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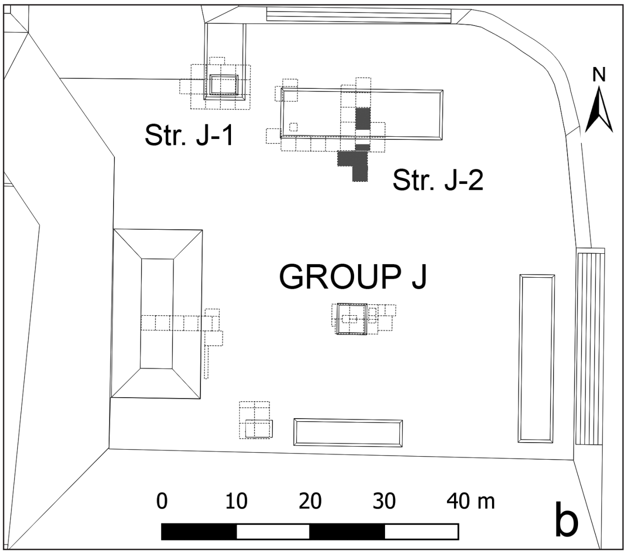
Figure 1. Map of Ucanal: (a) Location of Ucanal in the Maya lowlands; (b) map of Group J showing location of deep excavation units (in grey) that exposed the bone production deposit; (c) location of Group J within the context of the central zone of the site of Ucanal.

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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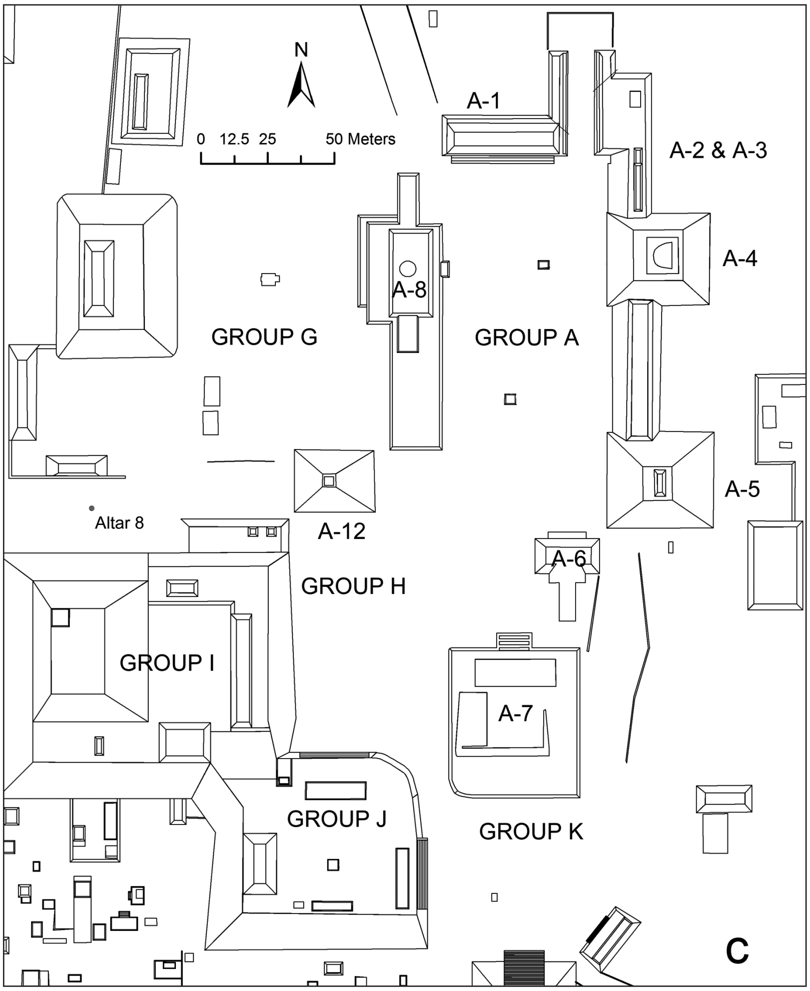
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during the Terminal Classic period (830-1000 AD) as other Maya centers were depopulated and abandoned at the end of the Classic period (Halperin and Garrido 2019, 2020).

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 wall 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 10.0kV × 500 BSE3D 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

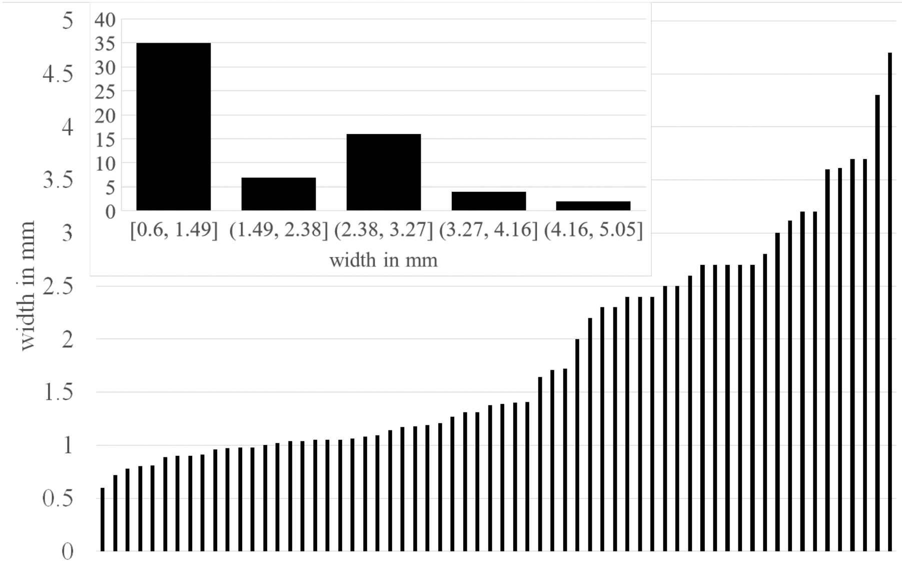

Figure 3. Maximum needle width (n=65). Inset shows two main size classes (by maximum width) in needle production.

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.

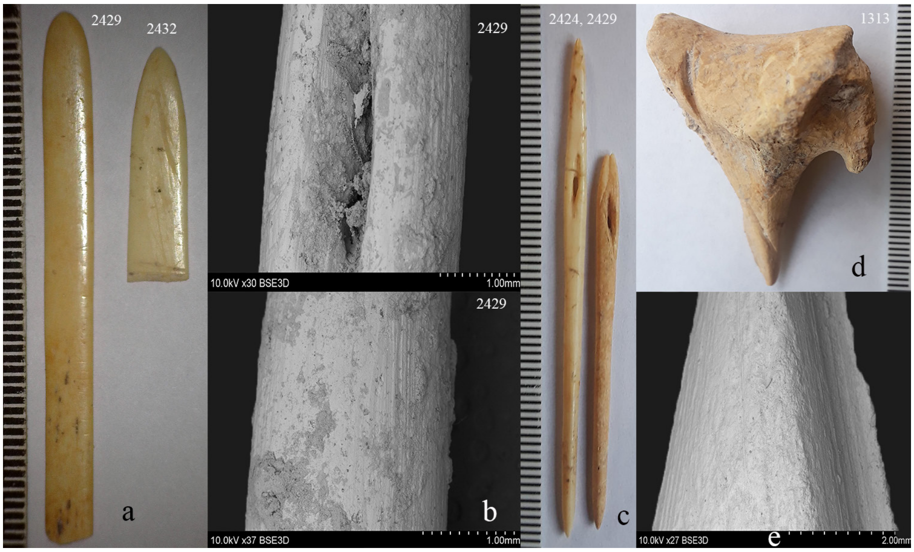

Figure 4. Perforators from Ucanal: (a) Two flat perforators with usewear (UCA.1B.27.8.2432); (b) SEM images showing production marks on a needle from Lot UCA.1B.26.10.2424; (c) complete needles UCA.1B.26.10.2429 and UCA.1B.25.7.2424; and (d) white-tailed deer proximal tibia awl with (e) an SEM image 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 and use 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)

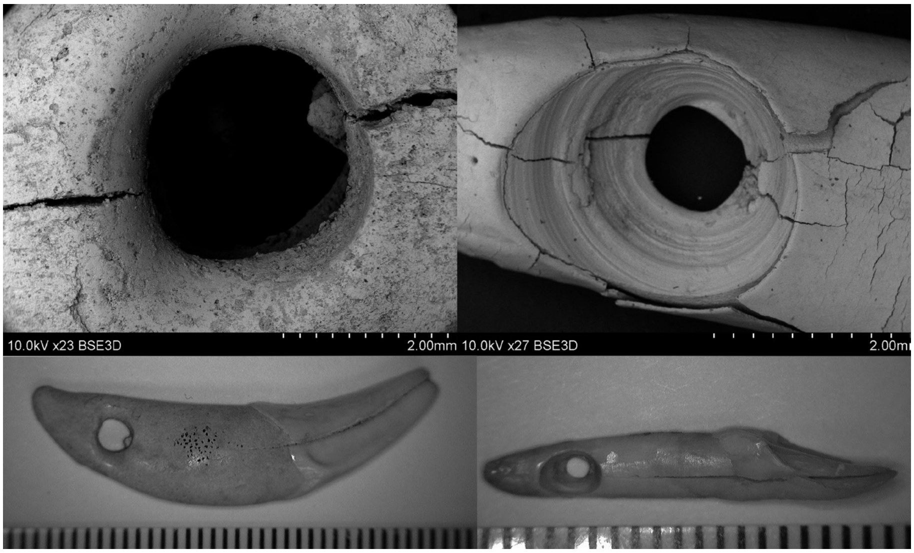

Figure 5. Left images show dog upper right canine bead UCA.1B.26.9.2406 (lateral view) with grooves worn lateral to drilled hole and visible on SEM image in black and white. A periosteal infectious process also is visible in the tooth root (medial view). Right images show a bead produced from a white-tailed 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).

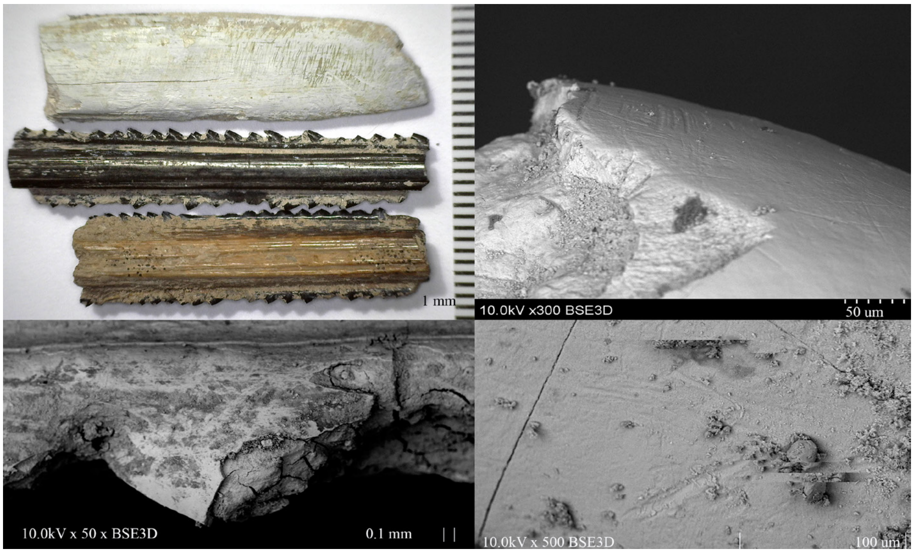

Figure 7. Three stingray spine fragments (clockwise from upper left): Three barbs with cut marks visible under low magnification on the calcined barb (upper); cut marks near the break of the central blackened barb (central); and multidirectional striations and broken serrations on the brown barb (lower)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