone assemblage box. This includes a bone manufacturing debris and two finished objects. While it is possible that the latter may have been curated and transported from another site, this seems less likely regarding the manufacturing debris, which indicates that a tool was made *in situ* using this moose bone. The rest of the moose skeleton may have been abandoned at the kill/butchery site, or at some unexcavated portion of the site. In any case, the addition of even a single moose bone to the faunal assemblage may have an impact on the identification of hunting strategies (since moose have their own geographic range, habitat, and behavior) and on the species representation in terms of meat weight or MAUs, for example. Likewise, 71% of the deer and beaver bones could have been excluded from the faunal assemblage of this site, were it not for the integrative approach (Table 3).

The very low frequency of deer bones in the faunal assemblage from the Droulers site would have been very surprising, since this was one of the two most important species pursued by Iroquoian hunters. Accordingly, it was most important that the faunal analysis include species identification from the assemblage of worked bone, where deer and beaver were proportionally much more abundant. In addition, most of the bones that were transformed were from the lower limbs (phalanges and metapodial bones, essentially). Thus, not only this species' importance to the diet would have been biased, but also the representation of its skeletal parts. In the case of the North American beaver, a similar bias would have occurred, since incisors would have been especially overlooked in the faunal assemblage, as they were frequently transformed into chisels or side scrapers and are consequently more abundant in the bone tool assemblages. In sum, white-tailed deer and American beaver were sought for their bones as much as their meat – not to mention their fur, grease, and other body parts and materials.

A dimension never comes alone

Thus far, we have emphasized the economic and technological information that can be extracted from animal bones and teeth found in archaeological sites. However, most bones have more than two dimensions, just like a biface has more than two sides (cf. Kelly 1988). During our research project investigating the exploitation of animal resources by St. Lawrence Iroquoians, it quickly became apparent that animals were not only sources of proteins and raw materials, but also sources of emblems, symbols, and myths, as well as sources of information on social organization. As noted above, these dimensions have already been presented elsewhere and will only be summarized here.

The social dimension was revealed through the spatial analysis of the faunal remains and worked bone at the McDonald, Droulers, and Mailhot-Curran sites. In each case, it was found that every household and household member had equal access to animal food products (Chapdelaine *et al.* 2018; Courtemanche and St-Germain 2019; St-Germain and Courtemanche 2016). Likewise, apparently any type of bone object could be used by any individual, and the technological knowledge and raw materials necessary to produce a bone object were not restricted to a small group of specialized crafters, but were available to all (Gates St-Pierre, Boisvert, and Chapdelaine 2016; Gates St-Pierre, St-Germain, *et al.* 2016). These socially shared products and knowledge among the St. Lawrence Iroquoians from St. Anicet reflect the egalitarian nature of the social organization that characterizes all Pre-Contact Iroquoian societies. Their political, confederal organization may have been complex, but they remained committed to the community spirit, to a strong sense of equity and to the domestic autonomy of the household, avoiding the development of craft specialists and social hierarchy.

Looking at how bone objects were made is interesting, but determining how they were used is equally important. This other dimension, that of function, can be unveiled through various methods, but one of the most efficient remains usewear (or microwear) analysis. Working in the context of an integrative approach, this method was included in our research project design right from the beginning. For example, we have questioned the asserted function of items described as bone awls and bone husking pins in the literature. The results highlighted the numerous problems emerging from tool functions determined on the basis of morphological criteria alone. They contributed to the identification of the appropriate criteria to be used to differentiate between the functions of similarly shaped tools (Gates St-Pierre and Boisvert 2015; see also Gates St-Pierre 2007).

The function of two types of bone needles was also investigated. The sewing needle, long and flat, with an eye towards the middle of the tool (Figure 2: 4), is stated in the literature to have been used for the weaving of fishing nets, thus providing evidence of fishing activities anywhere they are found. However, our microwear analysis indicates that they were more probably used to weave reed mats, which was an abundant item used inside Iroquoian longhouses (Gates St-Pierre, St-Germain, *et al.* 2016). Similarly, the microwear analysis that we have conducted revealed that objects traditionally called bodkins (or short awls) were actually used as tattooing needles (Gates St-Pierre 2018). This Iroquoian type of tattooing needle has a short and slightly convex shaft, with a small knob at its proximal end (Figure 2: 5), probably for easier handling (one could imagine handling the needle between the thumb and the middle finger, with the forefinger pressed on the knob to push the tip of the needle into the skin). This finding opens a little window on the archaeology of the body, including the public body, as most tattoos are made to be seen by others. On the other hand, it seems like the creation, the “giving and receiving” of a tattoo, was somewhat intimate or semi-private in this community, as every tattooing needle identified at the Droulers site was found inside a longhouse, never outside, in more public spaces (Gates St-Pierre 2018). This is another facet of the social dimension of a bone tool that we have just started to unveil and investigate.

But there is more. While tattoos are unquestionably part of one’s personal, individual identity, other bone tools can also carry information about social and cultural identities. For example, the conical and bevelled type of bone projectile point mentioned earlier (Figure 3), apparently unique to the St. Lawrence Iroquoians, could be considered as a marker of ethnicity (Gates St-Pierre 2014). Admittedly, to demonstrate this would require further support, as ethnicity is a complex component of identity, one that is very difficult to tackle, to define, and to recognize in the archaeological record. Nevertheless, we were intrigued by this particular type of bone point and wanted to know more. Because the anatomical element had been heavily modified from its original shape during the tool making process, it was not possible to determine precisely which animal species and skeletal elements these bone points are made of. All we could say was that long bones from medium to large-size mammals were used.

This is where zooarchaeology by mass spectrometry, or ZooMS, comes in. Eight of these projectile points were sent to the BioArCh Lab at the University of York for ZooMS analysis, testing a brand new method (“the bag method”) that is totally non-destructive, as it only tests the micro-particles in suspension inside the plastic bag containing the bone artifact (McGrath *et al.* 2019). Since, as we have seen, both the faunal and the worked bone assemblage from the McDonald, Droulers, and Mailhot-Curran sites were dominated by deer bones, we were expecting the tested bone points to have been made on the bones of this same species. However, the results indicate that these points were made from bear and human bones, something later confirmed by DNA analysis (McGrath *et al.* 2019). This totally unexpected outcome opened a window on a new dimension: the symbolic dimension of a bone. Bears occupy a special place in the mythology and cosmology of the Iroquoians, in part because they share so much with humans: their overall morphology (especially when they stand upright), their omnivorous diet, and their hunting abilities. It comes as no surprise that the bear is a brother, an uncle, a grandpa in the myths of nearly all Indigenous peoples of the circumpolar world (Berres *et al.* 2004; Hallowell 1926). Among the Iroquoian tribes of northeastern North America, the bear was also (and still is) a clan emblem, and historically the most prominent one at that. The use of bear and human bones to produce this singular type of projectile point most certainly represents a material and symbolic expression of this unique interspecies connection (McGrath *et al.* 2019; Gates St-Pierre *et al.* 2020).

Conclusion

The thoughtful integration of zooarchaeological, technological, microwear, biomolecular, and spatial analyses significantly improves our abilities to obtain a holistic understanding of the complex and multidimensional interactions between humans and other animals in the past. This opens up new perspectives on the interplay between the economic, technological, social, and symbolic dimensions of bone artifacts. Needless to say, many other kinds of analyses and disciplines should also be called upon. While the integrated collaboration between various specialists sounds obvious to many and is highly encouraged by most, in reality, obstacles of various kinds still make it difficult to genuinely implement the integrative approach. It necessitates a profound interaction between sub-disciplines and areas of expertise, from the beginning to the end of the research process. Moreover, not every research project or budget allows for soliciting such a large array of disciplines, methods, and techniques. This is why the integrative approach, interdisciplinary by nature, should always remain flexible and adapted to a project's needs and capacities, according to its own objectives, research questions, and context.

Despite previous calls by other researchers, the collaboration between bone technologists, zooarchaeologists, and other specialists, especially those in the field of archaeometry, is still in its early stages and sometimes seems to be running on parallel tracks rather than engaged in the dialogue and interplay that an integrative perspective necessitates. However, when a first version of this paper was presented at the ICAZ Worked Bone Research Group conference, held in Montréal in 2019, the audience expressed enthusiasm and a willingness to work in this direction, quite fortunately. The future will tell how realistic and useful it was to promote an integrative approach to study the many dimensions of a bone.

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BONES AT A CROSSROADS

Bone tool studies are at a crossroads. A current path is to go beyond the concatenation of methods or concepts borrowed from other disciplines and aim instead at a truly integrated approach that is more in line with the objectives of interdisciplinary and transdisciplinary research.

The papers in this volume follow this direction by adopting various forms of dialogue and integration between old and new methods and approaches, including technological analysis, usewear analysis, typology, zooarchaeology, stable isotope analysis, experimental archaeology or spatial analysis. They represent a mixture of methodological issues, case studies, and discussions of larger cultural and historical phenomena that span thousands of years and many parts of the World, from South Asia to the Near East and Europe, and from North to South America. The synergies deriving from these multi-perspective approaches lead to the repeated identification of diverse social aspects of past societies, including the identification of general social contexts of bone tool production and use, transmission of knowledge, the symbolic dimensions of artifacts, and intergroup relations as well as warfare and state formation processes.

All these papers grew out of communications presented at the 13th meeting of the Worked Bone Research Group (WBRG) on October 7th–13th, 2019, at the Département d'anthropologie, Université de Montréal, Canada. The WBRG is an official working group of the International Council for Archaeozoology (ICAZ) dealing with the study of worked faunal remains from archaeological sites.

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