The use of metal axes in butchery at Early Bronze Age Göltepe, Turkey: a new method for the differentiation of stone and metal axe marks on bone

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Abstract

Chopping carcasses into segments for effective distribution and processing is an essential part of the butchery process from the distant past to the modern era. However, identification criteria, definitions, and experimental work pertaining to chop marks is lacking in the zooarchaeological literature. Butchery marks on archaeological faunal assemblages provide indirect evidence for utilitarian tool use related to food processing and mitigates the need for the physical presence of the tool itself. This thesis uses an experimental approach to determine the axe material type (bronze, copper, ground stone, or chipped stone) that created the prominent chop marks found on the Early Bronze Age faunal assemblage from Göltepe, Turkey. Experimentation shows that both width and sharpness of the axe are the major aspects of the chopping tool that effect the morphology of the chop mark. A thick, dull axe is more likely to crush the bone rather than cut through it, and often leaves the bone highly fragmented. A thin, sharp axe is more likely to cut through the bone with little to no crushing, and leaves a smooth sheared surface extending from the point of entry. All chop marks can be classified according to both their levels of crushing and shearing on a scale from 1-5. Chop marks falling between a Class 1 and a Class 3 were likely created by stone axes, whereas chop marks that fall between a Class 4 and Class 5 were likely created by metal axes. The experimental results indicate that metal axes created the majority of the chop marks on the Göltepe faunal assemblage even though no metal axes were recovered from the site. The extensive level of shearing on many of the chop marks and relatively high number of bronze artefacts recovered from Göltepe, suggest that the dominate material type for axe heads used for butchery were either bronze or arsenical-copper.

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Introduction to the research

I. *Research agenda*

Metals have always been an artefact class of acute fascination for archaeologists as they are often seen as representing prestige, technological know-how, and artistic ability (Childe 1950, Kerner 2010, Stork 2015, Yener 2000). The production of ancient metals required complex social and technological networks including chains of production, and long distance trade networks that linked source materials to producers, and finally, to consumers. The Early Bronze Age (EBA henceforth) in Anatolia experienced developments in the complexity of metal production that coincided with major shifts in settlement patterns and social stratification (Fidan, Sari, and Türkteki 2015, Yener 2000). The archaeological study of metals aims to identify metallurgical systems and their connections to each other in an effort to gain perspective on the dialectic role between metals and society. The mountain village of Göltepe was an integral part of the Late Chalcolithic/EBA tin mining and production system in south central Anatolia (Yener et al. 2015). However, relatively few metal finds and copious amounts of ground stone tools suggests that utilitarian metal tools may not have played an important role in the daily lives of the residents. Utilitarian metal tools (axes, chisels) are found as early as the Middle Chalcolithic in Anatolian (Caneva, Palumbi, and Pasquino 2012), and by the EBA axes, metal chisels, knives and daggers are often found as grave goods, yet are rarely found in domestic contexts (Massa 2014). This makes it exceedingly difficult to know the actual availability of these tools and to what degree metal tools were integrated into everyday tasks at a time where both stone tools and their metal counterparts co-existed.

The study of ancient metals has, and continues to be approached from many different perspectives, including traditional typological approaches (Arcan 2012), mining and production sequences (Yener et al. 2015, Levy et al. 2002), experimentation (Greenfield 1999, Earl and Özbal 1996), and raw material sourcing through isotopic composition (Şahoğlu 2005, Webb et al. 2006). This thesis uses an experimental approach to identify the use of early metal axes in butchery. The main research question addressed is: Can we identify the signature criteria of metal and stone axes used on animal bones? If so, to what extent were metal or stone axes used in the butchery process at EBA Göltepe. Furthermore, how do temporal patterns of axe material type use in butchery relate to the known adoption patterns of metal knives in EBA butchery (Greenfield 2013)?

II. *Focus of research*

This thesis uses an experimental approach to understand what axe material type created the prominent chop marks found on the EBA faunal assemblage from Göltepe. The smooth morphology of many of the Göltepe chop marks suggest that they may have been made by metal axes, however, no metal axes were found at Göltepe. There is very little published zooarchaeological research that discuss chop marks in general, and even less that discuss the different morphological characteristics of chop marks created by stone and metal axes. Butchery studies in zooarchaeology focus overwhelmingly on slice marks. A vast literature exists to define, differentiate, and contextualize slice marks found on animal bone (Pickering and Hensley-Marschand 2008, Greenfield 1999, 2006, 2002, Pante et al. 2017). There is no single, clear reason as to why chop marks are not studied to the same degree as slice marks, as chopping is often an essential part of the butchering process. Chop marks can sometimes be difficult to differentiate from natural breakage, which may inhibit or discourage some zooarchaeologists from identifying and discussing this type of butchery mark. Due to the lack of specific identification criteria, discussion, and experimental work, chop marks are undervalued and understudied as a line of evidence for butchery practices and tool use. The limited literature that does exist defines chop marks as wide U/V-shaped marks (Olsen 1988: 349, Lyman 1987, Walker and Long 1977). However, the majority of the Göltepe chop marks do not fit this criteria as they are one sided, with the opposing side of the mark removed in antiquity by the chopping action. Therefore, there is no published zooarchaeological method to differentiate these chop marks as being made by either metal or stone axes, and very little standardized criteria exists to even discuss them.

The focus of this thesis has two methodological objectives. The first objective is to identify and define specific morphological characteristics of chop marks that can help to identify chop marks on archaeological assemblages. The second objective is to identify and define the macroscopic differences between metal and stone axe marks on bone.

This thesis proposes a novel method for tracking the use of metal axes in butchery and mitigates the need for the physical presence of the tool itself. The methods created in this thesis are universal, and are applicable to all zooarchaeological assemblages that show evidence of chopping activity. This thesis aims to identify the macroscopic signature criteria of metal (copper and bronze) and stone (chipped and ground) axe marks on animal bones through experimentation.

Chop marks are only one of multiple types of butchery marks (slice, saw, chop). Fortunately, the Göltepe faunal assemblage was previously subject to slice mark analysis

(Greenfield and Chaput in press). Conclusions from both chop mark and slice mark analysis are combined to create a robust picture of the butchery process and the tools used in everyday butchery activities at EBA Göltepe. Findings from Göltepe are compared to the EBA non-metallurgical site of Tell es-Safi/Gath, Israel where both slice mark and preliminary chop mark analysis has also been conducted. These data will aid in understanding if the patterns seen at Göltepe are due to the site's unique access to hard metal alloys, or if it is a larger Near Eastern phenomena.

III. General theoretical approach

The overarching theoretical paradigm used in this research is what Lemonnier (1992) deemed the "anthropology of technology", and similarly, what Dobres (2000) referred to as the social agency of technology. The investigation of technology through this social lens helps to redefine technologies as products of human agents. Agents are defined based on the scale on analysis and can be either individuals, or more often archaeologically, collectives/groups within a society, making choices appropriate to their worldview. Unfortunately, the material remains created by agents do not necessary reveal why agents made the choices they did, but the recognition that the action represents a choice is important and opens up avenues for discussion or further questions (Dobres 2000: 132). The study of ancient metallurgy is often aimed at the investigation of systems, and how and why systems change through time. The concept of "structuration" is closely connected to agency and provides reflexivity and insight into "systems", and is especially important in the study of ancient technology. Structuration is the constant, dynamic process in which the social and material world is maintained, transformed, and re-enforced by the agents within the system. Agents create the structured world in which they exist, but also have the ability to adapt and change these structures through choice and action (Dobres 2000: 133). A shift in technology then represents a choice by the agents to re-structure their physical and social worlds. To choose metal butchering technology over stone may seem like a small choice, but would affect multiple aspects of the social and physical world. For example, to choose a metal axe over a stone axe for butchering would require (1) means of producing the tool or access to the metal tool, (2) desire for the metal tool, and (3) the active choice to replace one technology with another. It is through active choice that individuals, families, groups, and societies continually structure and restructure their worlds, both physically and socially.

Social action theory, while aiming for interpretation of the socially contrasted world still implores the need for empirical data and methodologically sound middle-range research. The research contained within this thesis uses the experimental method to create analogical data in an effort to ask questions about how the choices of actors engaged with and transformed the worlds they lived in. These theoretical paradigms aim to make people the main interpretive focus of archaeological inquiry, and refocus the lens of technological advancement as social creations with influence that extends beyond that of efficiency and/or need (Lemonnier 1992: 1-3).

IV. General methodological approach

The methodological approach of this research utilizes two main methods: the analysis of faunal remains, and the experimental method. All interpretations, to differing degrees, incorporate these two methods, and are used as complementary to one another. Faunal analysis is used to identify the general make-up of the zooarchaeological assemblage (i.e. taxon, age, sex, taphonomy), and the experimental method is used to help answer specific butchery questions of the chopped assemblage. The two methods allow for a holistic picture of both the animal economy as well as butchering practices and tool choice during the EBA.

The experimental method is often associated with middle-range theory, which seeks a analogical bridge to connect physical attributes of the static/silent archaeological record to known process and variables in the present (Binford 1981: 22, Kosso 1991). This research uses experiments in chopping to better understand which type of material created the chop marks seen in the archaeological material. Experimentation in butchery practices have a rich history that will be further explored in Chapter 4.

Methodologically, this thesis focuses on behavioural replication and comparative experiments. Behavioural replication is used to test hypotheses, often using functional replicas to understand the function, use, and efficiency of past objects (Mathieu 2002: 3). This type of experimentation asks specific questions of an object's capabilities. Comparative experiments then "compare the results of different behavioural replications" (Mathieu 2002: 4). The behavioural replication within this study focuses on the testing of five functional replica axe material types on animal bone. This is done with the aim to identify distinct morphological traces of both stone and metal axe heads on bone. The comparison between the individual results allows for understanding the range of variability between each type of tool marks and helps to identify possible limitations within the experimental data.

The control of variables within the experiments as well as the understanding and acknowledgment of uncontrolled variables is of utmost importance in experimental studies and is directly correlated with overall confidences in the results. The purpose of behavioural replication and comparative experiments is to understand the resulting phenomenon when specific variables are changed, and thus, allowing for an actualistic range of possible explanations or interpretations for observed characteristics in the archaeological record (Mathieu 2002: 3-4). The experiments in this study were systematically controlled through multiple variables, and the results replicated with further experimentation. Specific controls are outlined in Chapter 5. All experimental methods and archaeological comparisons are contingent on standard faunal analysis methods.

V. Hypotheses

The hypotheses for this thesis relate to both the experimental and contextualized archaeological results. These are:

(1) A thin and sharp chipped stone axes will fracture upon high-speed impact.

(2) Ground stone axes will create significantly more crushing at the place of impact compared to metal axes.

(3) Metal axes will cut deeper into the bone tissue than ground stone axes.

(4) Metal chop marks will be 'more obvious' than stone chop marks (Binford 1981: 143).

(5) The degree of fragmentation within a chop mark will correlate to the width and sharpness of the axe (Wenham 1989).

(6) The presence of both crushed and sheared chop marks represents the use of both metal and stone axes on the Göltepe faunal assemblage.

(7) The use of metal axes in butchery will follow a similar trajectory to metal knives in the Early Bronze Age. If metal axes were used on the Göltepe assemblage, an increase through time should be detected.

(8) If the smooth chop marks seen on the Göltepe faunal assemblage were created by metal axes then the use of metal axes predates the use of metal blades in butchery by almost a millennium.

Hypotheses 1-5 are addressed through experimentation with five replica axes (two types of chipped stone, ground stone, copper and bronze) on multiple bone elements of different sizes classes and ages. Hypotheses 6 and 7 are explored through the application of the experimental results in regard to the archaeological butchered assemblage from Göltepe.

VI. Contribution of research

The adoption of utilitarian metal tools by a society is significant because it represents a major shift in technological choice. The large scale integration of metal tools into daily substance (e.g. butchery) actives implies sustained access to finished metal tools, and also the integration of that society into the larger networks of metal production and trade. Göltepe represents a unique space within metallurgical networks and systems as it seemingly had access to both raw materials and finished products.

Methodologically, this research contributes significantly to the very small body of literature on chop marks in zooarchaeological analysis. Chop marks are difficult to discuss due to the large amount of variations within this one type of mark. This thesis outlines a basic chop mark fragmentation scale (1-5) created using the results of the experimental chop mark study and is applied to the EBA Göltepe faunal assemblage. This scale takes into consideration multiple different characteristics of chop marks as seen in the experimental assemblages and outlines criteria for the identification for both stone and metal axe marks on bone.

The method aims to produce a reliable way to distinguish axe material type from chop marks in zooarchaeological assemblages to allow the tracking and use of utilitarian metal axes. Tracking the usage of metal axes in butchery is an important empirical step in understanding the social and technological networks of metal production in the EBA as the physical axes themselves can only reveal part of the story.

VII. Thesis structure

This thesis is divided into nine chapters. Chapter 2 reviews the archaeological evidence for the evolution of metal technology in Anatolia from the Neolithic to the Early Bronze Age with a specific focus on the axe. Chapter 3 explores the role of Göltepe as an EBA tin metal production site within the context of Anatolian metallurgy and outlines the ongoing debates over the feasibility of an EBA Anatolian tin industry. Chapter 4 looks into how butchery marks on animal bones can and have been used to answer archaeological questions using experimental methods. The experimental protocol for the axe study is outlined in Chapter 5 detailing the creation and choices for axe material type, bone samples, chopping procedure, and bone proccing methods. Chapter 6 outlines the detailed results of the experiments by axe type and fragmentation patterns (1-5), and describes the morphological patterns created by each of the axe types. Chapter 7 brings together the archaeological and experimental samples and uses the methods created by the experimental work to explain what type of axes created the chop marks found on the Göltepe assemblage. Discussion regarding the results from the Goltepe chop marks and previous slice mark analysis are brought together in Chapter 8 to illustrate how different tool types were used in butchery at

Göltepe. Comparison is also made to the butchered assemblage of EBA Tell es-Safi/Gath to better understand if the patterns found at Göltepe are unique due to the site's connection to the metal industry. The final chapter (9) reviews the hypotheses and findings and suggests avenues for future research.

VIII. Conclusion

This thesis presents a new method developed through actualistic study to identify the raw material used to chop animal remains – metal versus stone. The faunal assemblage from the EB site Göltepe are presented as an example of the method's potential. Göltepe is the only known/excavated tin production site in the Near East for this Period. As will be shown in later chapters, metal axes are used much earlier than metal knives at this site for butchery.

The following chapter explores the history of metal technology in Anatolia through the development of the hafted axe beginning in the Neolithic, through to the introduction of metal axes in the Chalcolithic, and the fluorescence of multiple metal technologies used to produce axes in EBA Anatolia.

Chapter 2: The evolution of axe technology in the Near East

I. Introduction

Impact tools with a sharpened edge used for chopping, slicing, or dividing materials are the oldest tool type known to be used by the genus *Homo* and their ancestors. The earliest in situ Oldowan choppers were founds at Lomekwi, Kenya and date to 3.3 mya (Larsen 2017: 340) and pre-date the appearance of the earliest *Homo* by 750,000 years (Larsen 2017: 358). The earliest possible evidence for butchery using Oldowan tools associated with early *Homo* dates to 2.6 mya (Dominguez-Rodrigo et al. 2005). The need to chop and divide bone during the butchery process continues into the present day.

Chopping tools have evolved and changed through time, aided by technological advances in knapping, metallurgy, and mechanics. By the time of the Anatolian Late Chalcolithic (4300-3000 bce) and Early Bronze Age (3000-2000 bce), the periods under consideration in this thesis, there were a multitude of different chopping tools and materials available. Axes in the Late Chalcolithic and Early Bronze Age included chipped stone axes, ground stone axes, and metal axes cast from copper, arsenical copper, or bronze. The Late Chalcolithic (LC) and Early Bronze Age (EBA) in the Near East were Periods of overlapping technologies. Ancient traditions of grinding and chipping stone into tools co-existed with new technologies that smelted and cast metallic minerals into tools that functioned in a similar way as their stone counterparts (Massa 2014, Gerritsen et al. 2010).

The introduction of new technologies as seen in the archaeological record represent choices made by ancient peoples. These choices were likely made for a multitude of reasons ranging from increased functional capabilities, social prestige, environmental pressures, and raw material availability. Metal axes and chisels are the earliest smelted and cast metal tools in the Anatolia and the Near East (Yener 2000: 32), yet their stone counterparts do not simply disappear upon their introduction.[1]

[1] Stone and metal axes are both commonly found throughout Anatolia during EBA, and have even been recovered from the same context (Massa 2014). This is not the case in the southern Levant. Ground stone and chipped stone axes seem to completely disappear after the EB I (Rosen 1997: 98).

This chapter traces the history of the axe in its many forms from the Neolithic through the end of the Early Bronze age in Anatolia. While this review focuses on Anatolia, it also touches on evidence from the southern Levant and Cyprus (see Figure 1 for site locations). The rich history on the development of metallurgy frames the evidence and helps to contextualize the evolution of axe technology.

Figure 1: Map of Anatolia showing the location of select sites mentioned in text

II. Metals and social complexity

More than other another material class, metals are often linked to emerging social complexity. The innate connection between early metal production and the increasing social complexity of the Chalcolithic and Early Bronze Age in the Near East is well established within archaeological literature (Yener 2000, Kerner 2010, Thornton 2009). Early metal production is a highly specialized process that demands cooperation between individuals and groups that requires advanced technological knowledge of both pyrotechnics and raw-material sourcing. Moreover, desire for these objects is needed to facilitate and grow highly specialized and time consuming operations within society. Metals are closely linked with early social complexity because metal objects, in and of themselves, are extremely complex to produce, and archaeologically they act as a proxy indicator for social configurations such as stratification, specialization, long distance trade, wealth accumulation, and the cultural desire for prestige objects and novelty. Metal objects have an extremely long history in Anatolia and are found as early as the pre-pottery Neolithic (PPN), although metal axes do not appear until the Middle Chalcolithic (Yener 2000).

III. Neolithic use of natural metals in Anatolia

The Neolithic in Anatolia was not void of metal artefacts. However, only naturally occurring metals were utilised during the Neolithic (Yener 2000: 19). Naturally occurring metals are metallic minerals that are grouped together in large enough quantities to be extracted from the surrounding ore without the need for smelting. Naturally occurring metals were worked in two different ways. The first is similar to, and has its roots in, lithic working traditions where the native metal was ground into beads or flat discs. This process does not represent innovation, but instead an extension of known skills applied to a new material. The second manufacturing process is hammering and annealing of sheet metal, and this does represent innovation. This process involves the intentional heating of coper to reduce brittleness caused by only cold hammering (Yener 2000: 21). These types of metalworking are found at Çatalhöyük, (Birch, Rehnen, and Pernicka 2013: 315), Aşikli Höyük, and Çayönü (Yener 2000: 22). Native copper working/metalworking is seen across the Anatolian plateau by the early/mid-6th millennium (Thornton 2009: 308). The earliest examples of small tools made from natural metals are the awls, hooks, and wire found at Çayönü dated to c. 8520-6150 BCE (Yener 2000: 20). Native copper is not, however, used to make larger tools in the Neolithic, and the primary construction material for tools continued to be stone. Ground stone tool technology, in particular, typifies the period (Wright 1993: 93). At Çayönü, small decorative metal objects and ground stone celts were some of the most common objects recovered (Özbek 2007: 216, Yener 2000: 20)

IV. Neolithic stone axes

Stone axes are categorized as celt tools. Celts are divided into three different types (axe, adze, chisel) defined by the size and shape of the bit (cutting edge) and the assumed function of the tool (Rosen 1997: 93). Axes are bifacial tools with a symmetrical bit that are, designed for high for impact chopping with the head hafted parallel to the handle. An adze has a non-symmetrical bit hafted perpendicular to the handle, and is designed for strategic woodworking (Özbek 2007:

217). A chisel is identified from the small bit length, but was also likely hafted, as were the axes and adzes (Rosen 1997: 93).

Neolithic axes in Near East were made exclusively from stone and produced using a number of production techniques, including chipping, grinding, pecking and polishing. Axes took a variety forms, including flint tranchet axes that are chipped stone axes with a relatively straight cutting bit (Yerkes et al. 2003), chipped and ground river pebble flat axes (Çelik 2010: 259), and ground stone axes made from a variety of stone types. However, the distinction between a chipped stone and a ground stone axe can sometimes be murky, as ground stone axes often begin as chipped stone pre-forms, and chipped stone axes were sometimes ground down along the bit to smooth and strengthen the edge. In general, ground stone axes produced from a variety of stone types were preferred in Anatolia, whereas chipped (sometimes chipped and polished along the bit) flint axes are more common in the southern Levant. Both regions however, likely followed a similar production sequence of reducing and creating axe preforms at quarry locations that were then transported and finished at habitation sites.

i. Stone axes in Neolithic Anatolia

Ground stone axes became increasingly abundant throughout the Neolithic in Anatolia, and by the later Neolithic were the preferred chopping tool. This is a major departure from the common chipped stone choppers found in the Epipaleolithic (Dinçer 2014: 42). The earliest ground stone axe recovered in Anatolia is from PPN Hallan Çemi (Özbek 2007: 215). One of the most thoroughly studied Anatolian Neolithic ground stone assemblages comes from Çatalhöyük East. Wright (2013: 365) notes that although the ground stone axes/celts do not change typologically, a significant increase in frequency occurs after level K, which suggests an increased need and importance of this tool type later in the late Neolithic. There is some evidence for site-level ground stone manufacture at Çatalhöyük, but at the moment is not known where the stone originated from, or if axes arrived at Çatalhöyük as already reduced pre-forms that were only finished and re-worked due to use and breakage (Baysal and Wright 2005: 312). Axe pre-forms were found in a number of households and indicates that at least the final step of grinding and polishing the axe was completed by individuals/households and was not a specialized task (Wright 2013: 413).

Late Neolithic/Chalcolithic axe factories are known from Turkish Thrace. The axes found at the quarries are chipped basalt preforms. Specific dating of the axe factories is difficult due to the mixing of strata and datable materials but seems to span both the later Late Neolithic and

Chalcolithic (Erdogu 2001: 18, 167-168). Axes made from the same type of stone as found at the quarry and factory were discovered up to 85 km away, suggesting that the axes were traded and transported considerable distances from the source location. Özbek (2000) analysed the axes from Hamaylitaria and found that the axes went through a long and tedious manufacture process including flaking, pecking, grinding, polishing, and sharpening. Erdogu (2001: 165) sugests that the final manufacture stages of grinding and polishing likley took place away from factory/quarry locations.

The production of ground stone axes, bowls, pestles, and figurines is typical of Anatolian, and Near Eastern Neolithic material culture in general (Baysal and Wright 2005: 324). More intensive use of ground stone materials is closely correlated with (newer) sedentary lifestyles of the Period (Wright 1993: 108). Anatolian ground stone axes appear to be both functional and ceremonial. Ceremonial axes are classified as such when they are smaller, there is a perforation through the body, or they are found in burial contexts with little or no use wear. Pre-pottery Neolithic Körtik Tepe, Turkey revealed a large ground stone assemblage with both functional and ceremonial axes (Özkaya 2009). Ceremonial axes at Körtik Tepe were only found in burial deposits, whereas larger axes with significant use-wear damage to the bit were only found in domestic contexts (Özkaya 2009). Ceremonial deposits of axes in cashes and in burials is a trend that continues and increases over time in the Near East.

ii. Stone axes in the Neolithic southern Levant

The situation in the southern Levant is somewhat different from Anatolia in that the frequency of stone axes increases from the PPNA through the PPNB, but then significantly declines in the Late Neolithic and become a somewhat rare fine, even at Jericho (Wright 1993: 105). The decrease in stone axes (ground and chipped) is mirrored by an increase in stone adzes. Chipped stone axes and tranchet axes are much more common in comparison to ground stone in the southern Levant. A collection of PPNA chipped tranchet axes and ground stone axes from Netiv Hagdud, Israel, display an interesting pattern in that the chipped stone axes all show evidence of use wear, whereas the ground stone axes do not. This may suggest that ground stone axes were votive in nature (Yerkes et al. 2003: 1054).

Evidence for a flint axe production site was found at DC3 near Mount Carmel, Israel. This PPNB site appears to have focused on the production of chipped flint axes from the numerous pre-form axes and axe-production debitage found across the site. However, finished axes were extremely rare, and it is thought that finishing stages such as abrading and polishing would have been competed at the home site rather than the production site close to the quarry (Rosenberg et al. 2009). Stone quarries in the southern levant seem to also be the primary location for lithic tool reduction that resulted in mass production of pre-forms that were then transported or distributed to habitation sites. Rosenberg et al. (2009: 35) hints that DC3 may have provided pre-form axes for a large number of sites in the region, although the distribution pattern is not yet well understood. Clark (1965: 6) also observed a similar pattern for Neolithic axe factories in Britain, where axes preforms were reduced at the quarry location and subsequently ground and polished at the habitation site.

Giv'at Kipod, located in northern Israel is the only known Neolithic/Chalcolithic basalt quarry location outside of Turkish Thrace in the Near East (Rosenberg and Gluhak 2016, Rosenberg, Shimelmitz, and Nativ 2008: 374). Basalt stone is closely associated with ground stone rather than chipped stone production, and thousands of discarded axe preforms were found at Giv'at Kipod. Giv'at Kipod functioned similarly to DC3 in that axes preforms were reduced at the quarry location and then transported to habitations sites where they were ground and finished. However, Rosenberg and Gluhak (2016: 49) suggest that ground stone tools made of basalt (and other exotic materials) held different social value than flint tools as they are often small or "miniature". Geo-chemical sourcing of the Giv'at Kivat basalt as well as ground stone tools from many sites across the Levant shows that the Giv'at Kipod stone was only used on a regional scale and was not traded or transported long distances. The authors find these results puzzling as the quarry production at Giv'at Kipod was immense and functioned for millennia, and yet they could only identify under 100 tools as originating from this source location (Rosenberg and Gluhak 2016). Clearly, more work is needed to uncover the complex ground stone production and trade networks of the Neolithic southern Levant that existed parallel to flint production.

iii. Value and cultural context of chipped and ground stone axes

Axes are a tool type that clearly gain importance throughout the Neolithic. Hafted axes are often associated with clearing land, construction, butchery, protection, and would have substantially aided with tasks associated with settled life (Özbek 2007: 219, Rosenberg and Gluhak 2016, Clark 1965: 18). The preference between either chipped stone or ground stone axes for the aforementioned tasks differed between Anatolia (preferred ground stone), and the southern Levant (chipped and polished flint). All types of chipped stone and ground stone axes fall under the same functional category (celts), and celt tools in general are one of the most common finds from the Neolithic Near East. Ground stone axes are a high-time investment tool, and even a chipped stone axe with a lightly smoothed bit and body can take about 3.5 hours to create (Nami 1984). A ground stone axe created by pecking and grinding can take between six days to six weeks to fully finish (Clark 1965: 21, 23, Pétrequin et al. 2013: 68). The abundance of these tools found in ceremonial, production, and domestic contexts suggests that this tool type was a valuable social and economic commodity. The preferred production techniques used for axe reduction and finishing were highly dependent on the cultural and natural environment. These culturally defined production methods were enduring in the Near East and continued into the Chalcolithic even after the introduction of their metal counterparts.

V. The Anatolian Chalcolithic: chronological problems and the development of metallurgy

The Chalcolithic, as a chronological and cultural Period in Anatolia is poorly understood from a culture history perspective (Düring 2011b: 797). It falls between the well-studied late Neolithic, and the emergence and spread of the Kura Araxes culture in the east and Troy in the west (the Early Bronze Age). Strong ceramic regionalisms, few absolute dates, and minimal horizontal exposures make any generalization of the Early Chalcolithic difficult. However, painted ceramics, stylistically similar to Halafian wares in Mesopotamia are found across eastern Anatolia beginning in the Early Chalcolithic, albeit in low quantities. This suggests some form of interaction with Mesopotamia, as well as significant inter-regional connectivity between settlements in south western Anatolia. The appearance of painted wares in the 6th millennium BCE marks the beginning of the Early (Halaf) Chalcolithic, as well as the long standing tradition of shared aspects of material cultural with Mesopotamia (Özbal 2011: 177-179). However, understanding Anatolia in regard to its Mesopotamian neighbours can only reveal a fraction of the story.

Recent survey and excavation work along with C14 dates has allowed for much more detailed discussion of the Anatolian Chalcolithic in its own right, and particularly of the central plateau in the Middle Chalcolithic (Hacar 2017, Gülçur 2012). The chronology for the central plateau differs slightly from eastern Anatolia as it is based on local pottery typologies and less on intrusive Mesopotamian styles. The Early chalcolithic on the plateau generally falls between 6100-5500 BCE (Schoop 2011: 153), the Middle Chalcolithic from 5500-4250 BCE (Schoop 2011: 157), and the Late Chalcolithic from 4250-3000 BCE (Schoop 2011: 161).

The Early Chalcolithic on the plateau continues to be poorly defined and commonly blurs with the earlier Late Neolithic as there is often no clear cultural break (Schoop 2011: 152). The appearance of painted pottery on the southern section of the Anatolian plateau is the only indicator or cultural change. Unfortunately the appearance of painted wares occur only on the southern plateau making the identification of Early Chalcolithic materials elsewhere on the plateau without C14 dates extremely difficult (Schoop 2011: 152). There is no current evidence to suggest any significant changes in metal working technology occurred between the Neolithic and Early Chalcolithic. Hacilar (5400-5200 BCE) levels I a, I b, and II a produced copper needles, awls, and beads, all manufactured through the manipulation of native coppers (Yener 2000: 31-32). The shaft-hole mace head from Can Hasan (ca. 5000 bce) was also formed using native copper and shows no evidence of casting (Yener 2000: 32). The major development in metal working traditions appears post 5000 bce with the introduction of smelting and casting in the Middle Chalcolithic.

VI. Metal axes in the Anatolian Chalcolithic

In Anatolia, the first evidence for finished, smelted metal objects, as well as the first metal axe, comes from Mersin-Yumuktepe. Excavations at Mersin-Yumuktepe level XVI is radio carbon dated to between 4600-4500 BCE (Caneva, Palumbi, and Pasquino 2012). Metallurgy is different from the manipulation and working of naturally occurring metals, and refers to the extraction of metallic minerals from mineral aggregates (ore) through smelting. The early smelting of metallic minerals was done in small crucibles (course ceramic bowls) where the crushed ore was heated to the point of melting. The heating and melting process allows the metallic minerals to separate from other mineral impurities to create both molten metal and slag (Lechtman and Klein 1999: 498).

The Mersin-Yumuktepe citadel is constructed in the traditional Anatolian radial plan, yet a (semi) contemporary tripartite structure and gate reflects possible Mesopotamian (Ubaid) cultural influence (Caneva, Palumbi, and Pasquino 2012: 355). The upper citadel contained finished metal products (pins, chisels, and axes), slag, and raw ore in many of the radial rooms as well as in the tripartite building. In comparison, no evidence for metallurgical activity or finished metal products were found in the lower town suggesting that metals were reserved for residents of the upper citadel. The excavators interpret the radial rooms of the citadel as the homes/workshops of specialized craftsmen. No prestige objects (other than metals) were found either in the citadel nor in the lower town and no clear difference in social status could be inferred between the lower and upper town other than function (Caneva, Palumbi, and Pasquino 2012: 356, 369-370). Düring (2011c) does not agree that the this settlement is a citadel at all. If it were a citadel, it would be tiny, at approximately 35 by 40 metres. Instead, Düring (2011a: 205, 250) believes the walls of the "citadel" are actually terrace walls that the houses/structures were built against. A cobble paved road that leads up to the "citadel" is also contained by large terrace walls. Nevertheless, whether or not the upper town was truly fortified, it is clear that the upper town functioned differently than the lower town in terms of production and was clearly a nucleus for metal production and use.

Although metal axes first appear in the mid-5th millennium bce in Anatolia, it is not until the later 5th and early 4th millennium that they are frequently found (Gerritsen et al. 2010: 207). Late Chalcolithic flat axes are found at Barcin Höyük, Illipnar, Beycesultan (Gerritsen et al. 2010), Bakla Tepe (Şahoğlu and Tuncel 2014: 71), Kuruçay (Efe and Fidan 2006: 19), and Ovçular Tepesi (Gailhard et al. 2017). Interestingly, not all metal axes are found at sites that are associated with metal production. No evidence for metal production was uncovered at Barcin Höyük as of yet. This indicates that some form of trade network for finished metal products probably existed in the Chalcolithic. This is not surprising, as there is substantial evidence for a well-established overland trade route across Anatolia in the Early Bronze Age (Efe 2007), as well as evidence for interaction between Transcaucasia and the plateau in the Chalcolithic (Steadman, McMahon, and Ross 2007: 391)

Many axes from the Late Chalcolithic are cast from arsenical-copper (Illipnar, Barcin Höyük). The earliest arsenical copper axes were found at Ovçular Tepesi located in the Caucasus (Gailhard et al. 2017). The three arsenical-copper axes, found within an infant jar burial, date from 4320-4040 bce, and straddles the transition from the Middle Chalcolithic to the Late Chalcolithic (Gailhard et al. 2017: 1, 5). Arsenical-copper is a harder finished product than pure copper, and the addition of arsenic to copper gives the finished product a silvery sheen (Meeks 1993: 268, 271). Some copper ores naturally contain arsenic and do not require additional arsenic, making it difficult to know whether or not arsenic was intentionally added (Lechtman and Klein 1999: 499). Whether or not arsenic was specifically added as an alloy, the consistent amounts of arsenic in many arsenical-copper artefacts do appear somewhat intentional. Yener (2000: 29) describes this as an accidental discovery of a natural alloy that was then selected for. yet proportions of arsenic to copper would vary significantly in the deposit because arsenic and copper would flow in a liquid state when the deposit was formed and being of different masses they would not uniformly mixed when they cooled in a seam. This is why the common arsenic-copper bearing minerals enargite (CU_3AsS_4) and tennanite ($Cu_{12}As_4S_{12}$) have different 'amounts' of arsenic and copper.

VII. The combined presence of metal and stone axes in the Anatolian Chalcolithic

The use of polished stone axes continued throughout the Chalcolithic in Anatolia, and it is not unusual to find both metal and stone axes at the same site (Şahoğlu and Tuncel 2014: 71-72). At Barcin Höyük multiple stone axes[2] were found in the Late Chalcolithic deposits along with an arsenical copper axe. As mentioned above, there is no evidence for metal production Barcin Höyük, and thus, we have no idea how readily available metal axes were to the residents of Barcin (Gerritsen et al. 2010: 207). Does the continued use of stone axes indicate that metal axes were rare, and therefore, stone axes continued to be a functional necessity? Or do the presence of both material types represent specific social desire for each material type? These questions are not answerable within the confines of the current evidence, however, this pattern is not unique to Barcin Höyük. At Late Chalcolithic Bakla Tepe a single metal flat axe was recovered along with many polished stone axes (Şahoğlu and Tuncel 2014: 71-72). It is interesting that only a single metal axe was recovered from this site when the site also produced evidence for metallurgical activity, and should theoretically have been able to produce as many metal axes as desired.

Hansen (2014: 245) identifies the recyclability of metal as an aspect that contributed to its value in antiquity. Metal is a substance that can be continuously recycled without detriment to the finished product. Comparatively, stone can only be reused by reduction, and eventually the stone can no longer be reduced into a usable tool or shape. Due to the value and recyclability of metal, metal objects, including axes are often only found in intentional depositional contexts. This means that metal artifacts may have been much more common than what is actually recovered in the archaeological record (Greenfield 1999, 2013).

VIII. Metal production in the Anatolian Chalcolithic

The metal production industry in the Anatolian chalcolithic developed and thrived within both regional and site specific contexts. The development of smelting and alloying technologies was an indigenous development within Anatolia beginning in the Middle Chalcolithic and grew in the Late Chalcolithic (Yener 2000). Modes and scale of production varied widely in what Yener (2000: 26) refers to as a "balkanized technological production", meaning that the organization of

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[2] Unfortunately, it is not stated whether the axes are ground stone or chipped stone.

production depended on the specific needs of the community. Not all communities participated in metallurgical production even when existing in the same cultural and interaction sphere. Although arsenical-copper became a common metal, older traditions continued to exist. If production was regulated, it was regulated only at the local level. Most settlements in the Chalcolithic do not show strong signs of social stratification and there is no true urbanism or even centralization on the Anatolian plateau during this Period. However, the appearance larger walled settlements, increased metal production including the introduction of metal weapons, long distance trade, and the emergence of strong local elites show increasing social complexity across Anatolia throughout the Chalcolithic (Yener 2000: 26).

The only site in Anatolia that shows signs of attached specialisation with regard to metal production is Arslantepe. Frangipane (2010: 289) describes the political economy of Arslantepe as both formative and experimental, meaning that the social, economic, and political systems were beginning to show strong signs centralization and political control unprecedented in Anatolia, yet was unsustainable in the long term. The political economy of Arslantepe should not be considered as representative of Anatolia as a whole. In fact, no Chalcolithic settlement in Anatolia except for Arslantepe shows any evidence for social stratification or social differentiation (Frangipane 2018).

Other metal production sites such as Hacinebi (Özbal, Adriaens, and Earl 1999: 62), Değirmentepe (Yener 2000: 33-44), Göltepe, and Çamlibel Tarlasi (Lehner and Yener 2014: 15, Schoop 2015) show that metallurgical activities were spread out across the site were not restricted to elite specific contexts. Hacinebi does have some specific areas within the site that are defined by the excavators as metallurgical workshops, however, there is no evidence for a regulatory administration that controlled production (Özbal, Adriaens, and Earl 1999). Dissimilar to this, Değirmentepe produced substantial evidence for regulation of production in the form of stamp seals and bullae, but metallurgical activity was found across the site as well as in most domestic structures. The evidence from Değirmentepe suggests that the majority of the population was involved in small scale metallurgical activity, and that it was possibly the community itself that specialized in the activity and not necessarily individuals within the community (Yener 2000: 33-44). Çamlibel Tarlasi, located on the central plateau, also produced evidence that the entire community participated in small scale metal production. The small, relatively ephemeral settlement of Çamlibel Tarlasi, also produced strong evidence for the intentional alloying of arsenic and copper (Schoop 2015).

Metal production cannot exist without mining. Pre-Uruk Hacinebi produced evidence for substantial metallurgical activity, yet metal ore sources are over 200 km away. Özbal, Adriaens, and Earl (1999: 60) hypothesizes that the mining may have been carried out by part time specialists as ore deposits are a significant distance from Hacinebi (over 200 km) and it is improbable that every metalsmith was sourcing, mining, and transporting their own ores. Hacinebi metal workers probably depended on a trading network with copper ore-rich areas or villages, as without this, metal production on the scale seen at Hacinebi would have be impossible. Subsequent phases at Hacinebi continued to produce a large amount of evidence for metal production but also exhibited evidence that the site became the location of a southern Mesopotamian Uruk colony. Metal production at Hacinebi continued into the later/Uruk Chalcolithic, but interestingly, did not take place in the Mesopotamian colony housed within Hacinebi (Özbal, Adriaens, and Earl 1999: 60).

Göltepe is the only Late Chalcolithic/EBA metal production site thought to be connected to a specific mine. Kestel mine is located 2 km away from Göltepe, a small, metal working site located in the Taurus mountains. Göltepe is unique, as there is no evidence for copper production, and instead the site produced tin from the cassiterite ore mined from Kestel. Göltepe functioned as a tin production site from the Late Chalcolithic to the end of the EBA (4400-2000 BCE), and grew during that time from a small, ephemeral, and seasonal settlement, to a fortified, permanent village[3] (Yener 2000, Yener 1995, Earl and Özbal 1996). Tin is an integral component of bronze, and it is not until the LC/EB I transition that the first bronze artifacts begin to appear in Anatolia.

IX. The Early Bronze Age in Anatolia (3200/3000-2000/1950 BCE)

The Early Bronze Age (EBA) in Anatolia is rightfully named as it is truly the emergent Period of 'bronze' metallurgy. Comparatively, there is no bronze manufacture in the southern Levant until the very end of the EBA, sometimes identified as the Intermediate Bronze Period (Rosenfeld, Ilani, and Dvorachek 1997: 857). The term bronze is confusingly sometimes used to refer to arsenical-copper as well as the alloy of copper and tin. In accordance with Muhly (2011: 866-867) the term bronze will only be used in this thesis to refer to the intentional alloy of copper-tin with a tin content greater than 2%.

[3] Details regarding the site history of Göltepe, and the debate regarding the production of tin can be found in Chapter 3.

Anatolia experienced major chances throughout the 3rd millennium: the disappearance of the Uruk culture complex and the introduction of the Kura-Araxes culture in eastern Anatolia (Palumbi and Chataigner 2014), larger regional centres with fortification walls (Çevik 2007, Düring 2011a: 76), the emergence of strong local elites (Yakar 2011, Çevik 2007), the accumulation of wealth in the form of elaborate grave goods and hoards (Massa 2014, Yıldırım 2006, Zimmermann and Yıldırım 2007, Yakar 2011: 345-362), and complex trade networks involved in metal procurement (Yener et al. 2015, Efe 2007). The dramatic increase of metal finds including new types of metal goods (weapons, vessels and jewellery), along with more elaborate manufacturing techniques (bronze, soldering and lost-wax casting) indicate a social desire for complex metal items beyond that of simple use/liquid-value (Yakar 2011: 245-267, Stork 2015: 117). Complex metal items are commonly found deposited as burial goods in both elite and non-elite burials and are often intentionally broken or bent and unused, signifying that the liquid value of these items were sacrificed for the individual as a show of status, or as an emulation of status (Stork 2015: 119).

i. Chronological issues

The transition Period from the Late Chalcolithic to the EB I is chronologically not well defined and in many parts of Anatolia there is often no cultural break that divides one from the other in terms of pottery styles or a hiatus in occupation. Often the later Late Chalcolithic is grouped with the EB I for this reason, and interestingly, this is the Period when the first bronzes and the first use of tin metal appears. However, many new sites are founded during the EB I (e.g. Troy) and recent radiocarbon dates have helped to sort out some ambiguous typological issues, especially in western Anatolia (Eimermann 2008: 364).

The EBA, as does the Chalcolithic Period, suffers from chronological issues (Massa and Palmisano 2018: 67). The original major type sites for the EBA chronology were Troy and Tarsus, but linking the strata into a coherent chronology for the EBA was/is extremely difficult. The general consensus is that Troy I is contemporary with Tarsus EB I (Easton 1976: 145). Strangely, most identifiably EBA material across Anatolia seems to fit into the typical EB III typologies, thus ending up with masses of sites and material culture from the EB III and almost nothing for the earlier EBA. New radiocarbon dates are beginning to fill this “void” (Geniş and Zimmermann 2014: 288), but the general rarity of radiocarbon dates makes synchronisms challenging. Well excavated sites with tight radiocarbon sequences are beginning to sort out reginal sequences (eg

Demircihöyük), but linking chronologies between sites continues to present significant challenges. Throughout the EBA, as in earlier Periods, Anatolia was highly regionalized, making inter-site comparisons of specific phases difficult. However, the wide dispersal of specific items such as *depas*, wheel made pottery, two-handled tankards, and eastern-style metal types (scroll pins) suggests that by the EB III, Anatolia was connected through some form of pan-Anatolian trade network in which metals likely played an important role (Steadman 2011: 232, Efe 2007).

ii. Social structure and luxury goods

The EBA is the first Period in Anatolia where there is enough settlement data to discuss significant patterning. Isolated pockets of centralization and unique instances of strong local elites are seen in the later Late Chalcolithic but did not characterize Anatolia in general. Whereas, during the EBA, the majority of Anatolia went through significant changes in political and settlement organization where people grouped themselves near to powerful local elites who differentiated themselves with luxury goods and monumental architecture (Sagona and Zimansky 2009: 144). The Anatolian plateau never achieved same scale of urbanism as seen in the south east, and some argue that the plateau did not have urbanism at all in the EBA, and instead, only a pattern of centralization (Çevik 2007). Centralization is described by Çevik (2007: 137) as a vertical change in social structure rather than horizontal. EBA Anatolian elites hoarded wealth within larger walled settlements that consequently attracted people to them. According to Çevik (2007), the presence of the elites did not alter the horizontal complexity of the social structure as there is little evidence for redistributive activities and the administration and control of trade goods. This however, is not actually the case at many sites, and there is evidence for small scale urbanism across the plateau in the EB II and III at Troy, Küllüoba, Bademağacı, and Liman Tepe (Fidan, Sari, and Türkteki 2015). Fidan, Sari, and Türkteki (2015: 62) goes as far as to call some of the regional urban centres "the mighty kingdoms of the EBA III in western Anatolia."[4] Whether or not these settlement and social changes should be described as centralization, proto-urbanism, or urbanism is likely to be the subject of debate for some time to come.

[4] At the moment, western Anatolia provides the best evidence for complexity in the EBA. Not because it was necessarily more complex than central Anatolia, but because multiple well excavated sites, and long term survey projects have helped to solve longstanding chronological issues still being grabbled with today in other parts of Anatolia (Fidan et al 2015).

By the EB III, the Anatolia plateau generally had a two tier settlement pattern (Çevik 2007) of small, sometimes urban, fortified/walled centres with surrounding hamlets. The larger settlements on the plateau are generally referred to as towns. However, small urban centre is also appropriate for many of these settlements as this best describes their actual characteristics. Settlement types during the EBA are not uniform but can be grouped into two general categories of walled settlements: 1) radial planned settlements with partial or total enclosure walls[5], both with and without larger public building in the centre, and 2) citadel type settlements with a fortified upper town and often unenclosed lower town (Çevik 2007: 135-136).

Many of the larger Anatolian centres that exhibit monumental architecture, elite goods, administrative tools, and a differentiated upper and lower town exit along the theorized "Great Caravan Route" that extended from Troy to Cilicia (Efe 2007). Extensive trade and access to luxury goods and wealth likely either speered or contributed to the growth and power of settlements such as Troy (Jablonka 2011: 719), Küllüoba (Efe 2007, Efe and Fidan 2008: 68), Seyitömer Höyük (Harrison and Bilgen 2019: 193-194, Harrison 2016), and Kültepe (Ezer 2014: 7) during the EBA.

While the EBA extramural cemeteries scattered across Anatolia demonstrate the grandeur of luxurious metal goods available to the people of Anatolia (Alaca Höyük, Resuloğlu, Demircihöyük), it was common for both elite and non-elite persons to be interred with metal objects (Massa 2014). Therefore, differential access to metal goods is best demonstrated by Troy and Seyitömer Höyük where there is a clear differential between elite and non-elite contexts within the settlements themselves. Troy is famous for its multiple EBA metal hoards found within the citadel. These hoards, including Prium's Treasure, continue to be considered some of the most elite, unique, and masterful creations of EBA metalsmiths. The hoards were exclusively found within the upper citadel of Troy II (2550-2300 BCE) and are thought to represent the wealth and power of the elite (Easton et al. 2002: 103, Jablonka 2011: 719). No such treasures were found

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[5] The typical Anatolia radial settlement plan is found across the plateau. First identified by Korfmann in 1983, these settlements are ring-shaped, formed by side-by-side hall and porch/megaron style houses that all face toward a central area. Often the back end of the houses abut a fortification or circuit wall. Sometimes a larger administrative or temple structure can be found in the central court. Examples of these settlement types are found at Demircihöyük, Seyitömer, Bademağaci, and Pulur. However, this settlement type is not apparent for coastal western sites that instead have a linear arrangement with streets and row houses (Fidan et all, 2015: 71).

within the lower town/surrounding settlement (although it has not been as extensively excavated). The first evidence for a lower town is during the Troy II. This is also the emergent Period for larger administrative complexes and the vast accumulation of wealth inside the fortified citadel. The lower town stretched for 9 ha surrounding the citadel and was also encircled by another circuit wall. Thus, indicating a substantial amount of people were connected to the administrative centre housed within the upper citadel (Jablonka 2011: 719).

Seyitömer (western plateau) is not a citadel style settlement, but instead has more linear plan of very similar row houses opening onto a central court with a megaron complex in the centre and a separate administrative complex, all surrounded by a circuit wall (Harrison and Bilgen 2019: 193-194). Thirteen depas (usually associated with Troy) were found across Seyitömer, as well as three very distinctive rhyta in the Megaron complex, with the only parallels found at Chalandriani cemetery in the Aegean. Cylinder seals were also found within the administration complex that show striking similarity to the Akkadian style. This is strong evidence for Seyitömer's participation in long distance trade both to the west and east (Harrison and Bilgen 2019: 195). Luxury goods and metals were almost exclusively confined to the administrative complex with only a single bronze needle found within one of the domestic row houses (Harrison 2016: 201, 251).

Both Troy and Seyitömer demonstrate that access to luxury or prestige goods were strongly associated with status and administration, and that these items were likely a way for the elite groups to differentiate and maintain their status. Interestingly, elite goods were available to lower status peoples as complex decorative and utilitarian (axes, spears, pins, vessels, and jewellery) metal objects are often found in non-elite graves (Zimmermann and Yıldırım 2007, Massa 2014, Zimmermann et al. 2009). This may indicate that the elite class did not fully control access to all luxury goods, but rather that they had the means to acquire a surplus of them.

X. Early Bronze Age metal production

Anatolian metal production during the EBA appears much more organized, and possibly regulated than in previous periods. Production likely existed within a two-tier production model comprised of primary mining and smelting sites located in the mountains that produced metal in ingot form. The ingots were then transported to larger settlements that produced finished metal products (Yener et al. 2015: 597, Yener 2008: 7, Yener 2000). This interconnected production system emerged as the demand for prestige metal objects increased. Prior to the EBA, metal was mainly used to create functional items such as tools, pins, and small bits of jewellery. However, during the EBA metal items became strongly associated with prestige, hierarchy, and wealth accumulation (Sagona and Zimansky 2009: 144). While functional metal items continued to be produced, new categories of prestige items emerged, including vessels, extravagant jewellery, weapons, and figurines (Yakar 2011: 345-476). Whether the increase in metal availability spurred the desire for prestige objects, or the desire for prestige objects facilitated increased production remains unclear (Yener et al. 2015). It is theorized by Yener et al. (2015: 609) that first-tier production sites were likely connected to larger lowland centres, although we do not know to what degree (or if at all) the lowland centre controlled the chain of production. It is also possible that the highland production sites were independent specialist communities that participated in a reciprocal relationship with larger lowland centres, with each benefitting from the economic relationship. The best example of a highland metal production site in the EBA is Göltepe, located in the Bolkardağ region in the Taurus mountains[6].

Multiple ancient mines have been identified archaeologically with the help of the General Directorate of Mineral Research and Exploration, in Turkey (Yener et al. 2015). These copper, silver, gold, and tin mines are known to have functioned during the EBA with some connected to specific processing sites (Kestel and Hisarcik) (Massa, McIlfatrick, and Fidan 2017: 72). Polymetallic ores were commonly exploited across Anatolia as evident through compositional analysis of finished metal products (Yener et al. 2015: 597). The goal was not to achieve the highest level of purity of a single metallic element, but instead to utilize what was available. Although copper-tin alloys (bronze) and arsenical-copper alloys were common, other combinations such as copper-arsenic-nickel, as well as varying amounts of antimony, silver and bismuth are found in many metal artifacts (Yener et al. 2015: 597). The use of polymetallic ores reflects the natural resources of Anatolia , and this is also true for the early appearance of bronze in comparison to surrounding regions.

i. Archaeological evidence for the first use of tin

The first use of tin metal is found at Tülintepe at the end of the Late Chalcolithic/EB I. The dating of the metal artifacts discovered at Tülintepe is the subject of some debate as a final report of the site was never published (Muhly 2011: 863) and some artifacts were lost in transport. Yalçin

[6] Detailed information on Göltepe is found in Chapter 3.

and Yalçin (2009: 127) suggest that the metal horde from Tülintepe should be placed in the later Late Chalcolithic/EB I (3400-2900 bce) due to the typological similarities of the spearhead to the spearheads found in the 'royal tomb' at Arslantepe (VIB), and the similarities of the pottery to the early EB I assemblage at Tumekic. The horde contained one short sword and five spear heads all coated/plated with a silvery metal assumed to be silver, but was later found to be pure tin! The weapons show no signs of use and are thought to be ceremonial in nature, since the tin plating gives the appearance of pure silver (Yalçin and Yalçin 2009: 128). A rolled pin, also found at Tülintepe, but through to be slightly earlier than the horde was found to contain 5% tin, making this the earliest bronze artifact ever recovered in Anatolia (Yalcin and Yalcin 2009: 129; Muhly 2011: 866).

The transition from the LC to the EB I is the pivotal moment in time for the appearance of bronze metal. Six bronze figurines were found at Tell al-Judaudah (Amuq region) date to 3000 bce, and multiple bronze pins from Kursura I date to the early EB I (Yener 2000: 74). An EB I cemetery, located near Birecik Dam in south eastern Turkey reportedly contained bronze spear heads and bronze pins among many other metal artifacts including axe heads and figurines. Unfortunately, the composition of the 'bronze' artifacts are not supplied and it is not clear whether the author is referring to tin-bronze or arsenical-copper (Sertok and Ergeç 1999: 90, 93).

The first use of tin, and/or bronze is not associated with functionality. Although the alloy of tin and copper (bronze) produces an extremely strong finished product, and is less volatile to cast than arsenical-copper, many argue that is was the colour of the alloy that originally attracted metalsmiths to tin (and bronze) (Mödlinger et al. 2017: 14). For example, bronze is the most common metal recovered at Late EBA Resuloğlu cemetery. The tin content of the bronzes are surprisingly high, and range from 1-17% (Zimmermann and Yıldırım 2007). Tin content beyond 2-3% adds no improved structural qualities to the finished product (Geniş and Zimmermann 2014: 287), and interestingly the functional weapons and tools are not the items with the higher tin content. Instead, it is the jewellery, pins, and vessels that exhibit the highest amounts of tin. This excludes most functional explanations for the substantial use of tin in these items. Tin, as understood today, is a very rare mineral that was laborious to produce with EBA technology (Earl and Özbal 1996). Zimmermann and Yıldırım (2007) suggest that the tin content was added to enhance the visual appearance of the metal, something that is also seen at Tülintepe with tin plating of spearheads to create a silvery appearance (Yalçin and Yalçin 2009: 128). The high amount of tin in the Resuloğlu bronzes may represent conspicuous consumption of a rare and likely expensive substance (Zimmermann and Yıldırım 2007: 5).

Analysis of the bronze artifacts from Resuloğlu supports the argument that bronze was not initially prized for it functional capabilities (hardness), but rather for its aesthetic qualities or its economic value. This is exemplified by the first uses of tin and bronze in the Early EBA I as a material used for figurines, pins, and plating for ceremonial weapons. Unfortunately, exact dates within the later EBA are not provided for the Resuloğlu cemetery (Zimmermann and Yıldırım 2006), but comparisons to EB III Alaca Höyük[7] by the excavators alludes to a date in the very late 3rd millennium (Yıldırım 2006: 7, Yalçın and Yalçın 2013). If this is the case, it indicates that some areas of Anatolia continued the practice of reserving tin purely for its aesthetic quality well into the late EBA.

Although bronze makes its first appearance at the beginning of the EB I transition, it remained relatively rare until the EB II/mid-3rd millennium[8]. A significant problem in understanding the extent of metallurgy and metallurgical development during the LC/EB I transition is the lack of final publications. Muhly (2011: 866) identified 4700 metal artifacts in the Elaziğ storehouse that date to this Period alone and that have never been published. Contrary to previous thought (e.g. Muhly 1993: 241), the demand for tin and bronze was significant throughout the 3rd millennium and it was not the influx of tin during the Assyrian trade Period in the early 2nd millennium that incited the Anatolian desire for bronze/tin[9].

ii. Early Bronze Age metal trade networks

The existence of an east-west pan Anatolian overland trade (Anatolian Trade Network and/or The Great Caravan Route) route by the second half of the third millennium is fairly well accepted by many Anatolian archaeologists (Efe 2007, Şahoğlu 2005, Massa and Palmisano 2018). Although metals are often assumed to have played a large role in this trade network, this is mainly

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[7] At the time Zimmermann and Yildrim (2006) published on the Resuloğlu cemetery, Alaca Höyük was dated to the late EB III. It was recently re-dated to the EB II thanks to a series of radiocarbon dates. The authors are not clear on how they arrive at a date for the Resuloğlu cemetery and make no reference to absolute dating methods. If they are basing the date of the cemetery purely on typological similarities to Alaca, a date in the mid-3rd millennium may be more appropriate (Yalçın and Yalçın 2013).

[8] This may be due to chronological and dating issues rather than actual archaeological patterning.

[9] For further information on the 'tin problem' see Chapter 3.

argued through the sudden introduction of new styles (spiral-head pins) and materials (bronze) into western Anatolia, and less on geo-chemical sourcing of the raw minerals themselves.

Webb et al. (2006) argues that the Anatolian trade network extended overseas as well. Three EBA artifacts from the Colocassides collection, that likely originated from Vasilia (Cyprus) were found to be made from tin bronze. Cyprus has no known natural tin deposits, and these three objects (axe, sword, and spear) are three of only four bronze artifacts that date prior to the Middle Bronze Age (2000 BCE) found on Cyprus. Geo-chemical analysis sourced the copper from the sword and the spear to the Bolkardağ region in the Taurus Mountains, meaning that these items were probably brought into Cyprus as finished objects. However, the coper in the bronze axe was found to be local Cypriot copper, which indicates that tin was either imported in ingot form, or other bronzes were recycled locally to create new metal objects (Webb et al. 2006: 274). The source of the tin in these artifacts likely originated from either the Kestel or Hisarcik tin mines in the Taurus mountains as these are the only known active sources of tin in Anatolia so far (Yener et al. 2015). These objects demonstrate the importance of the Bolkardağ region and tin to the EBA metals trade, as well as the complex and far reaching networks that existed to distribute metals (and other object classes) from producers to consumers.

Compositional analysis also indicates that the earliest (second half of the fifth millennium) metal awl found in the southern Levant may have had Anatolian origins (Garfinkel et al. 2014: 5, Massa and Palmisano 2018: 17). The awl contained an interesting mixture of copper, tin (6%), arsenic, and lead. The closest geographically known tin source comes from the Bolkardağ region in the Taurus mountains. The earliest radiocarbon date from Göltepe/Kestel is 4400 BCE (Yener in press: 130), making the Kestel tin mine a possible extraction local for the tin in the Levantine awl.

XI. Axes in the Early Bronze Age

Early Bronze Age axes in Anatolia are primarily made from metal. Along with the flat-axe, new forms of axes appear including the shaft-hole axe and the crescent axe (Efe and Fidan 2006: 24). Metal axes were cast from copper, arsenical-copper, and bronze in both open and two-part moulds, and using the lost-wax technique (Massa, McIlfatrick, and Fidan 2017). Although bronze axes are relatively rare across the plateau during the EBA, a large collection of bronze axes were found at EB II Troy. Five of the eight flat axes were found to be high quality bronzes (5-14% tin), and only three were unalloyed copper/low arsenical-copper (Stos-Gale, Gale, and Gilmore 1984:

38-40)[10]. The high frequency of bronze axes at Troy alludes that bronze axes may have been more common during the EBA across the plateau than is archaeologically visible. Interestingly, votive/ceremonial ground stone jade axes were also recovered from EBA Troy Treasure hoard L (Troy III) (Bachhuber 2009: 10).

Larger metal objects and tools are very rarely found in domestic contexts and are primarily found as funerary deposits during the EBA (Massa, McIlfatrick, and Fidan 2017: 53, Stork 2012: 57). Arsenical-copper and unalloyed copper were the predominate material used for casting axes across the majority of the plateau, whereas bronze was often used for smaller items for personal adornment. The extramural cemeteries of the EBA have produced a huge number of metallic artifacts, and show a dramatic increase in metal object types as well as metallurgical technologies (Yıldırım 2006, Zimmermann and Yıldırım 2007, 2006).

The meticulously excavated EBA I and II cemetery of Demircihöyük-Sarıket produced (among many other things) four different types of axes: (1) chalcolithic style pure copper flat axes cast in an open face mould, (2) an arsenical-copper shaft-hole (battle axe) cast using the lost-wax technique, (3) an arsenical-copper crescent-shaped axe cast in a bivalve mould, and (4) five ground stone, shaft-hole axes (Massa 2014: 84, Massa, McIlfatrick, and Fidan 2017: 55, 58, 63). A single copper knife, and several bronze and arsenical-copper double sided blades labelled as small dagger/knife were also recovered (Massa, McIlfatrick, and Fidan 2017: 61-65) The Demircihöyük-Sarıket cemetery was the burial location for a relatively small village that housed no more than 130 residents, and yet, the cemetery held over 250 metal artifacts including the earliest bronze artifacts (2700 BCE) from the western plateau region. The small, radial-planned village produced no evidence for metallurgical activity other than a single flat axe mould, thus indicating that the residents of Demircihöyük must have sourced the majority of their finished metal items from non-local producers (Massa, McIlfatrick, and Fidan 2017: 70).

Even when only examining a single artifact type (axes) it is clear that the complexity of metal production and technology grew exponentially throughout the EBA. Yet, older traditions such as unalloyed copper castings and ground stone continued to exist even while superior counterparts were readily available. The jade axes from Troy suggests that ground stone axes may

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[10] The compositional analysis is repeated in Stos-Gale et al. 1984 but were originally analysed by Esin (1969) and again by de Jesus (1980). The original articles were unable to be accessed.

have continued to exist for ceremonial or votive reasons, although the excavators of Demircihöyük-Sarıket make no mention of the votive nature of their stone axes. The EBA was clearly a period of non-standardized axes within a society that accepted both new and old forms of this multi-purpose tool. The ratio of stone to metal axes in the EBA is reversed from the pattern seen in the Late Chalcolithic, in that, stone axes had become the exception rather than the standard.

The lithic industry in general declined during the EBA in Anatolia. Lithic types became much more restricted and simplistic, and an increase in *ad hoc*/single use stone tools is noted (Yakar 2011: 518). This pattern is also seen in the southern Levant (Rosen 1997), and is often associated with the increased availability of metal tools (Yakar 2011: 518, Rosen 1997: 98). Stone axes, both chipped and ground (votive), disappear completely from the southern Levant after the EB I (Rosen 1997: 98), and occur only rarely in Anatolia throughout the EBA. Image 2 shows the latest identified votive axes in the southern Levant found at EB I Ai.

Figure 2: Photograph of two shaft hole votive axes from EB I Ai, southern Levant housed at the Rockefeller Museum, Jerusalem. ©Tiffany Okaluk

XII. Conclusions

The axe is one of the most enduring tool types throughout this history of the human species. The history of the axe is closely linked to aspects of social development, technological development, trade, innovation, and prestige. The axe is a versatile, multi-function tool that was never defined by its material, but rather, the axe was/is always defined by its function. This has allowed the axe to evolve alongside trends in material culture and value.

The formative Period for the axe as a hafted, wedge shaped, high-speed impact tool was the Neolithic. Neolithic ground stone axes were high-time investment tools essential to the agricultural lifestyle that carried significant social value. This social value is seen in the funerary deposition of 'special', or non-utilitarian axes for both adults and children (Özkaya 2009: 5, Bains et al. 2013: 340). The stone axe did not suddenly disappear with the introduction of cast metal (ca. 5000 bce), but instead went through a very slow and steady decline as metal become more available and technologies improved. Social complexity and trade in Anatolia also increases with advancements and availability of metals, which is why this social phenomena is so often linked with the desire for both utilitarian and prestige metal products. The extramural cemeteries of the EBA show the continued significance of the axe in its many forms (bronze, arsenical-copper, copper, stone, flat, crescentic, shaft-hole) but also the increasing importance of metals to society as a show or emulation of status. Stone axes are a rare find in the Anatolian EBA but do not completely disappear as they do in the southern Levant (Massa 2014, Rosen 1997).

Axes, as well as many other cast metal objects were rarely haphazardly discarded due to their value. Metals are precious not only for their complex and expensive production chain, but also because they can be endlessly recycled (Hansen 2014: 245). EBA Anatolia experienced a dramatic increase in the number of metal objects deposited as burial goods (Geniş and Zimmermann 2014, Massa, McIlfatrick, and Fidan 2017, Zimmermann and Yıldırım 2007, Zimmermann et al. 2009), which signals a social desire for wealth differentiation and display mirrored by significant changes to settlement patterns and social organization across the plateau.

The innovation and spread of bronze metallurgy across Anatolia was facilitated by two (so far) Late Chalcolithic/EBA tin mines, Hisarcik and Kestel. The discovery of Kestel, and its associated production village Göltepe was controversial, as before then, there were no known sources on tin in Anatolia. The following chapter reviews the evidence both for and against Göltepe as a tin production site.

Chapter 3: Late Chalcolithic/Early Bronze Age Göltepe, Turkey

I. *Introduction*

The major archaeological faunal collection used in this current study comes from the site of Göltepe, a highland metal/tin production site located on the south-eastern Anatolian plateau. Göltepe is an ideal assemblage to investigate the spread of metallurgy due to the site's active role in both mining and metal production during the Early Bronze Age. Although Göltepe is undoubtedly a metal/tin production site, finished metal products within secure EBA stratigraphic contexts were relatively rare and included only a few copper-based chisels and smaller bronze items of adornment (Yener in press: 387, 390). The relatively few metal finds reveal very little information on how finished metal items were used at the site, and to what degree finished metal products were integrated into the daily lives of the residents.

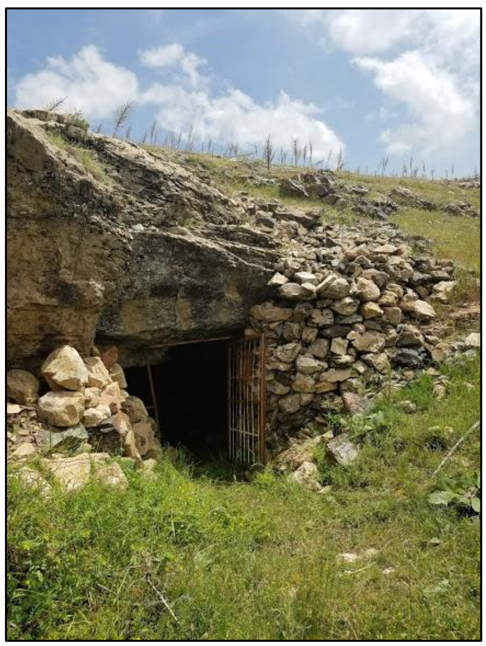
This chapter explores the Late Chalcolithic and Early Bronze Age site history of Göltepe as a tin metal production site. The debate over whether or not Göltepe was specifically a tin production site is explored. Detailed investigation of the material culture along with previous experimental studies of tin production leaves no doubt that Göltepe was an Early Bronze Age tin production site.

II. *The discovery of tin in the Bolkardağ region of Anatolia*

Ancient sources of tin in the Near East have always been a matter of speculation as no archaeological evidence for tin production had ever been uncovered in the Near East before the discovery of Kestel mine and Göltepe (Yener 2000). The renewed search for tin in Anatolia began with the publication of the analysis of slag material from the central Taurus Mountain range which showed remarkably high concentrations of tin (Yener in press: 82). Similarly, gold prospectors in the region were also finding high concentrations of tin in a mineral called cassiterite. Both tin sources were identified to come from the Taurus Mountain passes (Özbal and Yener 1987: 223). Lead isotope analysis conducted on the Late Chalcolithic/Early Bronze Age bronze figurines from Tell Judaidah (Amuq region) identified the tin within the figurines as also likely coming from the area of the Taurus Mountains passes (*aka* the Cilician Gates). These finding solidified the need to find the ancient mine. As a result of intensive hand panning of the streams around Niğde, high concentrations of cassiterite were found in the streams below the Niğde mountains. Cassiterite is a tin oxide mineral, SnO2 (Lehner and Yener 2014). It is the major tin ore used as tin throughout history and still is the most important source of tin today (Özbal and Yener 1987). This eventually led to the discovery of the Chalcolithic/Early Bronze Age Kestel mine, and Göltepe, its associated processing site.

Dr. K. Aslihan Yener excavated Göltepe in conjunction with the Niğde Museum and the Ministry of Culture from 1990-1991, and 1993, with parallel excavations at the Kestel tine mine from 1987-88, 1990, 1992, and 1996 (Yener; in press: 128). Göltepe is located on the next hill over from Kestel, 2 km directly south, with the mine and village visible to each other across a valley. The location of Göltepe also transects two major trade routes; the silk route through the Taurus pass, and the off shoot of the silk rout that travels northwest to Niğde (Yener in press: 1). The strategic location would have been ideal for both control over the mine, as well as accessibility for participation in the trade necessary for this very specialized metal production site (Yener in press: 83). Image 3 shows the current entrance to Kestel mine.

Figure 3: Photograph of the entrance to the Kestel tin mine, Turkey ©Tiffany Okaluk.



The discovery of Kestel was fraught with controversy, as later MBA Assyrian texts from Kültepe detail transactions for tin brought into Anatolian to trade for silver (Muhly 1985: 280, Hakan 2019: 790-791). This strongly suggests that tin was/is not locally available, or at the very least, not exploited. As tin is a vital component of bronze, the mystery of the extraction location(s) had littered the archaeological literature pertaining to metallurgy for almost 50 years (Renfrew 1967: 12, Muhly 1985, Weeks 1999: 49). Despite the ancient textual evidence of later Periods, the recent geological evidence can not be denied and tin was/is locally available within the Taurus Mountains (Yener in press: 82).

III. The debate over Anatolian tin

The identification by Yener et al. (1989) of Kestel as a tin mine was received negatively by many archaeologists (Weeks 1999, Hall and Steadman 1991, Muhly et al. 1991, Pernicka, Wagner, Muhly, and Öztunali 1992, Muhly 1993) Although many scholars (Earl and Özbal 1996, Laughlin and Todd 2000, Lehner and Yener 2014, Webb et al. 2006) now accept Yener et al. (1989) initial identification, it continues to spark debate within the archaeometallurgical community, and not everyone is fully convinced (Düring 2014: 17, Muhly 2011).

Yener argues that Kestel was a Late Chalcolithic and EBA tin mine, with the low-grade cassiterite ore processed and smelted into ingots at nearby Göltepe. Both Kestel and Göltepe were abandoned at the end of the EBA due to waning cassiterite ore production as Kestel today appears to be "mined out" (Yener 2000, Yener et al. 2015).

The source location of tin in the ancient Near East and eastern Mediterranean became a popular topic of theoretical debate with the rise of the material sciences in the 1960's. Renfrew (1967: 12) referred to this as the "tin problem". Meaning that, archaeologically, tin is identified in the metallurgy of the Aegean and the Near East as early as the Early Bronze Age, yet no mining or smelting operations had yet been identified. Additionally, known geologic occurrences of cassiterite are virtually non-existent in western Asia (Muhly 1985: 276), with the exception of Uzbekistan, Afghanistan, and India (Weeks 1999: 51). Historically documented tin extraction locations include: England, Thailand, Malaysia, or Burma (Muhly 1895: 275), of which, non were accessible to the peoples of the EBA or MBA Near East. Thus, early bronze production appears to have taken place far from potential extraction locals, with no evidence for local bronze innovation at source locations (Weeks 1999: 51)

With no physical clues to pinpoint extraction locations, scholars relied on scant textual sources (eg. Herodotus and Assyrian trade documents) to theorize extraction locals (Muhly 1985). Significant to this debate are the Akkadian texts of the Old Assyrian trade network found at Kültepe. Kültepe was a reginal centre located on the eastern part of the Anatolian plateau in the EBA and the locale of an Assyrian trade colony in the MBA. The Assyrian texts discuss trade transactions between the Assyrian merchants and the local Anatolian's. Tin, or *Anaku* in Akkadian, was one of the major commodities brought into Anatolia for the exchange of Anatolian silver, and to a lesser degree, gold (Hakan 2019: 790-791). Over the short span of 30 years (ca. 1893-1863 BCE), approximately 48 tons of tin was brought from Assyria into Anatolia (Hakan 2019: 791).

The MBA Kültepe texts are still a major point of contention in the debate over Anatolian tin (Muhly 2011). Some scholars assume from these texts that Anatolia did not produce tin locally, or alternatively, did not produce enough to satisfy Anatolian demand for the material. However, Yener (2000) does not ever suggest that Kestel tin mine was in operation during the Assyrian trade Period.

Another major point of conjunction raised by Muhly (1993) is connected to the demand for tin itself. Muhly (1993) claims that tin was so rarely used in Anatolia before 2000 BCE (MBA) that a local tin mine and production site would have no demand, and therefore, no reason to exist. This is wholly untrue, as is evident by the Kestel tin mine and its associated processing site Göltepe. As outlined in the previous chapter, tin began to make sporadic appearances as early as the later Late Chalcolithic. Throughout the EBA, tin grew in popularity as an alloy material across Anatolia. The EBA is widely known as a time of experimentation with copper-based alloys, and although tin percentages are often below the standard 10% of later periods, it is present. Muhly (1993) argues his point using the compositional analysis of the EBA II-III metals from Tarsus conducted by Esin (1967). Esin (1967) found that only 12% of the metal artefacts contained tin and that they are low-grade tin bronzes (4%) (Muhly 1993: 240). Muhly (1993) suggests that this is evidence for the lack of Anatolian interest in tin and bronze as a metal before the MBA. Yener and Vandiver (1993) used the same evidence to argue the opposite point. Even though the quantities are low, tin is present, and the tin would have needed to be suppled from somewhere.

Questions of feasibility regarding the low-grade ore and the ability to actually produce tin were rightfully raised in multiple articles (Pernicka, Wagner, Muhly, and Öztunali 1992, Muhly 1993). The extremely low-grade tin stannite contained within the mine today might require "more effort than it is worth" to produce tin. Muhly (1993) claims that the small tin prills produced by such low-grade ore could not possibly be detected by the EBA metalworkers, or the small amounts of tin would be obliterated by the smelting process itself (Pernicka, Wagner, Muhly, and Öztunal 1992). Alternatively, it was suggested that the mine may have produced silver, gold (Pernicka, Wagner, Muhly, and Öztunali 1992: 95-96), or even iron (Sharp and Mittwede 1994, Muhly 1993). The possibility that Kestel was mined for anything other than tin is refuted by Yener (in press) due to the complete lack of evidence for gold, silver, or iron production at Göltepe.

These questions are important to consider, yet it seems that investigations on only the mine itself can neither confirm or deny which minerals exactly were mined there, especially when they were “mined out” in antiquity. Rather, the answer to these questions are further revealed by the associated ore processing site, Göltepe.

IV. *Göltepe site description*

Early Bronze Age Göltepe and the associated Kestel mine are contemporaneous, with both sites containing similar/identical pottery types, typologically similar ground stone tools for ore processing, and overlapping radio-carbon dates (Yener in press: 92). Functionally, they are both intrinsically part of the same EBA highland metal production system that relied on both extraction and smelting of ground ores (in highland regions) for distribution to larger lowland centres (Yener et al. 2015).

Göltepe is a 5 hectare village site on the summit of a hill. The hill top settlement is surrounded by a circuit wall. Survey work and test units identified sporadic occupation outside the circuit wall that likely existed (possibly seasonally) within a 60 hectare radius of the village and mine site (Yener in press: 568). The occupation of Göltepe is chronologically sub-divided into four Periods (see Table 1). Period 1 is Iron Age, dating between the 10th through 8th centuries BCE. Period 1 will not be further discussed in this overview as it falls outside the period of study. Pertinent to this study are Periods 2-4 that fall between the Late Chalcolithic through to the end of the EBA III (4400-1900 BCE). These are discussed in detail below. The horizontal exposures at the site are divided into Areas A through E. Structures and pit houses within each Area are numbered beginning with 1, so there are multiple mentions of similarly numbered pit houses and structures delineated only by their area.

Table 1: Periodization of Göltepe based on architecture and radiocarbon dates (Yener in press: 130).

Period	C14 dates	Architectural Style
1	Iron Age 10th-8th cent BCE	Ephemeral above ground structures; re-use of earlier pit houses
2	EBA III 2400-1900 BCE	Above ground stone built buildings

3	EBA II 2900-2400 BCE	Semi/subterranean pit houses and semi-subterranean terraced buildings
4	EBA I/Chalcolithic 4400-2900 BCE	Semi/subterranean pit houses

i. Period 3 and 4

Periods 3 and 4 must be discussed in conjunction with one another as there is no hiatus in occupation or change in architectural styles between Period 4 and 3 as there is between Period 3 and 2. Period 3 and 4 are characterized by many sub-terranean pit houses with associated outdoor activity areas, and two semi-subterranean terraced buildings. Only a few features and structures are securely dated to Period 4, these are: Pit house 1 in Area A, Pit 34 (associated with/cut by Pit house 1) in Area E, and the trackway in Area E. However, features without radiocarbon dates, or that do not clearly cut older material cannot always be securely dated to either Period 3 or 4 (Yener in press).

The trackway is likely the earliest feature that runs SW-NE through the site and down the slope to the Kuruçay River. Although exposed only in Area E (the lower slope), it presumably continues up along the summit and would fall in perfect alignment with the Period 3 and 4 oval pit houses (Yener in press: 2010). The oval pit houses scattered atop the summit of the hill (Area A) are the earliest forms of architecture at the site. While these 12 pit houses vary in size and detail they were all constructed in a similar fashion. Dug into the basal clay bed rock, they were small sub-subterranean structures consisting of one or two rooms with a wattle and daub superstructure, and an associated outdoor activity area. All 12 pit houses in Area A contained similar material culture including evidence of metal working such as crucible fragments, ground stone tools, crushed ore, thermal installations, and domestic debris (Yener in press).

Pit house 1 in Area A provides the only example of a Late Chalcolithic structure at Göltepe. Pit house 1 was a multi-roomed semi-subterranean dwelling with a wattle and daub super-structure. The main room was approximately one metre deep and four metres across, carved into the natural clay and bedrock. A wall, constructed of square limestone blocks helped to support the east wall and likely also held up wooden posts to support the roof structure. A small pantry/niche located on the west side of the wall contained a *pithos* jar and a multitude of stone tools. Access to the structure was via the annex to the south, which likely functioned as a small storage room.

The annex room contained storage jars and a carved stone bench. The walls of Pit house 1 were lined with lime plaster and the floor was packed earth. The floor surface (Floor 10) shows evidence for variable burning activities and temperatures with variations in colour across the surface as well as distributed charcoal. A carved hearth identified on the west side of the main room containing ground stone tools and charcoal provided radiocarbon dates. Calibrated radiocarbon dates place this hearth firmly in the Late Chalcolithic between 4616-3424 BCE. This pit house, as with many other within the site was destroyed by a burning event in which the vitrified remains of the wattle and daub superstructure sealed the structure. Occupation in this pit house is confined to Period 4 (Yener in press: 131-135).

The outdoor activity area associated with Pit house 1 consists of multiple shallow pits (one lined with stones) and smaller hollows that contained crucible fragments, ground stone tools, and ore. This was likely the location of smelting related activities possibly reserved for the inhabitants of pit house 1. Most pit house structures had a related outdoor activity space with similar features and material culture as Pit house 1 (Yener in press: 134-135).

Some pit houses and outdoor activity areas appear to have been shared spaces. Pit houses 6 and 7 (Area A) shared the only sub-terranean door within the settlement. Pit house 7 shares an outdoor activity area with Pit house 8 which was sheltered by an open air roofed structure (Yener in press: 148). Pit house 7 was destroyed by fire and is radiocarbon dated to 2761-2342 BCE (Yener in press: 146), placing it in Period 3 (EB II). *In-situ* finds from Pit house 7 include clay tuyère fragments, slag, moulded architectural fragments, crucibles, and other ceramics. Pit 16, located within Pit house 7 and approximately a half metre deep, was sealed beneath the floor of Pit house 7. Finds within the pit include smelting debris, ground tin ore, crucibles, bone, and stone tools. This pit clearly predates the Period 3 pit house and possibly dates to Period 4. The pit is thought to represent an earlier function of the space as a smelting locale (Yener in press: 146).

The subterranean door/passageway that connected Pit house 6 and 7 is visually very similar to a mine shaft that can only be used when crouching or crawling. This is similar to the mine shafts at Kestel that are so small that they led the excavator to conclude that the miners must have been either children or young adults (Yener in press: 568).

The *in-situ* floor accumulation of Pit house 5, Area A, (similar in construction to the other pit houses and destroyed by fire) revealed more information about how the indoor spaces may have been used. Multiple loop-handles cups were found filled with various different ground ores with varying degrees of both tin and iron. In the same room, a horse-shoe shaped hearth installation contained wheat, barley, and ground ore. This indicates that space was not necessarily delineated by function and that food processing and storage took place in the same context as ore preparation and/or smelting (Yener in press: 141).

Pit house 12 (Area A) only measured 3.2m by 2.5m and 1.3m deep. This Pit house had five separate thermal installations carved into the floor and walls that all showed signs of extreme heating, that are all dissimilar in construction to one another. The pit house and thermal installations contained hematite weights, ground stone tools, crucibles, an obsidian tool, a moulded architectural relief, a copper chisel, and lots of ground ore and ceramics (Yener in press: 165-168).

Two terraced buildings (Area B), or possibly one, multi-story terraced building were carved into the western slope of the hill face. The two structures may have been contemporary to each other according to the site director, but it is unknown how or if they are related to one another. Radiocarbon dates do not suggest the building are contemporaneous as thermal installation 1 in building 1 was assigned a date between 2878-2581 BCE. This thermal installation is constructed using moulded architectural elements similar to those found in the Area A pit houses. These elements, however, are clearly reused as they are were all found face down and mixed with other building material to create the thermal installation. This suggests that the construction of Thermal installation 1 and Terraced building 1 may post-date the 3rd Period pit houses in Area A (Yener in press: 185). Terraced building 2 is identified as a metallurgical workshop. Charcoal from the lower floor level is radiocarbon dated to between 2481-2205 BCE, which possibly dates this building to Period 2, although the architecture fits with Period 3.

Pits are another feature type that were found scattered across all areas of Göltepe. Generally flat bottomed, filled with metallurgical debris, and sealed with rubble stones, these pits are difficult to assign to either Period 3 or 4. Pit 34 in Area E, however, is cut by Period 3 Pit house 1, and likely dates to Period 4. Pit 34 is unique at Göltepe as a smaller sealed pit sits within this pit. This pit contained a rather large and unusual deposit of highly butchered sheep, goat, and cattle horn cores and frontal bone segments (Yener in press: 211-213).

Occupation during the later Chalcolithic and EBA I (Period 4) at Göltepe was small, likely seasonal, and highly related to metal production and ore processing from the nearby Kestel mine. During the EBA II (Period 3) the site grew substantially to include 18 pit houses, 1-2 terraced buildings that functioned as metallurgical workshops, and a circuit wall. However, it remains unknown if the site was inhabited year-round or remained a seasonal local for specialized metallurgical activity. The existence of a circuit wall suggests year-round habitation as well as the need for separation and protection from the surrounding area. Abandonment of the site at prescribed times throughout the year would leave it vulnerable to invasion and endanger precious metallurgical resources. Infant remains in one of the pits, along with the remains of females and children found within Kestel mine would suggest that the inhabitants of Göltepe were multi-generational families (Yener in press: 568), not only specialized workers who came to Göltepe for specific intervals of time.

ii. Period 2

The Early Bronze Age III (Period 2) at Göltepe was architecturally very different from the preceding periods. Subterranean structures were replaced by above ground stone buildings finished with wattle and daub superstructures. The construction of the stone buildings required a building effort to fill and level the older pit houses, which also re-used and extended some of the larger Period 3 walls into the new buildings (Yener in press: 568). Construction of the new above-ground walls incorporated a significant amount of discarded ground stone tools. Period 2 is less coherently understood than Periods 3 and 4, although the structures appear more permanent in nature. Metallurgy continued to be the main activity at the site with tin-lined crucible fragments, and grinding stones found within the majority of buildings and outdoor activity areas.

Building 1 in Area A was likely a metallurgical workshop. Constructed directly above the earlier pit houses, it does not appear that a significant amount of time passed between occupational phases. This stone walled structure consisted of 4 long cell-like spaces constructed longitudinally north-south. All walls except the eastern wall was constructed of stone. The eastern face of the building was lined with post holes, and it appears as if the eastern face was left open to face a covered open air workspace adjoining or adjacent to the building. Within the cell-like workspaces were copious amounts of ground stone tools, ore, a stone mould, a copper toggle tin, a vanning pan, obsidian, and stone built benches or platforms (Yener in press: 217-225). Building 2 in the same area contained a tin-bronze bracelet, a multi-faced stone mould, ceramics, stone stools and ore (Yener in press: 226-227).

In Area E, there was a very different type of architectural structure. This was an 8 m by 9 m stone platform likely with an associated (but not surviving) building on top. The platform (and possible associated building) was heavily robbed out making specific inferences about the structure difficult. The platform itself was constructed of worked stones and rubble filled. It is the associated deep middens along the south of Wall 1 wall that help denote the function this platform and possible super-structure (Yener in press: 241-243).

The midden deposits, at over a metre deep, were the only middens found and/or excavated within the site and were situated against exterior of the south wall and at the edge of the southern hill slope. The stratigraphy of the middens was difficult to decern, but it is clear that they were used for refuse disposal over a substantial period of time. Considerable amounts of silty material was recovered and interpreted as discard from vanning activities as they contained small amounts of tin and other minerals. Other materials recovered included bone, worked bone, ceramics, ground ore, grinding stones, and smelting debris. The location of the midden on the edge of the settlement along the hill slope might suggest that other middens deposits exits along the steep slopes and that refuse material was deposited outside of the settlement area. The large amount of metallurgical debris suggests to the excavators that metal production activities may have taken place on the stone platform or within a building on the platform (Yener in press: 244-245). If this is indeed that case, it would mean that metal production in Period 2 became a more centralized activity that moved away from individual households as seen in Periods 3 and 4.

The Period 2 structures clearly represent permanent settlement at Göltepe. The drastic shift in architectural style may reflect the increased importance and centralization of this highland metal production site in the later EB. The above ground stone built architecture of Period 2 is much more consistent with EB architectural styles seen across Anatolia such as at Kültepe (Atici et al. 2014). Metal production in Period 2 continued to be the major production activity at Göltepe. Similar to Periods 3 and 4, substantial amounts of metal production debris was recovered from across the entirety of the site including, ground ore, crucibles, grinding stones, and thermal installations (Yener in press: 568-569).

Metal production is evident throughout the entirety of the EBA Göltepe, although the organization of production at the site appears to have changed from the EB I & 2 to the EB III. Evidence for household and cottage level production was found for Periods 3 and 4, but is less clear for Period 2. In Period 2, metal production clearly continued to be the major production activity as the copious amounts of ground ore, crucibles, and stone tools attest to. The shift to more permanent architecture also suggests the continued (possibly gaining) importance of the site, yet the organization of production at the site level in Period 2 remains unclear (Yener in press: 585).

V. *Evidence for tin production*

Functionally, Göltepe was unquestionably a metal production site, but did they produce tin? Evidence for this comes from both the types and amounts of specialized features and artifacts found across the site from all levels. Ground ore was recorded by the kilogram, grounding stones by the thousands, and crucible fragments by the metric ton. The metal "production tool kit" (Yener in press: 376) can clearly be recognized at Göltepe. Many multi-faced moulds also attest to the casting of finished metal objects and ingots, and although the metal finds themselves are not overly impressive they do attest to the use of metals for both functional and decorative purposes.

i. *The metal finds*

Twenty-eight metal artifacts were recovered from all Periods at Göltepe, but only 13 come from secure EBA contexts. These objects are almost all copper-based alloys with a mixture (but ranging amount) of both tin and arsenic additives. One lead ingot, a silver alloy necklace, and a true bronze ring wrapped around the bones of a bird from Period 3 were also recovered. Ten of the eleven copper-based artifacts recovered are from Period 3 contexts, making Period 3 the richest in finished metallic finds. Only a single bronze bracelet was recovered from Period 2 (Yener in press: 387). Six of the eleven copper alloy artifacts have a tin content of above 5%, and thus, qualifies them as true bronzes (Earl and Özbal 1996: 302). That means that 54% of the copper-based artifacts from EBA levels are true tin-bronzes.

Returning to Muhly's (1993) argument outlined in section 2, he deemed a 12% bronze artifact ratio was too small to support a local tin industry. However, it is obvious from examination of only one other site (Göltepe) that the utilization of tin and bronze varied widely (likely due to availability), and the use/demand for tin should not be estimated on the basis of a single group of artifacts from a single site.

The majority of the metal finds are ornamental, or decorative in nature. Toggle pins, rings, bracelets, a pendent, and a necklace make up the majority of the assemblage. Utilitarian tools, although present, were not abundant. The functional tools found are from Period 3 and include two copper-based chisels, and awl, and a needle (copper, tin, and arsenic). However, one open face flat head axe mould with evidence for use suggest that copper-based axe heads were made on-site (Yener in press: 370).

ii. Moulds

Ground stone and clay open faced moulds were found both on the surface and within stratified contexts across the site. A total of 18 moulds were recovered. Unfortunately, 9 of the 18 can-not be assigned to a specific period. The clay axe mould, along with a clay based chisel/ingot mould date to Period 3 and are the only clay moulds recovered. The axe mould is part of the floor assemblage for Pit House 1 in Area C/D and is radiocarbon dated to between 2881-2617 BCE (202). The majority of the moulds found within stratified contexts date to Period 3. One of the seven Period 3 moulds might even date to Period 4. Only two moulds can be securely dated to Period 2. Many of the moulds are multi-faced. This refers to a rectangular cube shape (stone or clay) with two or more sides that have negative impressions used to cast different shaped metal objects (Yener in press: 375-382). An example of a multi-faced mould is shown in Figure 4. These types of moulds are theorized to represent mobility as multiple moulds can be transported as a single object (Biçer 2005: 24). Some of the moulds recovered were single-faced and these are through by the excavators to represent moulds that remained in fixed locations.

Figure 4: Photograph of a multi-faced MBA mould from the southern Levant housed at the Rockefeller Museum, Jerusalem ©Tiffany Okaluk.

Both single and multi-faced moulds are found at sites associated with metallurgy in Anatolia. The earliest moulds for casting metal objects were found at Arslantepe (ca. 3500 BCE) with other early examples were also found at Tel Brak, Syria (Biçer 2005: 26). This type of open faced mould became a common part of the metallurgical production tool kit across the Near East in the EBA, but multi-faced moulds are more commonly found in Anatolia rather than other parts of the Near East (Biçer 2005: 26). If multi-faced moulds are indeed associated with mobile Anatolian metalworkers, their presence at Göltepe in Periods 3 and 4 makes sense, as Göltepe was presumably a seasonal settlement at that point. However, their continued presence into Period 2 would no longer be necessary, but may represent a stylistic continuation of a familiar took kit. Image 5 shows a selection of moulds, crucibles, and ceramics recovered from Göltepe.

Figure 5: Photograph of moulds, crucibles, ore, and ceramics recovered from EBA Göltepe housed at the Niğde Museum, Turkey ©Tiffany Okaluk.

iii. Crucibles

A very large quantity (1.5 metric tons) of crucible sherds were recovered from Göltepe (Yener in press: 358). Unfortunately, no intact crucibles were found, but this may be due to how they were used. The excavators theorize that the crucibles were deliberately broken apart during the smelting process, possibly to help release the prills from the slag, or to release the glassy slag from the crucible itself. The inner surfaces of the crucible fragments have hard residues, bloating, vitrification, and small amounts of slag material adhering depending on the functional type of crucible (Yener in press: 361-362).

The presence of tin within the crucibles was confirmed by elemental analysis that compared the exterior to interior surfaces. The soil matrix was also tested to confirm that small amounts of tin was not absorbed through depositional processes (Yener in press: 363). Tin concentrations within the slag on the crucibles are low, but detectable. This is to be expected, as the aim of the smelting process is to separate the tin from the slag material. The residual tin in the slag is thought to be a result of the vapor phase (Yener in press: 362).

Crucible fragments are found across the entire site within each period (2-4). However, the majority come from the pit houses and the terraced buildings of Period 3. A notable difference between Periods 2 and 3 is the increasingly size of the crucibles themselves. For example, a Period

3 crucible averaged about 8 cm in diameter, yet Period 2 crucibles ranged anywhere from 20-60 cm in diameter. This likely indicates a higher demand for tin, or as Yener (in press: 574) also suggests, “increasingly low grade tin content in the ore”. The stone tools, unlike the crucibles, did not change stylistically between Periods 3 and 2 (Yener in press: 414).

iv. Ground stone tools and grinding stones

The ground stone tool assemblage at Göltepe is immense. Over 50 000 ground stone tools were identified and recorded including, saddle querns, pestle and mortars, upper grinding stones, and very large, non- portable lower grinding stones.

The differentiation between domestic use grinding stones and ore processing grinding stones is vital for the interpretation of metal production at Göltepe. Yener conducted grinding experiments with the different tools and material types to aid in this identification. She found that the saddle querns, always made from a porous basalt, are not efficient for grinding ore, but are exceptionally efficient for grinding grain. Saddle querns were found across all contexts of the site, meaning that domestic activities were not isolated to specific buildings or areas (Yener in press: 400). Ore processing grinding stones were also often found in association with the saddle querns. This indicates to the excavators that production at Göltepe likely functioned at the cottage level, especially in Periods 3 and 4 (Yener in press: 401). This means that individual household groups produced a surplus of metallurgical material within their own domestic spaces, rather than in designated communal spaces. This changed slightly in Period 2 when the majority of grinding stones are found in the long, narrow workshop rooms that have little evidence for associated domestic activity. This may indicate a change from cottage-level industry to workshop scale production (Yener in press: 402), although there is no evidence to suggest that production was ever centralized (Yener in press: 401).

Many of the stone tools, despite scale of production or period they are associated with, were found to have traces of tin-rich hematite on the surface. Even the small amount of ground stone tools securely radiocarbon dated to the later chalcolithic have evidence for working with tin-rich hematite (Hard and Rossuh 2021).

v. Crushed ore

While all the evidence presented thus far clearly identifies Göltepe as a metal production site, it is the ground tin-rich cassiterite ore found across the entire site that solidifies its identification as a tin production site (Yener in press: 574). The ground ore was found within thermal installations, inside crucibles, scattered across floor surfaces, and filling multiple jars and looped handled cups. The crushed ore was found to contain varying degrees of tin. This is normal when one considers the different forms the ground ore would take throughout the various processes: (1) ground ore, (2) vanned/concentrated ore, and (3) ground slag material (Earl and Özbal 1996: 296). While the ore contained high amounts of tin, it also contained high amounts of iron. This is due to the nature of ore deposit itself, as the tin was contained within larger hematite veins. Grain size analysis conducted on nine ore samples demonstrated that the ore was consistently ground to below the ideal grain size for iron working, but which was ideal for tin extraction (Earl and Özbal 1996: 296). The red/purple colour of the mineral due to the hematite composition would have aided miners in the extraction process, even in a low yield mine. Chemical analysis of the ground ore from Göltepe and material from the Kestel mine was very similar to each other in all but tin content, which is to be expected if the tin rich veins were mined out in antiquity (Earl and Özbal 1996: 296).

Seventy kilograms of ground ore was recovered from the site "and 50 kg of ore chunks" (Yener in press: 574). This is a significant amount, especially when one remembers that we are only seeing what was left behind, forgotten, or discarded.

VI. Experimental tin smelting

Experimental studies conducted by Earl and Özbal (1996) aimed to test the feasibility of extracting tin from the low-grade cassiterite ore found within one of the Period 3 pit-houses. The ore was tested prior to the experimental smelting and was found to contain only 1% tin. Vanning (with a shovel and water) improved the content level to about 10%. Both vanning pans and tuyère were found within stratified contexts at the site. The material was smelted in reproduction open crucibles and heated with blowpipes (tuyère). Within less than a half hour, the material had separated into a glassy slag material with small tin prills trapped inside. The glassy slag then required grinding to release the tin prills. The prills were approximately 2 mm in diameter (large enough for the eye to see) and were comprised of 92.17% tin and 5.15% iron. The grinding of the slag/tin material is important to note as the slag material was reduced to a power, and thus, left no easily identifiable slag material, or slag heaps (Yener in press: 575). The slag could then be further refined to release residual tin material from the ground slag by again replicating the process of grinding, washing, and smelting. When the smelting process was repeated again on the original experimental sample the metallic prills were found to contain 88.38% tin and 5.67% iron (Earl and Özbal 1996: 300).

Earl and Özbal (1996) also explored the idea of using low-grade ores for tin production. They found that, historical tin production in England had always used low-grade cassiterite ore, and that "tin ores almost always contains unimpressive amounts of cassiterite" (Earl and Özbal 1996: 209). Low-grade ores are easily concentrated through multiple vanning processes. Contrary to Muhly's (1993) argument, this suggests that low tech smelters did not require high-grade ore to either recognize the ore, or successfully smelt it into tin.

The inclusion of iron within the ground tin ore likely presented a challenge to the Early Bronze Age smelters. Interestingly, the ground ores from Göltepe are high in magnetic particles. Experiments found that an initial roasting of the ore caused the iron rich particles to become magnetic. When the roasted and ground ore is panned with water, the iron clumps together and enables separation of the iron from the very fine grained cassiterite particles (Laughlin and Todd 2000: 272, Earl and Özbal 1996: 297).

These replicative experiments strongly support the argument that EBA tin production was not only likely, but also achievable with the (ancient) local ore from Kestel, using only EBA technology (Yener 2000, Yener et al. 2015, Yener et al. 1989, Yener 1995, Yener et al. 2003). Although the process was laborious, tedious, and relentless, it was possible for the ancient people of Göltepe to extract cassiterite from Kestel and produce tin.

VII. Conclusions

The presence of Anatolian tin is now generally accepted by many prehistoric Anatolia scholars (Hacar 2017, Laughlin and Todd 2000, Webb et al. 2006, Earl and Özbal 1996, Lehner and Yener 2014), yet often, mention of the mining, production, and trade of Anatolian tin is conspicuously missing in discussions of EBA metallurgy (Biçer 2005, Massa and Palmisano 2018: 16). The later MBA evidence from Kültepe is often given Textual Priority, even for the EBA (During 2014: 17). This is disappointing as the Kültepe texts are only concerned with Assyrian trade, which did not exist during the EBA. The Kültepe Assyrian documents make no mention of local Anatolian tin sources, while other metals such as copper, gold and silver are frequently mentioned (Karaduman 2008: 82). This is not curious if the Assyrians already (as we know they did) have a reliable tin source that produced enough tin for them to use and export. Whatever the case, it should not be assumed that a local tin industry did not exist in the EBA since there is now evidence to the contrary, especially when the trade documents were written by non-local colonists long after the mine and site were abandoned.

Yener's (1989; 2000; 2015) claim that Göltepe was a EBA tin metal production is now difficult to refute. The vast amount of ground stone tools and crucible fragments, many of which show evidence for tin production, combined with the ground, tin-rich ore, thermal installations, moulds, vanning pans, and tuyères demonstrate a complete tin smelting production tool kit. The material evidence combined with the lack of slag material would be odd if the site produced other types of metals such as copper or iron. Experimental studies demonstrated that tin production obliterated any slag material as well as required a smaller cassiterite gain particle size than iron production.

The low-grade cassiterite (tin) contained in the ancient hematite ore veins of Kestel mine requited multiple intensive grinding processes. Although difficult, the processes were not overly complex, and produced relatively pure tin prills (Yener in press, Earl and Özbal 1996). The argument that tin production would have been impossible with the low-grade ore (Pernicka, Wagner, Muhly, and Öztunali 1992), should now be dismissed. The argument brought forth that Kestel may have functioned as a gold mine, however, is not as easily dismissed. Rather, it seems more likely that Ketel may have yielded both tin and gold, and the extraction of one ore does not dismiss the possibility of the other. Both Yener (in press: 576) and Earl and Özbal (1996) agree that miners may have initially been attracted to Kestel due to the small presence of gold. However, no traces of gold production are found at Göltepe, nor were any gold artifacts found, but this does not discount opportunistic gold mining at Kestel in conjunction with larger scale tin mining

Yener does not claim that Göltepe was a bronze production site. She states very clearly (Yener in press: 576) that Göltepe was a tin production site, yet it is obvious from the varied moulds found that finished metal products as well as tin ingots were cast on site. The chisel and axe moulds are particularly interesting in this regard as there is **no** evidence for copper production (Yener in press: 576). If the moulds were used to cast finished copper-based tools at Göltepe, pure cooper ingots would need to be brought into the site. This is only a hypothetical suggestion, and likely one that can never be corroborated, but it would account for the existence of the moulds.

Both Kestel and Göltepe were abandoned at the end of the EBA III, presumably when the mine no longer produced usable ore. Interestingly, this coincides almost exactly with the insurgence of Assyrian tin. Şahoğlu and Tuncel (2014: 355) suggest that the beginning of the second millennium was the pivotal point when the demand for bronze surpassed the capabilities of local tin production in Anatolia.

The search for Anatolian tin is far from over, and recently another new EBA tin mine (Hisarcik) close to Kültepe was discovered by the General Directorate of Mineral Research and Exploration (Yener et al. 2015). Evren Yazgan, a geologist, found that tin/cassiterite is associated with a newly discovered iron-arsenic mineral, Yazganite (Yener et al. 2015: 54). This geologic configuration of tin/iron deposits is vastly different than how cassiterite ore is found in other parts of the world, and may explain why it was not previously noticed. This also helps to explain the high iron content of the ground ore found at Göltepe. This research is ongoing, and continues to reveal complex components of early Anatolian metallurgy.

The study of ancient metallurgy is clearly complex and needs to bring together multiple lines of evidence to support new theories. Butchery analysis can function as a way to indirectly study the use of metal tools. The marks that tools leave behind on bone during the butchery process often leaves specific signatures that indicate the type and material of the tool. The following chapter reviews the published literature on identifying axes of different material types on bone and how this can be applied to the Göltepe faunal assemblage.

Chapter 4: Actualistic butchery research methods and methodology: how and why chop marks are (not) studied

I. *Introduction*

Experimental archaeology has long formed an important component of butchery studies in zooarchaeology (Seetah 2008, Binford 1981, 1978). The cultural marks and modifications studied by zooarchaeologists on animal bones represent aspects of past behaviour, choice, technology, and cultural setting. These marks and modifications, whether they are slice marks, chop marks, or use-wear abrasion, all represent past decisions. Zooarchaeologists who aim to study the meaning and processes behind these modifications stress the important epistemological issue that past processes can-not be assumed to be self-evident (Binford 1981).

Experimental butchery studies attempt to understand how the modifications observed on animal bones came to exist through controlled, replicable experiments with specific research questions. This has proven a successful method for inferring past butchery behaviours and tool use and separating them from other taphonomic sources (Olsen and Shipman 1988, Soulier and Costamagno 2017, Binford 1981, Greenfield 1999, Olsen 1988). The study of butchery marks allows for indirect access to the types of tools and their materials used in the butchery process. This information is essential for understanding the use and availably of tools in antiquity. Butchery analysis enables the visibility of this information without the need for the tools themselves which are often a rare find in the archaeological record due to recycling and reuse (Greenfield 1999: 797). Experimental butchery studies attempt to act as the bridge, and create modern analogues between static tools and their marks left behind on bones.

This chapter outlines the history and limitations of published chop mark research and its applications within the current butchery experiment. While the zooarchaeological research is sparse (Olsen 1988, Walker and Long 1977, Olsen and Shipman 1988), the forensic literature has some actualist studies that focus on the mechanics and morphological pattering of chop marks (Wenham 1989, Lynn and Fairgrieve 2009, Humphrey and Hutchinson 2001). However, the forensic literature only deals with and tests for the patterns generated by metal axes. The need for comparative chop mark data from the multitude of ancient axe technologies and types (chipped stone, ground stone, copper, bronze, and iron) in the zooarchaeological literature is highlighted.

II. *Replicative experiments: the use of analogy in archaeology*

Actualistic research is an important part of understanding the processes and actions that helped to create the materials of the static archaeological record (Binford 1977). It attempts to recreate past dynamic environments using controlled variables to observe specific outcomes. Butchery studies often use this technique to observe the effects of specific tools types on bone with the aim of describing the “causal linkages” between tools and the butchery marks (Kosso 1991: 622). Although comparable datasets are the main goal of experimental archaeology, the experiential knowledge of creating or performing said tasks is also an important part of interpretation and highlights the connection between doing and knowing (Binford 1981, Seetah 2008: 144).

The study of butchery marks in archaeology falls under the general category of taphonomic studies (Soulier and Costamagno 2017, Lyman 1987, 1994). Taphonomic studies aim to understand any process that inflicts change to or on bone from the death of the animal, up to when the bone is recovered and processed in the laboratory setting (Orton 2010: 1, Lyman 1994). This includes both cultural and natural processes either to reconstruct the life history of the bone, or to understand these processes in their own right. Understanding natural processes such as weathering, root etching, and gnawing are essential for the differentiation of cultural processes such as butchery, cooking, and tool manufacture.

Animal bones recovered from archaeological sites represent much more than just the species and elements from which they came. However, the changes that occur to bone once the animal is slaughtered can vary considerably due to cultural and environmental contexts. This is why controlled experimental studies are essential for contextualizing these changes. Experimental archaeology does not assume a 1:1 relationship between experiments and the archaeological record. Experimental archaeologists recognise that the systems and procedures that create experimental samples can never truly mimic the past. However, if agent identification is the goal, the use analogy is unavailable (Gifford-Gonzalez 1991: 217). Analogy is the comparison between (or amongst) objects and processes to determine similarity (Gifford-Gonzalez 1991: 219). This hinges on the assumption of uniformitarianism, meaning that processes of the past continue to function the same way in the present (Gifford-Gonzalez 1989b: 43). This does not assume that behaviour and thought in the past was the same as today. Instead, only “the physical, mechanical and chemical principals by which alteration in bones and teeth are produced” (Shipman 1981: 360) remain constant throughout time.

Experimental archaeology aims to extrapolate information by replicating items, processes and phenomena seen in the archaeological record in an effort to test hypotheses and produce useful analogues to understand past processes in the present (Matheieu 2002: 1), which is similar to what Gifford-Gonzalez (1989a) refers to as “methodological uniformitarianism”. The use of analogy in archaeology is not without its limitations, and uncritical or uncontrolled experiments can lead to flimsy and incorrect interpretations of the past (Wylie 1985). Therefore, experimental archaeology aims to focus on controlled experiments with minimal variables to test specific research questions (Mathieu 2002: 1). The level of scientific control, testability, and re-testability within the experiments correlate to the reliability of the results for use in archaeological interpretation.

Semenov (1964) and Coles (1966) were among the earliest archaeologists to synthesise and formally discuss the use of experimentation and experiments in archaeology. Imitation and use of past artefacts are identified as the two main ways archaeologists utilize experiments (Cole 1966: 1). More recently, Matheieu (2002: 2) used the terms ‘replicative’ and ‘simulative’ to describe in more detail the scale of process that an experiment intends to replicate. Mathieu divided the process into further stages, including object replication, behavioural replication, process replication, and system replication (Matheieu 2002: 2-6).

Experiments in butchery fall under the category of object replication, specifically functional replicas. A functional replica is intended to be used and tested in an effort to understand creation “and/ or their associated features and debris” (Mathieu 2002: 3). An essential key to butchery experiments is the term ‘associated features’, as a butchery mark is considered to be an associated feature of the butchery tool itself (Matheieu 2002: 3). Experimental butchery therefore, offers a relational analogy (Gifford-Gonzalez 1989a: 46) that aids in the interpretation of faunal/ butchered assemblages (Lyman 1994, Burke 2001).

Butchery marks are often the unintended consequence of the butchery activity, and thus, do not always represent the desired intention of the butcher (Pickering and Egeland 2006). This is particularly true for chop marks. For example, some chops result in the complete fragmentation of the bone and leave behind no discernible traces of a chop mark. High fracture levels and splintering are considered an unintended and unfavourable consequence of chopping in the dismemberment stage as small bone fragments become lodged in the consumable meat. Incomplete chop marks, meaning a chop mark that does not succeed in severing the bone and instead leaves behind a deep V-shaped mark, is also an unintended consequence of chopping. The zooarchaeological literature on chop marks is extremely limited and mostly discusses only these rarest types of chop marks – those that leave a clear V-shaped mark. Experimental studies with thorough descriptions of complete chop marks made by multiple axe types do not yet exist in the zooarchaeological literature.

III. Butchery analysis in zooarchaeology

Butchery, as a taphonomic process is often the first to affect the bone material. Butchery begins with the initial slaughter of the animal and includes dismemberment, disarticulation, and filleting. Butchery is the entire process of preparing the carcass for consumption before cooking. This is why butchery marks underlie other later taphonomic process, such as weathering, gnawing, and root etching that occur after the bone is discarded.

Early studies in experimental butchery focused on distinguishing certain butchery marks (ie. slices) from other forms of taphonomy, such as trampling and gnawing that can create similar types of grooves (Olsen and Shipman 1988, Gifford-Gonzalez 1985, Shipman and Rose 1983, Potts and Shipman 1981a). Since the main debate in butchery analysis continues to focus on slices made by stone blades, the recognition of stone blade marks in relation to other taphonomic processes, and the relationship between butchery marks and subsistence strategies (Monnier and Bischoff 2014, Domínguez-Rodrigo et al. 2009, Lloveras, Moreno García, and Nadal 2009, Bello, Parfitt, and Stringer 2009, Pickering and Egeland 2006, Blumenschine, Marean, and Capaldo 1996), these will be discussed first.

i. Slice mark studies for the differentiation between metal and stone blades

While the experimental study of stone slice marks on bone is well established in the literature (Binford 1981, Walker and Long 1977, Greenfield 1999), yet there are still surprisingly few that deal with the differentiation between stone and metal slice marks (Soulier and Costamagno 2017, Walker and Long 1977, Greenfield 1999). The first to microscopically investigate butchering grooves to distinguish tool type was Semenov (1964). This was followed by Walker and Long (1977) who tried to differentiate blade marks made by metal and stone tools from Holocene sites in North America. Their method is of limited use since it examines only a small cross section of the groove from which it is difficult to make consistently accurate identifications. Their method is also time consuming, requiring moulds and multiple thin sections made of each slicing mark. Although their method is not widely used, it was the first to explore the differentiation of metal and stone blades using controlled scientific methods.

Further study of the differentiation between metal and stone slice marks was developed by Greenfield (Greenfield 1999, 2002, 2006) using silicone moulds of slice marks viewed through a scanning electron microscope (SEM). Greenfield's (1999) experimentation with multiple types of stone blades as well as metal blades refined earlier diagnostic observations and had a greater success rate in differentiation between metal and stone blades. It also stimulated further research by a number of scholars around the world (Domínguez-Rodrigo 1999, 2003).

Slice marks viewed through a SEM have the advantage of being able to see the entire groove clearly since it allows for great depth of field. Seeing the entire mark at high magnification allows any slight variation to the apex and walls of the groove to be immediate visible. This method allows even the sharpest and smoothest of stone blade marks to be differentiated from metal. Stone slice marks contain variation in wall profile and microscopic striations within the walls of the slice mark. A metal slice mark will instead have even wall profiles with no striations (Greenfield 1999). These differences are due to the differences of the tools themselves, as a stone blade will always be slightly asymmetrical, whereas a metal blade, cast in a mould, will not exhibit these slight variations and will create a very even and clean mark.

Experimentation using new techniques for the identification of cut marks continues to be explored and refined by zooarchaeologists. For example, Pante et al. (2017) explores the uses of 3D scanning for the identification of stone slice marks. Bello et al. (2011) also used 3D images to better understand the Middle Pleistocene slice marks from Boxgrove, UK. However, recent literature rarely focuses on the differentiation of stone vs metal blades and Greenfield's (Greenfield 1999, 2002, 2006, 2013) method remains the most reliable for this task.

IV. Chop mark terminology

Within the zooarchaeological butchery literature, chop marks, if mentioned at all, are always discussed as a side note to slice marks (Walker and Long 1977, Binford 1981, Fisher 1995, Shipman 1981). As such, the terminology associated with chop marks is often confusing, or not defined at all. To successfully describe and discuss chop marks is important to first clarify chop mark terminology. In the zooarchaeological literature, chop marks are almost always defined as a deep V/U-shaped mark presumably made by an axe (Dı et al. 1999: 629, Olsen 1988: 349), yet chopping is also defined as the act of severing the bone (Olsen 1988: 344). These terms are not fully compatible. If the act of chopping is defined as severing the bone, but the marks discussed are a deep V-shape, this means that the marks that are studied are not the marks actually intended by the act of chopping. A chop mark is intended to dismember a carcase and often results in the severing of the bone. Therefore, if the bone is chopped through completely or chopped and then broken, the chop mark will not have both sides of the mark preserved on a single piece of bone. In consequence, the marks that are usually studied in experimental zooarchaeology studies (deep U/V-shaped marks) are the unintended consequence of a failed dismemberment butchery activity. A chop mark, therefore, has two very distinct and different forms rarely distinguished within the literature: complete and incomplete chop marks (Lupo, Fancher, and Schmitt 2013: 431, Gifford-Gonzalez 2018: 290-291). Complete chop marks are almost never described in the zooarchaeological literature and are usually represented by those actions that do not completely sever the bone. (Lupo, Fancher, and Schmitt 2013: 431). Gifford-Gonzalez (2018: 290-291) does attempt to define these differences in chop mark morphology, yet still offers the reader a rather confusing picture of what a chop mark should look like since she uses the word to define itself. Chop marks are defined as a "planar, flat surface on the chop mark itself," that are comparatively wider, and deeper than slice marks (Gifford-Gonzalez 2018: 290). Gifford-Gonzalez (2018: 290) does importantly point out that not all chops leave recognizable traces on bone. In consequence, this leaves room for further definition of the action and the subject.

ii. Chop marks studies and experimentation in zooarchaeology

Chop marks have received surprisingly little attention by the zooarchaeological community even though they often make up a substantial portion of the butchered assemblage. The first published experimental studies on chop marks aimed to answer basic questions, such as, 'what does a chop mark look like in relation to a slice mark' (Walker and Long 1977)?, or 'how do chop marks relate to tooth puncture marks' (Shipman 1981).

Walker and Long (1977) were some of the first to discuss axe mark characteristics. They used the above-mentioned method to examine steel axe marks. Within their overarching study of butchery marks, they briefly discuss the characteristics of chop marks and how they differ from slice marks due to compression rather than dragging force. They do not, however, test more than one axe type and their main aim was to demonstrate that it is possible to differentiate chop marks from slice marks.

Brief mention of stone chop marks is made by Shipman (1981) in an overview of many different taphonomic agents. Stone chop marks are described as wide V-shapes with some internal crushing (Shipman 1981: 366). There is no mention or description of compete stone chop marks, nor is there any mention or image referring to the fragmentation of the chopped surfaces. While these very basic observations might help to differentiate chop marks from slice marks, they fail to discuss the characteristics of complete chops (chops that successfully sever the bone), nor do they acknowledge the vast variation possible within individual stone chop marks. Shipman's (1981) study on experimental taphonomy was broad, touching on many different forms of human inflicted taphonomic processes on bone, and thus was never meant to be an exhaustive resource for any single process. Her work with stone chop marks highlights the ability of stone axes to create visible chop marks in a butchered collection, therefore, reinforcing the need for comparative studies between stone and metal axe marks.

An experimental study by Olsen (1988) was the first to briefly discuss chop marks made by different axe types in her study of Bronze Age bone tool manufacture in England. Through experimental work and SEM analysis, she concludes that metal axes were used in bone tool manufacture. She describes metal chops as "quite deep and narrow, with smooth, or lightly striated walls (349)." Comparatively, she describes stone chop marks as having "a broad V shaped profile, sometimes with parallel striations running vertically down the cut (349)." These brief descriptions offer little usable information beyond her study as chop marks are only rarely found with a completely intact double-sided profile. In addition, she does not discuss the application of her method to complete chop marks (one sided marks). Description of the experimental process is also limited and leaves the reader unsure of the type of stone axe used (i.e. either chipped stone or ground stone) and no photos of the experimental stone chop marks are provided as a comparison to the metal marks. This study clearly shows that axe material types can be differentiated, yet detailed published information on method for this task is lacking for replication.

A similar definition of a deep, broad V-shape is also provided by Olsen and Shipman (1988: 544, 547) in their experimental study to differentiate butchery marks from trampling. The difference here is that they specify that the experimental chops were made with an obsidian chopper, meaning that this was a chipped stone tool. The chipped stone axe left marks that had many undulating perpendicular striations within the chop mark, and the photograph shows a wavy apex line. Also noted with the obsidian chopper was the presence of many chop marks in the same place that were required to chop through the bone and meat material as the chopper could not do this in a single blow. This observation will be further tested within the current experimental study.

iii. Axe efficiency experiments

Mathieu and Mayer (1997) conducted an archaeological experimental axe study focused on the defining the relative efficiency between stone and metal axes. However, this was an efficiency study aimed to at quantifying and distinguishing tree felling abilities between steel, bronze, and ground stone axes. It did not deal with butchery practices. They found the capabilities of steel and bronze to be similar and both fairly efficient for tree felling. The stone axe heads were significantly less efficient, requiring much more chopping time to fell a single tree. Although the stone axes were much less efficient than metal, they were still capable of completing the job, particularly for small trees. The chop marks left behind by each axe raw material type were unfortunately, not discussed.

Both ground stone and polished flint axes were tested. Mathieu and Meyer (1997: 343) found the edge polished flint axe was significantly thinner and sharper than the ground stone that was wider and duller. The polished flint axe was able to penetrate into the surface of the wood better and deeper than the ground stone axe, but was also susceptible to breakage. The study suggests that stone axe type (ground or chipped) may correlate to local flora types, as polished flint axes are capable of felling soft wood relatively well, and the more sturdy ground stone axes were better at felling hardwood. Clark (1965: 18) also noted that Melanesian tribesmen tended to use Thicker ground stone axes for high-impact chopping activities, and thinner, smaller ground stone axe heads for more delicate chopping and woodworking.

iv. Hammer stone butchery experiments

The experimental work of Pickering and Egeland (2006) examines the characterises of hammer stone butchery. Hammer stone butchery leaves signature criteria, such as percussion marks (pits and striations), notches, and impact flakes. The placement and quantity of these percussion marks can indicate both the intensity of marrow processing and the texture of hammer and anvil stones. Although these marks are evidence of human butchering activity, they caution that the creation of any type of butchery marks is influenced by a multitude of variables that are not always easily controllable in an experimental setting (i.e., shape of bone, surrounding meat, and periosteum). Butchery marks should be considered the unintended consequence of the behavioural activity, and thus, do not always represent the desired intention of the butcher. Pickering and Egeland (2006) focus on the effects of hammer and anvil force on long bone shafts where the main aim is to simply to break the bone apart into multiple fragments. This is not the aim of chop marks that instead, aim to sever the bone at specific spots appropriate for further processing. High fracture levels and splintering would be considered an unintended and unfavourable consequence of chopping.

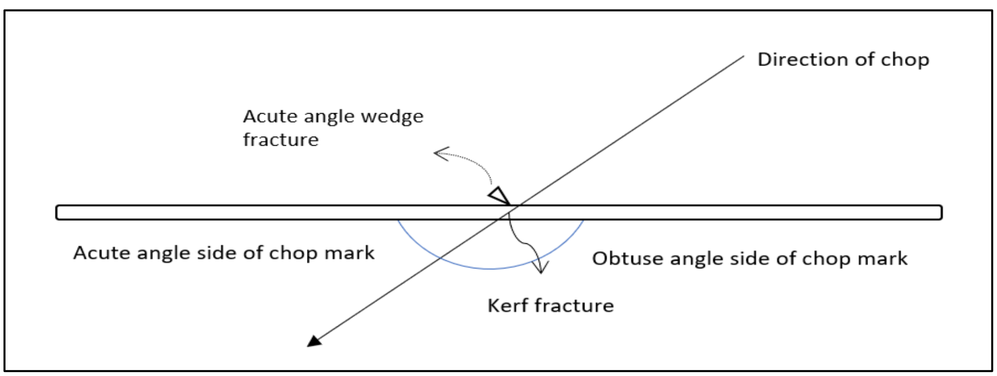
There is little experimental work in zooarchaeology that aims to describe the nature of stone chop marks and even less on metal chop marks. Chop marks are found in butchered assemblages prior to the advent of metal (Greenfield, Galili, and Horwitz 2006: 183), which means that stone axes were used (among other uses) in butchery. Whether stone axes continue to be used in butchery after the advent of metal axes remains unknown. How closely stone chop marks resemble hammer stone butchery is another aspect that is not discussed yet, and most analysts seem to lump them together. Hammerstones and axes are two different tool types with differing functions (marrow extraction vs. dismemberment) and need to be identified and distinguished in any analysis.

V. Metal chop marks in experimental forensics

It is forensics rather than zooarchaeology and taphonomic studies that has produced the only substantial experimental work to understand the nature of metal chops and the traces they leave on bone (Lynn and Fairgrieve 2009, Wenham 1989, Humphrey and Hutchinson 2001, Tucker et al. 2001, Gruchy and Rogers 2002). Axe force trauma to bone is the result of both shearing and compression forces. This means that the force can be either directed downwards (compression) which often results with high fracture rate and heavy splintering, or from an angle (shearing), associated with dismemberment that often results with a partially clean chopped surface in combination with a fractured or broken exit point (Lynn and Fairgrieve 2009: 786, Humphrey and Hutchinson 2001: 232). Chops are the result of dynamic forces, meaning that force is applied at a high speed using varied pressures, and is therefore, often associated with high fracture/splintering rates (Lynn and Fairgrieve 2009: 786). According to Wenham (1989), blade thickness, sharpness, and length are the three major characteristics of the chopping tool itself that are discernible from the marks left behind. These characteristics are particularly relevant for differentiating metal from stone axes as ground stone axes are likely always duller and thicker than their metal counterparts (although this is dependent on the culture, time Period, and region under study). Humphrey and Hutchinson (2001: 232) found that thinner hacking implements (such as machetes) were able to penetrate far into the surface of the bone before fracture occurred. This created cleaner chopped surfaces with less fragmentation from breakage when compared to thicker chopping implements such as axes or hatchets.

Experimental forensic studies, as in experimental butchery and taphonomic studies are driven by specific research questions, however much of the information uncovered in forensic research is applicable for the zooarchaeologist and butchery analysis. For example, Gruchy and Rogers (2002) aimed to understand the effects of cremation on cleaver chopped bone in a forensic setting. Although the cleaver is not an Early Bronze Age (EBA) tool, the morphological descriptions of cleaver chop marks are similar to those found within the current axe study. They describe cleaver marks as V-shaped, with a relatively clean entry point and minimal crushing with a rough or broken exit point (Gruchy and Rogers 2002: 2). Cremation or burning did not affect the morphology of the chop marks beyond the point of recognition. They noted that the exit point became accentuated by the burning process, and that all chops on ribs (due to size and density of the bone) were obliterated by the burning process (Gruchy and Rogers 2002: 3). They conclude that cleaver chops can be recognized on cremated fragments as small as a few millimetres if the analyst is trained to identify chops. This is extremely relevant to the zooarchaeologist as butchered animal bone is often found partially burned or calcined. The description of complete chop marks exhibiting exit fractures is interesting and suggests that axes (or cleavers) rarely sever the bone completely without breakage. This pattern of a clean entry point with an exit fracture was also found by Wenham's (1989) foundational study of axe force trauma.

Figure 6: Schematic of chop mark characterises (adapted from Wenham 1989).



Wenham (1989: 127, 131-132) used an experimental approach in an attempt to understand the traumatic wounds found on group of Anglo-Saxon skeletons from the Eccles cemetery in Kent. Through experimental work, Wenham found that only one side of a metal axe mark will produce a clean, smooth chop mark. When the axe enters the bone at an angle the obtuse angle side will be smooth, and the acute angled side will be jagged. The acute angle side will also often fracture at predictable locations and leave discernible fracture scars along the entry and exit points (see Figure

2). These fracture scars can be described as flakes or chunks of bone that are removed due to the wedge force action of the tool. Thus, even with only one side of a chop mark the acute angle can be differentiated from the obtuse. Terminal exit fractures (kerf fracture) are a key marker of axe force trauma caused by the axe acting as a wedge into the bone that causes the bone to fracture once the tool has penetrated to the point where the bone can no longer sustain the pressure. Therefore, a thin axe will penetrate significantly further than a thick axe before causing a terminal exit fracture. Axe chops can also be differentiated from sword chops by the length of the mark, as the mark can only be as long as the tool that made it unless the chop was created by a slicing motion. As axes are not typically used with a slicing motion, the mark cannot be longer than the tool itself. According to Wenham (1989), chopped bone will exhibit linearity, a well-defined edge, and smoothness. These features differentiate chopped surfaces from natural breakage within an archaeological assemblage. Wenham's study formed the basis for further experimental work by other forensic studies on chop marks (Humphrey and Hutchinson 2001, Lynn and Fairgrieve 2009).

Humphrey and Hutchinson (2001: 232) examined the macroscopic differences between cleaver, machete and axe trauma on bone. Their description of metal axe trauma is detailed. They found that axe entry points are the most variable of all tool types tested, but that most exhibit a "clean entry, chattering [defined as small fragments or chips], crushing, and fractures (Humphrey and Hutchinson 2001: 232)". They also note that the bone sometimes completely fractures upon the impact of the axe, and almost all exit points are fractures as the axe rarely cuts through the entire bone due to the width of tool and compression forces. This study is important because it recognises the extreme variability of chop marks and the difficulty in recognising. While the chop mark model as proposed by Wenham (1989) presents an uncomplicated picture and a rather idealistic model, however, Humphrey and Hutchinson (2001: 232) found that 30-40% of all chops resulted in complete fracturing of the material and that variability in chops marks is the norm rather than the exception.

VI. Limitations of the butchery literature for the study of chop marks

Butchery experiments in archaeology/zooarchaeology are common and used for many different purposes, including understanding butchering techniques (Lloveras, Moreno García, and Nadal 2009), tool technology (Greenfield 1999, 2002), and early hominin subsistence and tool use (Potts and Shipman 1981b). Although there is no shortage of butchery experiments, the literature is very limited in the application of these methods to the investigation of early metallurgy (Greenfield 1999, Olsen 1988). For the investigation on the use and adoption of early metal tools, butchery analysis is ideal as different butchery tools often leave specific and identifiable traces on bone. The early work of Olsen (1988) on the differentiation of stone and metal axe marks is incredibly brief and provides no specific details on the experimental method and is of little use to zooarchaeologists studying chop marks.

The effects of metal axes on bone are well established within the forensics literature, however the literature lacks comparable stone chop mark data. Brief mention is made of chipped stone choppers by Olsen and Shipman (1988), but there is no discussion of ground stone axe marks in most of the relevant zooarchaeological literature. The only possible proxy for ground stone chop mark data lies in experimental work with hammer stones, which mostly focuses on Palaeolithic issues. The problem with comparing hammer stones and chop marks data lies in the function of the tool, as hammer stones are not intended to cleanly sever bone. Lack of experimental stone chop identification criteria presents a major problem if one intends to use butchery marks to study the adoption process of metal tools in butchery contexts.

VII. The application of experimental methodologies to the current chop mark study

One of the main objectives of taphonomic studies is to distinguish between cultural and natural processes on bone. Shipman et al. (1981: 259) and Lyman (1987: 259) both identify the structure of the bone itself as the initial variable to consider when attempting to decipher whether a mark or breakage pattern is natural or cultural. As chopping often results in substantial breakage as well as cutting of the bone tissue (Humphrey and Hutchinson 2001), it is essential to distinguish natural breakage from axe breakage. Shipman et al. (1981: 259-260) discuss the potential to confuse natural breakage related to structural weakness of the bone with breakage caused by a cultural agent. They attempt to mitigate this with three steps: (1) compare bones with bones of a similar structure from similarly sized species, (2) "use a standardized classification of breakage types recognizable to other researchers (Shipman et al. 1981: 260)", and (3) whenever possible, look at the breakage pattern and not only specific examples of breakage. These three methodological elements are essential as bones come in many different shapes, sizes, and densities and will not always fracture in the same way. Moreover, breakage patterns should be grouped and discussed regardless of their causal agent as this may help to identify variables within separate causal agents that produce similar morphological results.

Breakage patterns can only be linked to a specific cultural agent by either experimental or ethnographic research (Binford 1981). An experimental approach has the advantage of controlled variables that can be tested and re-tested to solidify the relationship between aspects of morphological patterning left by a causal agent, and aspects of the causal agent itself.

Identifying the relevant features of analogs can be difficult (Gifford-Gonzalez 1991: 222). Actualistic butchery studies now have a long history of sound research methods that recognize the limitations imposed by analogs, inference, and, uniformitarian principles (Gifford-Gonzalez 1991, Seetah 2008, Binford 1981). Chop marks, while understudied and poorly defined in zooarchaeology, do have a history of research that aids in the identification of these relevant features. All experimental chop marks studies in zooarchaeology conclude that aspects of the mark will reflect specific aspects of the tool used to create the mark (Walker and Long 1977, Olsen and Shipman 1988, Shipman 1981, Olsen 1988). Yet these studies are often vague in bridging the experimental mark morphology with the tool itself (Olsen 1988).

Experimental chopping studies in forensics clearly identify and articulate the "determining structure[s] (Gifford-Gonzalez 1991: 223)" of the chopping tool that relate to chop mark morphology. These are both the width and sharpness of the axe, and this is confirmed by repeated experimental testing (Lynn and Fairgrieve 2009, Humphrey and Hutchinson 2001, Wenham 1989). Thus, relevant features of the experimental analog should be linked to these two aspects of axe morphology.

VIII. Conclusions

Hammer stone bashes, stone and metal slices, and chipped and ground stone and metal chop marks are all identifiable on archaeological bone material. However, the recognition and differentiation between marks types can be difficult and requires a keen eye skilled in understanding the effects of multiple tool types on bone structures. Slice marks are the most thoroughly investigated taphonomic mark type. Methods of analysis and criteria for the differentiation between metal and stone slice marks are well established and have proven extremely useful in understanding adoption rates of metal blades in butchery (Greenfield 2002, 2013, 1999).

Numerous forensic studies have shown that chop marks created with metal axes can produce a range of marks, from completely fractured, to very smooth/sheared (Humphrey and Hutchinson 2001, Lynn and Fairgrieve 2009, Wenham 1989). However, it remains unknown if chipped and ground stone axes produce this same pattern as there are no published studies on the macroscopic variation of complete stone chop marks. Axe marks, especially in the zooarchaeological community are understudied and their occurrence in butchered assemblages are likely underrepresented in consequence. As a highly variable mark, the identification of axe marks can be more challenging than slice marks or saw marks, yet they offer a potential wealth of information especially when used as a proxy for the adoption of metals as they have never before been studied in this way. As explored in this chapter, chops and the mechanics behind chopping are rarely explored in the zooarchaeological literature. After almost forty years, Binford's (1981: 147) lament remains true today:

"It is clear that chopping is documented to have been used in butchering animals, but there is no methodology for recognizing the consequences of this tactic, in either forms of breakage or bone destruction, that is not ambiguous and subject to alternate interpretation. This is an area in need of strong methodological development."

The following chapter outlines the experimental protocol and process for testing five replica Early Bronze Age axes as to understand their effects on animal bones. The axes are tested on multiple bone elements from a variety of species to better understand and identify dismemberment by chopping in the archaeological record. As metal axes are a common metal tool type from the Chalcolithic on in the Near East (Massa 2014, Gerritsen et al. 2010: 207-208, Fidan, Sari, and Türkteki 2015: 64), identifying an analytical method for the differentiation between metal and stone chop marks is vital for identifying butchery tools used in the EBA Near East. It will aid not only in understand adoption rates of metal axes in butchery, but also inform on very early metal availably within regions, communities, and even between social classes.

The experimental protocol for the chop mark study is presented in the following chapter. The experiments test both metal and stone axes to first either confirm or deny that EBA metal axes produce similar types of marks as reported by Humphrey and Hutchinson (2001) and Wenham (1989). The second goal of the experimental research is to see whether or not this pattern also correlates to stone chop marks and if either of these axe heads can be differentiated by their marks alone. In short, the study aims not only to identify marks by material type, but create a knowledge base for the general description of chop marks on archaeological faunal assemblages.

Chapter 5: Chopping experiments: protocol for experimentation and experimental axes

I. *Introduction and purpose for experimentation*

Within butchered assemblages, there are multiple types of marks that represent the use of different tool types. Chops made by wedge-shaped sharp impact tools are most often seen in either the dismemberment of bones or the disarticulation of bone joints. Dismemberment is defined as is the separation of the major carcass parts, often at joints, to create smaller pieces that can then be further processed. The use of heavy chopping tools is not necessarily required in butchery as evidence from North American indigenous groups shows that full carcasses can be processed using only small tools alone (Binford 1981: 142).

Multiple cultural styles of butchery exist cross-culturally as well as in the same region over time (Binford 1981: 142). For example, Near Eastern assemblages from the Neolithic to the present show changes over time in butchery style that reflect changing technology (e.g. Greenfield 2013, 2018). However, there is little published evidence for intensive chopping in Holocene studies since zooarchaeologists have either not systematically collected or not published data related to such activities. Nevertheless, as will be shown in this thesis, chops often represent a substantial part of the butchered assemblage and offer a wealth potential information on tool use and technology.

The main aim of this study is to understand the morphological differences in chop marks made by stone and metal axes through experimentation. In conjunction with this, it is also imperative to clarify and discuss general chop mark attributes to better understand how to recognize these marks within an archaeological assemblage. These aims can only be achieved through rigorous and controlled experimental testing of multiple chopping tools on different types of bone.

This chapter outlines the research design and protocol for the experimental chop mark study. Details are provided for construction materials and techniques used for the experimental axes, the rationale behind bone choice, post-chopping bone preparation, and potential biases created by the experiments themselves.

II. *The experimental research design*

The experiment is designed to answer three related research questions pertaining to chop marks found in archaeological assemblages: (1) what are the macroscopic morphological characterises of ground and chipped stone chop marks?, (2) what are the macroscopic morphological characteristics of metal (copper and bronze) chop marks?, and (3) what, if any, are the morphological characteristics that differentiate these two types materials from the butchery marks alone?

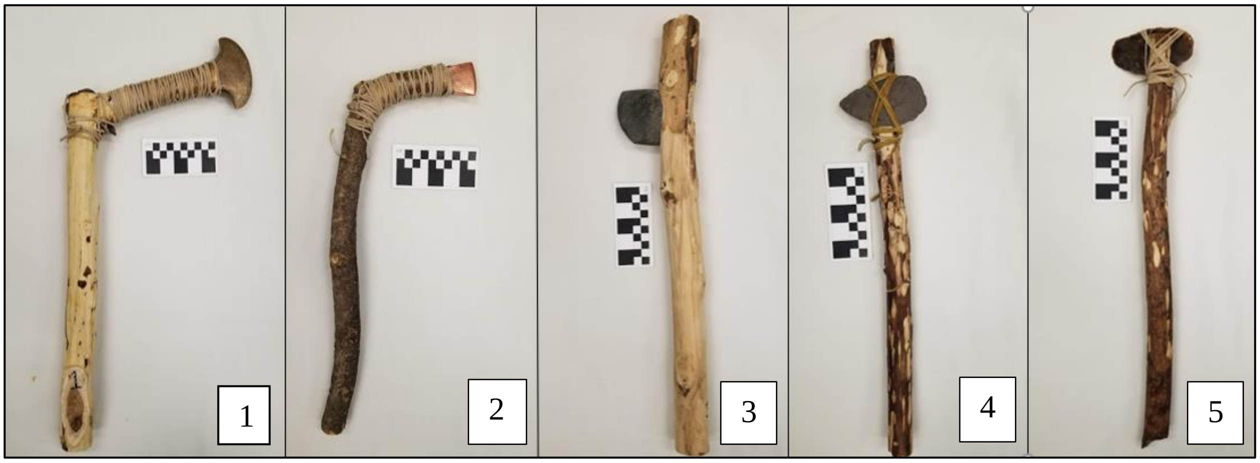
The axes were tested on wood and multiple types of bone to account for variation in bone densities and shape. Each axe was tested on a straight flat piece of whole wood (pine) (see Image Appendix Figure 48). Each axe was tested five to seven times on various different types of bone elements (e.g. ribs, long bones, and crania) with multiple chops from each axe on each type of bone. Each chop occurred in a separate location to ensure that the morphological diagnostics were not obscured by later chops occurring over the first chop. All bone elements were chopped with at least 5 mm of meat covering the bone and periosteum to better simulate real-life dismemberment activities. Chops were directed into the bone by all axes at both a 90˚ angle and at a 45˚ angle to test for differentiation between these angles, as Wenham (1989) specifically discusses chop marks made a 45˚ angle, and Humphrey and Hutchinson (2001) state that they saw significantly more fragmentation when the bone was struck at a 90˚ angle. Lynn and Fairgrieve (2009: 786) agree with Wenham (1989) that dismemberment with an axe will almost always occur at a 45˚ angle because a chop directed into the bone at even a slight angle will cause significantly less overall fragmentation.

The major variables controlled for in the experiment are the shape and raw material of the axes, the chopped material, the angle of the chop, the processing of the chopped material, and the butcher. All chops were made by the author. A single butcher (myself) was used in order to attempt to have some consistency and control in both skill and force. Although force is technically an uncontrolled variable in this study, the force inflicted by all individual chops is limited to the ability of a single butcher. Use of mechanical means to control force within this study is deemed unnecessary and would be counterintuitive as varied force is a realistic fact of past butchery activities.

III. The experimental axes

Five different axe types of different raw materials were made and tested for this study (bronze, copper, chipped stone, and ground stone, see Figure 3). The five axe types are necessary since they represent the variation in raw materials of chopping tools found in the archaeological record during the Late Chalcolithic and Early Bronze Age in Anatolia (Massa 2014). Although chipped stone axes are rare in Late Chalcolithic and EBA Anatolia, they are common in the southern Levant. For this study to be relevant within the larger Near East chipped stone axes heads were included.

Figure 7: Photograph of the experimental axes made with different raw materials (from left to right): 1. bronze, 2. copper, 3. ground stone, chipped stone, 4. chert, and 5. Knife River Flint © Tiffany Okaluk. For additional photographs of experimental axes see appendix.



i. *Bronze*

Axe 1 consists of a bronze axe head (10% tin) hafted with pine resin, bound with synthetic sinew and leather cord to a fruit wood handle (Figure 1.1). The bronze axe head was borrowed for use in this study from Prof. Haskel Greenfield. The axe head was purchased as a full-scale reproduction of a bronze axe found at the prehistoric site of Flag Fen, UK. The handle was created for this study by selecting an L-shaped branch with a knot at the bend. The bark was stripped and the wood was left to cure for two weeks. A notch was created for the haft with the aid of a table saw, and the butt of the axe was then fit into the notch and secured with wet sinew and leather cord. The greatest width of the body of the axe is 12 mm with a 15˚ angle pitch leading to the cutting bit.

Including tin bronze in these experiments is important due to the archaeological context of the faunal assemblage in this study. Göltepe was an EBA highland tin metal production site located close to one of the only identified Early Bronze Age tin mines in the Near East.

ii. *Copper*

Axe 2 consists of a pure copper axe head, smelted and cold hammered to a Brinell hardness of 100-135, supposedly making it comparable to mild steel (Figure 3.2). The Brinell scale for hardness is commonly used in engineering to indicate penetration capabilities of different metals.

There is evidence for the cold hammering of native copper as early as the Neolithic at Çayönü (Yener 2000). Pure copper without cold hardening is too soft to be used for any kind of chopping. The handle is pine and the copper axe head is hafted into the handle with pine resin and secured using synthetic sinew and leather cord. The axe head was designed after the famous Chalcolithic "Ötzi" axe (3500-3000 bce) (Artioli et al. 2017: 7) created by Eric Swart from Waterbury Connecticut, USA who specializes in prehistoric copper reproductions. The greatest width of the body of the axe is 12 mm with a 20˚ angle pitch leading to the cutting bit.

iii. Ground stone

Axe 3 is a ground stone axe (Figure 3.3). The ground stone axe consists of a large fine-grained basalt river pebble, ground and fitted into a carved hollow of a thick cedar handle. The basalt cobble was initially pecked and ground by hand, but due to time constraints, the axe head was finished on an electric stone grinder. The cutting edge (bit) of the axe is fairly broad in comparison to the metal axes, with a steep pitch leading down to the cutting bit. The width of the axe retained the original width of the pebble at 32 mm with a 50˚ pitch leading down to the cutting bit. This tool is significantly wider than the others with a steeper pitch leading down to the cutting bit. The width of the axe head is important for the tool to maintain the structural integrity while inflicting high-impact chops. The axe head was hafted into the handle using a modern epoxy to ensure stability. The axe head and haft was designed based on the shapes of multiple examples of Chalcolithic ground stone axes housed in the Sanliurfa Archaeology and Mosaic Museum in south eastern Turkey.

Figure 8: Chalcolithic ground stone axe heads housed in the Sanliurfa Archaeology and Mosaic Museum, Turkey ©Tiffany Okaluk.

iv. Chipped stone

Both Axe 4 and 5 are chipped stone axes (Figure 3.4 and 3.5). Neither axe head was ground down to smooth the cutting bit. Two chipped stone axes were created and tested due to the potential variation between chipped stone axe heads. Axe head 4 is a thicker and cruder biface created from a fine grained chert. This axe head was hafted with a side notch into a pine handle using leather cord and artificial sinew. The greatest width of the body of axe head 4 is 16 mm with an approximate 25˚ angle pitch leading to the cutting bit. Axe 5 is made from Knife River flint. This thinner, very sharp-edged biface was hafted into a two sided notch at the top of the handle secured tightly with a leather cord. The greatest width of the body of axe head 5 is 11 mm with an approximate 15˚ angle pitch leading to the cutting bit. No glue or resin was used to secure the head to the haft for either axe. The hafting styles of chipped stone axes were significantly less secure than for the other axes. Epoxy and/or pine resin were not used to secure the axe heads in place for these axe heads because both bifaces, created by local Manitoban flint knapper Mr. Gord Hill, are to be returned after the completion of the project.

IV. The experimental procedure for each bone sample

Multiple different osteological elements and species were used to test the effects of chopping with all of the experimental axes. A total of seven separate series of chopping tests were carried out on wood, *Ovis aries* (sheep) crania, *Bos taurus* (cow) and *Sus scrofa* (pig) ribs, *Sus scrofa* vertebra, and *Odocoileus virginianus* (deer) and *Sus scrofa* long bones.

i. Wood

The axes were first tested on wood. One-inch thick flat pine wood boards were chosen for their relatively soft and consistent structure (as per Greenfield 1999). The axes were first tested on a pine board as this wood is flat and has a consistent texture throughout, whereas bone density varies depending on element, age, and species. Each axe was tested three times on wood. The tests were: (1) a single strike, (2) two strikes in the same location, and (3) multiple strikes in the same location with the aim of severing the board. None of the axes successfully severed the board. The marks on each board were labeled and photographed and examined both macro and microscopically. See Figure 47 in image appendix.

ii. Ovis aries crania

Each axe was tested on a separate sheep cranium (Figure 9). Two of the crania were skinned but not de-fleshed, while the other two crania had both their skin and flesh intact. The cranium was positioned on the ground (grass) in front of the experimenter. The chops were aimed to cross from left to right sides of the cranium, through the posterior of the frontal bone and posterior to the orbits in an effort to isolate the anterior and posterior portions of the cranium. This location on the cranium is meant to simulate the chop patterns seen on sheep and goat crania from Pit 34 at Göltepe (for further description of Göltepe see Chapter 3). As it became clear that this was difficult to achieve, an attempt was made to completely remove the posterior of the cranium behind the base of the horn cores along the coronal plane.

The Ovis aries crania used in this test were relatively young because these were the most easily available through local butchers. The crania range in age from juveniles to young subadults. The age of the animals and the significance to the study were only determined after the crania were de-fleshed, cleaned and processed. Age estimates are based on tooth eruption and wear, along with osteological fusion. As the crania were relatively soft and suture fusion, particularly of the occipital and parietal bones of some specimens, was not complete, the bone segments came apart during post-chop processing. To some extent, this hindered a complete analysis of some chop marks since they were on two different sides of the cranium – left and right frontal elements. Nevertheless, it demonstrated that the age of the animal may have an effect on the identification of different chopping raw materials. In general, it was observed that younger animals with softer cranial bones exhibited more crushing than older animals with harder bones. This problem extended also to long bones, ribs and vertebra, but to a lesser extent.

Figure 9: Photograph of skinned and defleshed (processed) *Ovis aries* skulls ©Tiffany Okaluk.

iii. Bos taurus ribs

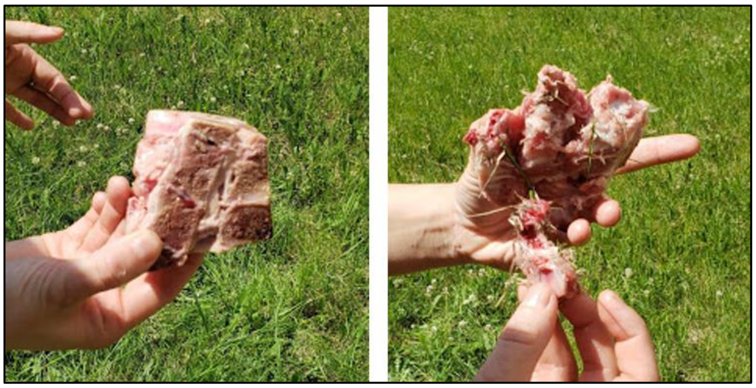
The axes were then tested on cattle (*Bos taurus*) ribs (Figure 10). Cattle ribs were chosen for their dense and relatively consistent structure, particularly in the middle of the shaft. The mid-shaft rib segments were chopped multiple times while they still had c. 5 mm of meat on the bone. Each axe was tested on a separate rib segment. None of the axes penetrated the bone when struck at a 90˚ angle that was perpendicular to the long axis of the bone. The axes were then tested parallel to the long axis of the bone at a 90˚ and 45˚ angle with a minimum of three impact incidences. All axes were able to penetrate the bone's surface with the exception of the chipped stone axes. Chipped stone Axe 5 was not tested as the axe head suffered significant damage in the first test. The bones were then boiled, de-fleshed, re-boiled, left to dry, and labelled.

Figure 10: Photograph of bronze axe in *Bos taurus* rib bone ©Tiffany Okaluk.

iv. Sus scrofa vertebrae

The axes were further tested on pig (*Sus scrofa*) cervical vertebrae (Figure 11). The meat was not removed from the bones prior to being chopped. This created a problem for ensuring that the chops hit directly into the bone and created significant fragmentation making the edges and profiles of the chops difficult to identify. The young age of the animal in this test also created problems as outlined above. The imprecise aims of the chops caused fractures along unfused/fusing epiphyseal lines that further limited the visibility of the chop marks. Only the ground stone and copper axes produced chops clear enough to be analysed. Once chopped, these bones were also boiled, de-fleshed and left to dry, and labelled.

Figure 11: Before and after photographs of the ground stone chops on *Sus scrofa* vertebrae ©Tiffany Okaluk.



v. Odocoileus virginianus long bones

All axes were tested for a fifth time on long bones of a juvenile white-tail deer (*Odocoileus virginianus*) (Figure 12). The deer was found freshly dead and was not killed for this study. The metal axes were sharpened for the first time before beginning this test. The bronze axe was used to dismember the lower limbs from the torso.

Figure 12: Photograph of dismembered *Odocoileus virginianus* limbs ©Tiffany Okaluk.

The skin and flesh were left intact and each axe was tested on a different limb of the animal. Once the bone was successfully chopped (severed) perpendicular to the long axis, no more chops were inflicted. Each sample was then skinned, de-fleshed, boiled, de-fleshed again, and left to dry.

vi. Sus scrofa ribs

The sixth test for the axes was carried out on pig (*Sus scrofa*) rib bones (Figure 13). This test was conducted to confirm the patterns seen in the metal and ground stone axe from previous tests. The chipped stone axes were not tested as both axes had suffered significant damage by this point (Figure 32), but had also produced a strikingly unique pattern dissimilar to all other axe types (described in Chapter 6). Ribs were chosen for their consistency in texture and shape as well as the ease of aiming the axe at the bone within the meat. Chops were inflicted perpendicular to the long axis at various angles with the meat and periosteum intact. Both of the metal axes and the ground stone axe were tested on the ribs and produced multiple complete and incomplete chops. The meat and bones were then roasted, de-fleshed, boiled, de-fleshed again, left to dry, and labelled. This group of chop marks produced the most consistent marks for each axe type.

Figure 13: Photograph of chopped *Sus scrofa* rib bones made by the copper, bronze and ground stone axes (grouped from left to right) ©Tiffany Okaluk.

vii. Sus scrofa long bones

The metal axes were tested a final time on a pig (*Sus scrofa dom.*) ulna/radius (Figure 14). This element, unlike ribs, was chosen for its dense and differential structure along its length as a contrast to the thinner and more porous bone structures used in the rib tests. The metal axes were not sharpened before the first test on dense bone, but were subsequently sharpened for the second test on these bones. The ground and chipped stone were not tested on these bones, as their chop mark patterns were very clear from the previous tests. Only the copper are was re-sharped before the beginning of this test. The copper axe was tested on the distal half and the bronze axe was tested on the proximal half. The meat was not removed prior to chopping. Multiple chops at various angles, both perpendicular and parallel to the long axis, were inflicted on the bone. The copper axe had little effect on the bone surface, but the bronze axe created a single complete chop and multiple incomplete chops. Once the test was finished the bones were boiled, de-fleshed, left to dry, and labelled.

Figure 14: Photograph of *Sus scrofa* radius chopped in half through the midshaft © Tiffany Okaluk.

V. *Conclusion*

The five different axes constructed from multiple materials represent the wide variety of possible EBA chopping implements. The experiments tested all the chopping implements on a combination of bone elements with various densities in a controlled effort to understand the variation of marks produced by each axe type. All experimental bone material was cleaned separately according to axe type, and no mixing of samples occurred during processing. All axes required more testing than originally planned for, but this resulted in a robust experimental sample of marks on several types of bones. The tests on the *Sus scrofa* ribs and long bones were conducted to further examine and confirm the patterns observed in the previous tests. The following chapter presents the results of the chopping experiments. These data are presented by chop mark type and then by axe type, with a general discussion of the high variability of these marks and methods for the differentiation between marks made by metal and stone axes.

Chapter 6: Results and discussion of experimental data

I. *Introduction and general description of the experimental data*

This chapter presents the results of the experimental chop marks. A total of 113 chop marks were created by the five different axe types including, bronze, copper, ground stone, and two types of chipped stone. This experimental study aims to understand the macroscopic differences between chop marks made by different types of metal and stone axes available in the Early Bronze Age. The macroscopic, rather than the microscopic scale, is used for three very simple reasons: 1) chop marks are often large marks with extreme differences in slope along the edge of the mark that make it difficult to examine them under high magnifications.[11] 2) High magnification restricts the line of vision to only very specific aspects of the chop mark and makes it impossible to see the entirety of the chopped surface and slope of the mark. 3) A very clear pattern is observed with simple macroscopic observation.

The chop marks are first described and grouped according to shared characteristics as to better understand the wide variation in mark type and therefore determine if axe type coincides with fragmentation patterns. Each side of a complete chop mark is analysed as a separate mark, as both sides of a chop mark are almost never found together in archaeological contexts. A summary and discussion is also provided for each axe type describing the general characteristics and fragmentation pattern of the chop marks. All axes produced multiple types of marks that span several fragmentation patterns. However, a general pattern is observed in fragmentation patterns between the metal and stone axes.

II. *Variables and biases*

All bone material was chopped with the meat and periosteum intact to better simulate dismemberment. Only the juvenile deer was chopped with skin and fur intact as this was the only specimen where these not removed by a butcher. Two of the sheep skulls were also chopped with the skin intact as this was how they came from the butcher. Skin and fur (where available) was left

[11] An attempt was made to examine the experimental chop marks under an Olympus LEXT OLS4000 microscope. This is a confocal laser measuring microscope that integrates sliced images for precision measurements. Unfortunately the large size of the marks combined with the extreme slope did not allow the microscope to focus. The depth of field needed to see the entirety of the mark was outside the capabilities of this high power microscope. Similar results would plague the use of a SEM, as well.

in place to see whether it might affect the morphological results of the chop marks. Due to limited availability of older individuals, all chopped material came from younger animals. Although this caused some problems in chop mark visibility, as the bone was often crushed, the combined use of thinner/lighter elements as well as dense elements helped to counteract any potential bias in preservation of morphological diagnostics.

The number of times the axes were tested was not pre-determined since it quickly became apparent that multiple tests were needed to clearly differentiate fragmentation patterns between axes. Each of the axes were tested until a clear pattern emerged and variation in resulting chop marks was understood. For the metal axes, this required more testing as metal axes can produce both highly fragmented and very clean chop marks.

The meat left covering the exterior of the bone prevented some chops from producing clear diagnostic marks on the bones since they could not penetrate the flesh all the way to the bone. This resulted in less overall experimental chop marks by the duller axes (especially the chipped stone). Diagnostics were also not preserved in marks that were inflicted on soft bone as the chop mark became very fragmentary and fell apart during maceration to the point where the morphology of the chop mark could not be recorded after processing. This is particularly true when the highly fragmented, juvenile samples were boiled, leading to further fragmentation at fusion points. This made these samples more difficult to work with and identify raw material type. Ideally, older individuals would have made processing the samples much easier. However, this study was limited by the meat and bone available in butcher shops (with the exception of the juvenile deer).

III. Chop mark terminology

As with any highly specialised discussion, terminology is important. Below is a list of terms used within the discussion of the results of the experimental study. The definitions are compiled from the zooarchaeological and forensics literature on chop marks in conjunction with observations from this experimental study.

- Chop: a butchery mark created by high-speed compression forces inflicted from a sharpened wedge shaped tool with the intention of severing a bone (Olsen 1988: 344, Lynn and Fairgrieve 2009).
- Complete chop: a chop that severs the bone into two pieces (Lupo, Fancher, and Schmitt 2013: 431).

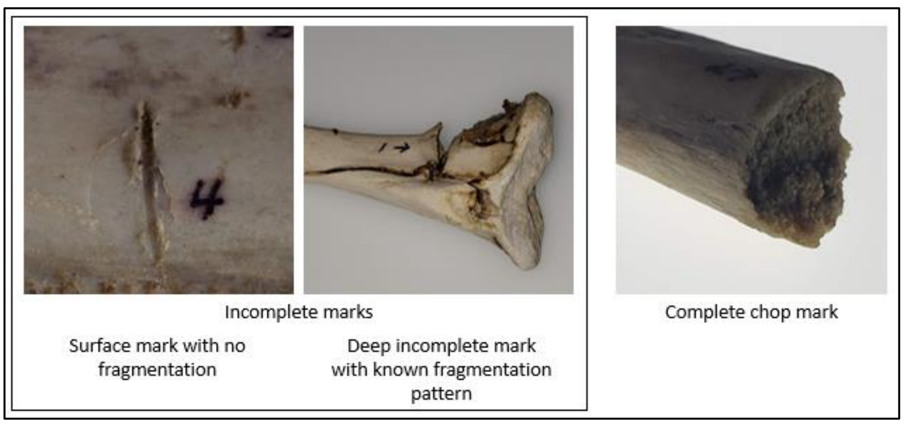
- Incomplete chop: a chop that does not sever the bone, but leaves a mark (deep or shallow) in the surface of the bone, often with an acute angle wedge fracture. This includes deep V- or irregular U-shaped groves (Olsen 1988: 349, Lupo, Fancher, and Schmitt 2013: 431).
- Axis/kerf line: the final penetration point of the axe into the bone surface. Often only visible in incomplete chops.
- Fracture: breakage of the bone with no visible chop mark characteristics (Humphrey and Hutchinson 2001).
- Obtuse angle of chop: inferior side of chop when chopped at 45˚ (see Figure 28) (Wenham 1989: 130).
- Acute angle of chop: superior side of chop when chopped at 45˚ (see Figure 28) (Wenham 1989: 130).
- Bit: The sharpened cutting edge of a wedge shaped impact tool (axe).
- Sheared surface: a very clean, smooth, cut surface that extends into the bone for at least 3 mm (Humphrey and Hutchinson 2001: 232).
- Crushing: fractured bone surface pushed into the chop mark due to the force of impact (Humphrey and Hutchinson 2001: 232).
- Acute angle wedge fracture: a small segment of bone on acute side of chop that fractures and is pushed out of chop mark (see Figure 28) (Wenham 1989).
- Impact marks: small pits and striations along the place of impact (Pickering and Egeland 2006: 462).

IV. Complete chops vs. incomplete chop marks

Within the study of chop marks, it is very import to differentiate between a complete chop mark and an incomplete chop mark as these are two overarching and distinct types of chop marks that are not always comparable. A complete chop mark successfully severs the bone, whereas an incomplete chop mark does not. The benefit of an incomplete chop is that both sides of the mark are preserved and available for analysis. An incomplete chop is not always a deep mark. It can also be just a slight indentation or imprint of the tool’s edge on the bone’s surface. Incomplete marks somewhat resemble slice marks, although they are often deeper and do not have the indicative slicing drag on one side of the mark.

In this study, these shallow marks are referred to as surface marks and are not included within the larger sample of complete marks. Surface marks are discussed separately as their comparable characteristics are distinct and separate from compete chop marks. Deeper surface marks that penetrate more than a few millimetres into the surface of the bone, but do not sever the bone, leave either a deep V or U shape. Deep incomplete marks often share enough characteristics with complete chops to be included within the complete chopped sample. For deep incomplete marks to be classed within the complete chop marks they must exhibit a discernible entry point, and deep enough radial cracking to understand how the bone would have broken apart or fractured if more force was applied. Images for surface marks, deep incomplete marks, and compete marks are seen in Figure 15.

Figure 15: Photographs of incomplete (left) and complete (right) chop marks made on a *Bos taurus* rib (left), *Odocoileus virginianus* tibia (centre), and *Sus scrofa* rib (right) © Tiffany Okaluk.



V. *The 5-point fragmentation scale for complete chops*

The experimental chop marks are incredibly variable. As such, the experimental chop marks are grouped and discussed according to specific characteristics regardless of axe material type. The most common characteristic of all the experimental chops is fragmentation/breakage. This ranges from nil, to severe in all chop marks. The purpose of a chop is to separate the bone into two separate pieces through the use of high-speed directed force. The high speed and high force directed into the bone is meant to cause controlled breakage at a specific location. An ideal chop mark, from a functional perspective, creates two separate pieces with no/low fragmentation on either side of the chop.

Understanding fracture patterns is vital as fragmentation can take distinct forms on a scale of 1-5. The degree of control over how a bone breaks apart is observed on the experimental sample and measured on a scale from 1-5. Thus, high levels of fragmentation and crushing register lower on the scale (1-2) and low levels of fragmentation and crushing register higher on the scale (4-5). Some marks exhibit extremely low fragmentation, particularly on one side of the mark. These smooth, cut surfaces are referred to as sheared surfaces.

A scale is a metric of intensity. The fragmentation scale is necessary in this study as it facilitates comparison within a highly variable group of marks by assigning them to defined groups based on shared attributes. The groups are based on the intensity of fragmentation seen in the experimental sample. A total of 88 experimental chop marks are grouped according to this scale.

i. *Classification criteria for fragmentation Class 1*

For a chop mark to be defined as 1 on the fragmentation scale, crushing and impact marks are often the only indicators of impact (Figure 16). Without the crushing at the edges, this chop mark is indeterminable from natural breakage as the bone may have completely fractured into multiple pieces upon impact. In consequence, it is easy to misidentify this chop fragmentation pattern as natural breakage. This type of chop mark only penetrates the very surface of the bone and causes it to fracture into two or more pieces. Crushing and sometimes impact marks are the only identifiable criteria left behind by this chop mark, making this the most challenging mark to identify. An example of a Class 1 chop mark is seen in Figure 16.

Figure 16: Photograph of a Class 1 experimental chop mark on a *Sus scrofa* rib ©Tiffany Okaluk.

Twenty percent of the complete chops are Class 1. Of the axes, the ground stone axe produced the majority of the Class 1 marks (67%), chipped stone produced 11% of the marks, and copper produced 22%. It is likely that more chops should be attributed to this category, however if the bone completely fractured upon impact and left no discernible traces, the chop could not be properly recorded. Chopping the bone with meat and periosteum still on the bones adds to the difficulty in identifying this mark, as it is impossible to know if a strike caused complete fragmentation until the bones were de-fleshed and processed.

ii. *Classification criteria for fragmentation Class 2*

The second class of fragmentation is a somewhat defined chop mark (Figure 17). This chop mark is less likely to be confused with natural breakage than a Class 1. This mark penetrates slightly further into the bone surface before fracture occurs. The edges of a Class 2 chop are always jagged and fragmented as the axe does not penetrate very far into the bone before breakage occurs. This type of chop can exhibit significant crushing, breakage, as well as impact marks and/or percussion notches. The breakage of a Class 2 chop is more controlled than a Class 1 as the chop is more visible as an intentionally made mark. An example of a Class 2 chop mark is seen in Figure 17.

Figure 17: Photograph of Class 2 experimental chop mark made on the proximal end of a *Sus scrofa* rib ©Tiffany Okaluk.

Of the experimental chops, 19% are classed as a Class 2, and all axes created at least a few marks that are classed as a 2. The ground stone axes once again produced the majority of these marks at 47%, but copper also produced a significant 35% of the marks. The bronze axe created 12% of the marks, while the chipped stone axe only created 6% of the Class 2 marks. An interesting pattern emerged with the metal axes in regard to this category. In rare cases when both sides of the chop mark were preserved and it was possible to fit them back together, the acute side of the mark was often identified as a Class 2 mark, while the obtuse side was anywhere between a 2 and a 5.

iii. Classification criteria for fragmentation Class 3

A Class 3 on the fragmentation scale is a well-defined chop mark that clearly represents intentional severing (Figure 18). This chop mark can have moderate to mild crushing with more limited fragmentation and breakage than a Class 2. The edge of this type of chop mark is not smooth, yet it is not nearly as jagged and fragmented as a Class 2. With this type of chop mark, the axe penetrates into the bone further than the previous category and often has a kerf fracture[12] (Figure 18), but does not have a sheared surface. The difference between this chop mark and a Class 4 mark is that the chopped surface itself is variable and slightly fragmented from breakage. This is the dreaded 'murky middle' where a bone has clearly been severed, but does not exhibit significant characteristics on either side of the scale.

Figure 18: Photograph of a Class 3 experimental chop mark on the midshaft of a *Sus scrofa* rib ©Tiffany Okaluk.

Class 3 is the most common type of mark created by the experimental axes, and 33% of all experimental chops could be placed in this class. The chipped stone axe only produced one mark comparable to a Class 3. The majority of these marks were created by the copper (45.5%) axe, and similar proportions were created by the bronze (27%) and ground stone axes (27%). A similar pattern is observed with the metal axes in this category as in the previous category. The two best examples of Class 5 shearing on the obtuse side, are mirrored on the acute side with a Class 3. Whereas the cleanest Class 3 marks made by the ground stone axe are mirrored on the acute side with heavy fragmentation (Class 1).

iv. Classification criteria for fragmentation Class 4

A Class 4 chop mark on the fragmentation scale is the first to exhibit shearing. Shearing is the absence of fragmentation, meaning that the axe entered into the bone by cutting it and did not cause the chopped surface of the bone to break apart or flake off (with the exception of a kerf fracture). A Class 4 mark can have light crushing, will almost always have a kerf fracture exit point, and will have at least some mild shearing (3-10 mm sheared surface). A sheared surface is clean and smooth with no undulation or parallel striations on the planar surface of the chop mark.

[12] A kerf fracture is simply an exit fracture. However, for a kerf fracture to occur, the axe must penetrate the bone far enough to create a wedge force action to split the bone instead of simply fracturing it at the surface.

It is extremely identifiable (Figure 19). A Class 4 has a smaller sheared surface area than a Class 5 because the axe does not penetrate/cut as far into the bone before kerf fracture occurs.

All experimental chops classed as a 4 were made by metal axes and represent 17% of the total complete chop marks. The copper axe produced 60% of the Class 4 marks and the bronze axe created the other 40%.

Figure 19: Photograph of Class 4 experimental chop mark made on the mid shaft of a *Sus scrofa* rib ©Tiffany Okaluk

v. Classification criteria for fragmentation Class 5

A Class 5 chop mark on the fragmentation scale exhibits little or no crushing with moderate to extensive shearing (Figure 20). These are highly recognisable marks that have a clean entry point, smooth chopped surface with no pitting, and an exit fracture. The fracture pattern of a Class 5 chop mark is extremely controlled, and fragmentation limited to only the kerf fracture at the base of the chop mark.

Figure 20: Photograph of a Class 5 experimental chop mark on an *Odocoileus virginianus* distal humerus ©Tiffany Okaluk.

Only 11% of the experimental chops are classed as a Class 5 mark. Of these, only 2 marks were made by the copper axe and the remainder were created by the bronze axe. This is clearly the rarest type of mark. Even when chops only made by the bronze axe are considered, only 30% are classed as a 5. Shearing was found to only occur on one side of a chop mark. Therefore, even if one side of the mark is perfectly smooth (exhibits no fragmentation), the other side of the mark cannot be classed any higher than a Class 3 mark. Shearing was also found to only occur on the obtuse side of the chop mark, whereas the acute side was always the fragmented side (Figure 28).

VI. *Chop mark variation by axe*

All axes created incomplete surface marks as well as marks measurable in terms of the fragmentation pattern. Although all axes were tested multiple times, some axes produced considerably fewer complete marks than others, making them significantly less 'efficient' chopping tools. This section outlines the general characterises of the chop marks made by each axe type.

i. *The chipped stone axes*

The chipped stone axe produced the most unique marks in comparison to the other axes. The undulating and non-uniform cutting edge produced a 'wavy' chopped surface with uneven macroscopic striations running parallel to the direction of the axe impact. This 'wavy' pattern is also noted by Olsen and Shipman (1988: 547) in their experiments with obsidian choppers. Due to the uneven surface of the tool, it was not able to create a sheared chopped surface on bone. Only rarely did this tool penetrate the surface of the bone further than a few millimetres. The chipped stone axes created only 4 complete chops that were clear enough to be analysed after processing, and all of the marks ranged between Classes 1 and 3 on the fragmentation scale. See Table 2 for percentage of chipped stone marks by fragmentation class.

The majority of chipped stone marks are incomplete marks as they only penetrated the surface and did not result in any fragmentation. The incomplete marks are also morphologically unique compared to any other axe type. These marks are punctuated, with various depths along the apex. The marks and their apexes are not straight as they reflect the irregular (wavy) cutting bit of the chipped stone tool. The chipped stone axes required many strikes to the bone before fragmentation occurred, which led to the creation of more incomplete than complete marks. The morphology of these incomplete marks is indicative of only this tool type (Figure 23, 24, 26, 27).

Table 2: Absolute and relative frequency of chipped stone marks by fragmentation class.

Mark Class	Absolute count of chipped stone marks	% of chipped stone marks
1	2	20%
2	1	10%
3	1	10%
4	-	-
5	-	-
Surface marks	6	60%
Total	10	100%

ii. The ground stone axe

The ground stone axe produced the least distinct marks of any axe type. The ground stone axe produced the heaviest degree of crushing at the entry point of the chop mark and rarely penetrated the surface further than a few millimetres before fragmentation occurred. A rough chopped surface with no macroscopic parallel striations is common for these chop marks. The majority of ground stone marks (see Table 3) are difficult to recognize as chop marks due to high fragmentation and are classed as a number 1[13]. Only a single mark out of the 32 ground stone chop marks has a relatively smooth at the point of entry. However, this relatively smooth surface is very small (2 mm) and the remaining bone quite fragmentary, which is why the mark is classed as a 3 and not a 4 Class mark.

All ground stone chops on the *Sus scrofa* ribs were directed into the bone at approximately a 45˚ angle to test shearing capabilities. Only a single rib bone was divided into only two separate sections, while the majority fragmented into three or four pieces, and the most fragmented rib was divided into 12 pieces (that could be recovered). No sheared surfaces were identified. The chop

[13] The *Sus scrofa* rib meat was consumed by the author after the bones and bone fragments were carefully picked out of the meat for examination. When the meat was consumed, the meat was full of tiny bone fragments and required very careful chewing as to not hurt one's teeth. The meat from the *Sus scrofa* ribs chopped by the copper and bronze axes was also consumed and did not have this problem.

mark with a relatively smooth entry (mentioned above) was directed into the bone at a very low angle (approx. 15˚).

When both the acute and obtuse sides are examined together, it is clear that the ground stone axe created heavy fragmentation on both sides of the chop mark and many of the chop marks would be difficult to identify as chop marks within an archaeological assemblage. When chop marks are more identifiable (a Class 2 or a 3), the other side of the mark is often very fragmented and would not be identifiable as a chop mark outside of an experimental setting. Thus, many chops made by ground stone axes are likely to be missed in an archaeological assemblage due to lack of discernible features.

The ground stone axe produced noticeably fewer surface marks compared to the chipped stone axe, and these marks once again, are much more indicative than the compete chop marks. However, only 12.5% of the ground stone axe marks were surface marks. These marks are much less common than complete chops made by the same instrument. The surface marks are more often U-shaped rather than V-shaped, with a pitted, relatively straight apex line (Figure 25, 26, 27). Examination of the pitted apex line can be aided by a low powered microscope.

Table 3: Absolute and relative frequency of ground stone marks by fragmentation class.

Mark Class	Absolute count of ground stone chop marks	% of ground stone chop marks
1	12	37.5%
2	8	25%
3	8	25%
4	-	-
5	-	-
Surface marks	4	12.5%
Total	32	100%

iii. *The copper axe*

The copper axe produced the most variable chop marks of any of the axes and produced a number of chops from all fragmentation classes. Most chops have light crushing at the point of entry, with only a few that exhibit heavy crushing (see Table 4). The copper axe produced more

Class 3's than any other fragmentation group. The second highest group is Class 2 and the third most frequent group are Class 4.

Of the 41 copper chop marks, 17% have some level of shearing on the chopped surfaces. The majority of the sheared surfaces average 5 mm in length, with a single sheared surface closer to 10 mm in length. While the level of shearing is not extensive, it is present and macroscopically recognisable. Shearing occurs more often when the bone was struck at a 45˚ angle as opposed to a 90˚ angle.

The majority of the chop marks made by the copper axe are recognizable on both sides of the chopped surface with only 7.3% of the marks appearing highly fragmented. This means chop marks made by copper axes are more likely to be recognised as chop marks than marks made by stone axes.

The copper axe created V-shaped surface marks. The deeper V-shaped surface marks often exhibit a lightly sheared obtuse side (Figure 21). However, it is difficult to gauge the extent of the shearing since it is impossible to know how the bone would have continued to fracture. The apex lines of the copper axe surface marks are distinct from the stone axes. The apex lines are straight and exhibit no pitting when viewed under a low power microscope (Figure 26, 27).

Table 4: Absolute and relative frequency of experimental copper chop marks by fragmentation class.

Mark Class	Absolute number of copper chop mark	% of copper chop marks
1	4	7.3%
2	6	19.5%
3	11	31.7%
4	9	12.2%
5	2	4.88%
Surface marks	9	24.4%
Total	41	100%

Figure 21: Photograph of incomplete copper axe mark on *Sus scrofa* rib mid shaft ©Tiffany Okaluk.

iv. The bronze axe

The surface marks of the bronze axe are always a deep V-shape, either with or without an acute wedge fracture. These marks vary in depth from 1 mm to almost 1 cm, and similarly to the copper axe, always have a straight apex (Figure 26, 27). The bronze axe was the only axe to produce no Class 1 marks. The bronze axe created the least amount of crushing at the point of entry and was also the least likely to leave a surface mark. It was also the only axe to produce more sheared marks than non-sheared marks (see Table 5). The shearing on some of the chops is extensive, with one sheared surface continuing almost completely through the bone (Figure 20). The fragmentation from the bronze axe was more controlled than any other axe type, often resulting in only two pieces. The bronze axe was the only axe type capable of cleanly penetrating the hard and dense outer bone surface of the *Bos taurus* ribs and *Sus scrofa* long bone shafts without creating crushing at the surface. However, even the bronze axe had difficulty penetrating dense long bones when struck perpendicular to the long axis of the bone at a 90˚ angle.

Table 5: Absolute and relative frequency of bronze axe marks by fragmentation class.

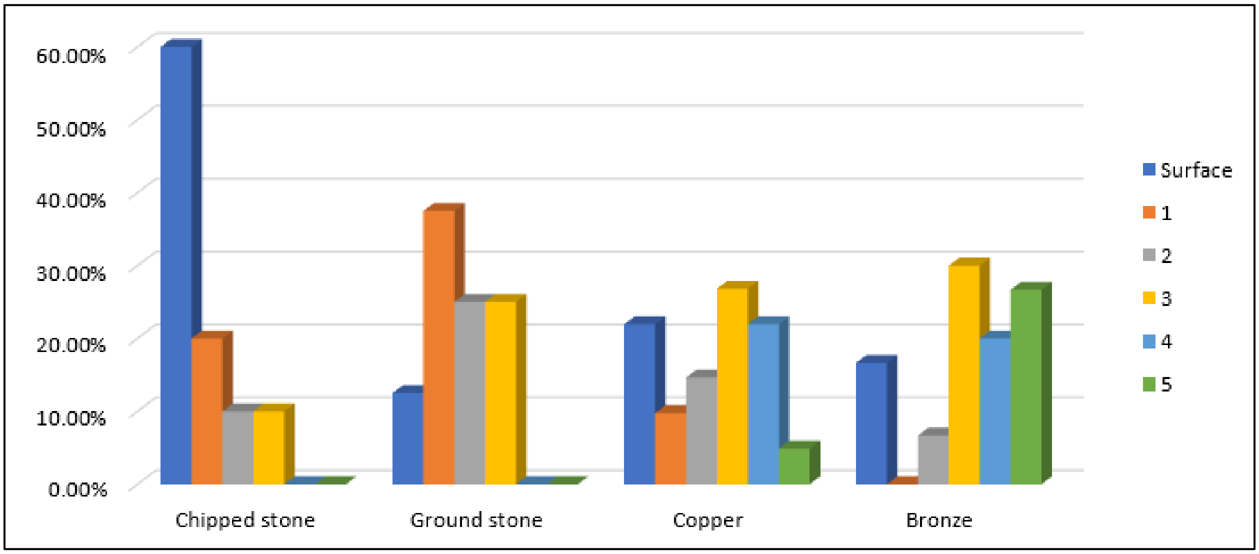
Mark Class	Absolute number of bronze chop marks	% of bronze chops
1	-	-
2	2	6.67%
3	9	30%
4	5	16.67%

5	9	30%
Surface marks	5	16.6%
Total	30	100%

VII. Discussion

The high level of variability in chop marks makes it almost impossible to discuss chop marks as one generalized group (see Figure 22). The major division in chop marks exists between complete and incomplete marks. This is never fully clarified in the literature (Shipman 1981, Olsen 1988, Binford 1981). The zooarchaeological studies that discuss the morphological patterning of chop marks seem to only discuss incomplete surface marks (Olsen 1988, Walker and Long 1977), although they do not explicitly state this. As exemplified in this experimental study, complete chop marks are more common than incomplete surface marks.

Figure 22: Bar graph displaying Class (1-5 and surface) percentages for each axe type.



i. Surface marks (incomplete chops)

The chipped stone axe left behind many surface marks due to the inefficiency of the tool as a chopping device. Two chipped stone axes were tested. The thin and sharp Knife River Flint biface was the only chipped stone axe to cut through the surface of the bone in one strike, although this impact did not actually sever the bone (Figure 23). Although the sharp chipped stone axe was able to cut through the bone, the cut surface was not flat. Upon the second strike the biface broke significantly and rendered the tool unusable.

Figure 23: Photograph of chop mark made by Knife River Flint biface on the superior face of the frontal bone (between the orbits) of *Ovis aries* cranium ©Tiffany Okaluk.

The thicker chert biface was able to continue to be in use through all phases of testing, but the cutting edge of the biface flaked and dulled quickly. The chert biface was not able to penetrate into the bone more than a few millimetres and required multiple strikes at the same location before the tool eventually hit a weak spot in the bone and the bone cracked. This tool was also very difficult to hit the same location. The irregular cutting bit of the axe led to even more incomplete surface marks. The uneven 'peck' marks (Figure 24) scattered around the breakage area are more indicative of chopping activity with a chipped stone axe than the actual fragmentation of the bone. Stout et al. (2014: 580-581) found marks very similar to these at the Lower Palaeolithic site of Boxgrove, UK on red deer antler tools. The marks had microscopic pieces of flint embedded into the surface and are thought to be made by Acheulean hand axes from about 500,000 years ago. The experimental results from this study closely resemble the marks from Boxgrove and closely resemble the experimental marks described by Olsen and Shipman (1988: 544, 547).

Figure 24: Photograph of multiple strikes from the chert biface on the superior face of the frontal bone (behind the orbits) of an *Ovis aries* skull © Tiffany Okaluk.

For all other axe types, incomplete marks, including surface marks, were much less common than complete chops. Morphology of the marks do, however, correlate to material type. The ground stone axe left either a shallow U-shape or deeper U/V-shaped mark with a pitted apex line with crushing around the entry point of the mark. A shallow U-shaped groove is more likely created when the axe is directed into the bone at a 45˚ angle rather than a 90˚ angle (see Figure 25).

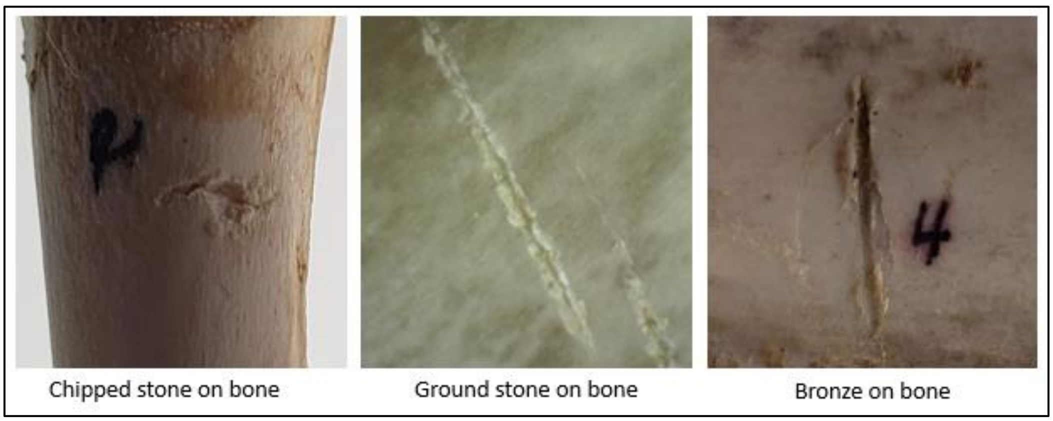
The metal (bronze and copper) axes left deep V-shaped marks with a straight, non-pitted apex line. Incomplete surface marks are, therefore, indicative of axe material type and a clear distinction can be made between chipped stone, ground stone, and metal axes merely on the basis of their surface marks. An example of these marks are seen in Figure 25, 26 and 27.

Figure 25: Photograph of ground stone (surface) chop mark on an *Odocoileus virginianus* radius directed at a 45˚ angle ©Tiffany Okaluk.

Figure 26: Photograph of surface marks made by chipped stone (left), ground stone (centre), and bronze (right) axes on pine wood plank at a 90˚ angle ©Tiffany Okaluk.

The details of incomplete marks are best observed in the shallowest of marks. The deeper the mark, the more difficult it is to clearly see the apex line, even with the aid of a low-power microscope. Moreover, as incomplete marks are an unintended consequence of the butchery activity (Mathieu 2002), it is risky to rely entirely on this type of mark for material identification. An individual consistently engaged in butchery chopping would likely create fewer incomplete surface marks than found in this experimental sample created by an unskilled and unpractised butcher (the author). The indicative features of the surface marks are also much clearer on wood than on bone, as the wood provides a soft, consistent material for the axe to penetrate. An example of surface marks on bone are seen in Figure 27. Surface marks are more identifiable when directed into the bone at a 90˚ angel as opposed to a 45˚ angle. This, however, is once again a less common mark, as a 90˚ angle is less efficient for creating complete chop marks and may not have been commonly be used.

Figure 27: Photograph of 90˚ surface marks of chipped stone on *Odocoileus virginianus* radius (left), ground stone on *Bos taurus* rib (centre), and bronze axe on *Bos taurus* rib (right) on bone.



ii. Complete chops

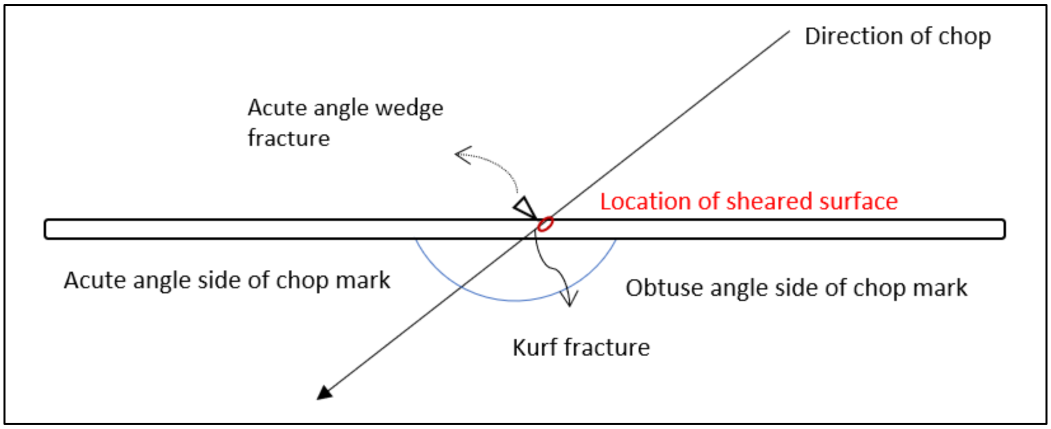
Complete chops make up the majority of the experimental assemblage. These range from a mass of tiny fragmented pieces, to perfectly smooth chopped surfaces that divide the bone into only two pieces. The overall rate of fragmentation within a chopped assemblage does generally correlate with axe material type, yet all axes can produce multiple types of fragmentation patterns. The stone axes created more limited patterns of fragmentation than the metal axes. While the stone axes can divide the bone into only two separate pieces, they always create an uneven or fragmented surface on both sides of the chop mark. Even with the more controlled ground stone chop marks, the chopped surface always exhibited some fragmentation within the mark itself and exhibited no cutting.

The metal axes produced a wider variety of fragmentation patterns than the stone axes. Both the copper and bronze axe created some marks very similar to the ground stone axe. These marks had light crushing at the point of entry, penetrated only a few millimetres into the bone, and then caused the bone to fracture into two or more pieces. These types of marks would either be classed as a 2 or 3 on the fragmentation scale, and there are no defining characteristics within these marks to indicate axe material type. However, metal axes were much more likely to create this type of mark when the bone was struck at a 90˚ angle as opposed to a 45˚ angle, or even just a slight angle. Whereas, the ground stone axe always created this pattern regardless of angle.

The definitive morphological characteristic of metal axe marks is shearing, or the absence of fragmentation on the obtuse chopped surface. Shearing is the result of cutting rather than breakage and is only found on Class 4 and 5 chop marks. None of the stone axes created Class 4 or 5 chop marks, meaning that no sheared surfaces were created by the stone axes. Breakage can create a relatively flat surface, but it cannot create a smooth/cut surface. The problem with this morphological characteristic is that not all chops made by metal axes create sheared surfaces. Only 17 % of the experimental chops created by the copper axe exhibit sheared surfaces (combined Classes 4 and 5), and 47% of the chops created with the bronze axe exhibit sheared surfaces (combined Classes 4 and 5). Shearing is also limited to one side of the chop mark As noted previously, a sheared mark will away always produce an opposing side that is never classed higher than a 2 or a 3. Although shearing does not appear on all metal chop marks, it is never associated with stone chop marks.[14] This is due to the two major variables within the axes themselves: width and sharpness (Wenham 1989). The idealized metal axe breakage pattern as described by Wenham (1989) is modified slightly to include the results of this study and is illustrated in Figure 28.

[14] Very small smooth surfaces (less than 2 mm) at the point of entry can be created by ground stone axes when the bone is struck at an angle less than 45˚ as it skims off the surface . This type of very small smooth surface at the point of entry is also common with marks classed as a number 3 made by metal axes. Due to this similarity and the extremely small size of the smooth surface this is not considered shearing.

Figure 28: Schematic diagram of metal chop mark that exhibits shearing.



The width of an axe determines how deep the axe can penetrate into the surface of the bone before causing the bone to split, either at the kerf, or completely (Humphrey and Hutchinson 2001). If the axe is quite wide, it does not have the ability to penetrate further than the relatively short portion that was sharpened before it splits the bone as a wedge. This results in breakage at the point of impact rather than cutting through the bone. The sharpness of the axe determines how cleanly the axe can enter the surface of the bone. The sharper and thinner the implement, the more concentrated the force that will continue down into the bone instead of spreading out over the surface of the bone and will create a smoother and deeper chopped surface. Humphrey and Hutchinson (2001: 232) found that metal axes, unlike thinner metal tools such as machetes and cleavers, sometimes pushed bone material into the chop mark itself. This is defined as crushing, and crushing is more likely when the both the width of the tool is increased and the sharpness decreased.

In this study, the copper axe produced less instances of shearing. This may be due to the overall weight differences between the two metal axes. The bronze axe is significantly heavier than the copper, the extra weight of the bronze axe likely helped the tool to penetrate deeper into the surface of the bone. However, copper also produced more surface crushing than the bronze indicating the tool was not as sharp even though both tools were sharpened with the same metal file. The copper axe also, did not retain a sharp edge for as long as the bronze axe and required repeated sharpening, whereas the bronze axe did not. Moreover, even with repeated sharpening of the copper tool it was never as sharp as the bronze axe when slice tested on paper. The copper axe created much more surface crushing at the point of entry than the bronze axe. As there is no way to know how sharp (copper vs. bronze) or dull metal axes were in antiquity, this is an unreliable characteristic to infer axe material type on an archaeological chopped bone assemblage.

iii. Criteria for identifying complete chop marks

Identifying chop marks that fall lower than a Class 3 on the fragmentation scale is difficult as these marks often do not display a clear point of entry. Without knowing where the axe struck the bone, it is almost impossible to argue that the breakage displayed was in fact created by an axe and not by other depositional or taphonomic processes. A point of entry is defined either by concentrated crushing, impact marks, a relatively straight line from which breakage begins, or the beginnings of a sheared surface. Any of these criteria indicate the place of impact from a wedge shaped tool. As this experimental study shows, metal axes create these diagnostics more frequently than stone axes. This means that there is a clear bias for the recognition of metal axe marks as opposed to stone axe marks. Close attention to the placement of high fragmentation could be referenced in relation to ethnographic butchery mark placement (see Binford 1981: 143). However, without direct evidence for the butchery marks themselves, this remains only an anecdotal inference.

Stone axes do not produce marks similar to hammer stones. Percussion notches are one of the most common macroscopic characteristic of hammer stone butchery (Pickering and Egeland 2006: 464). Percussion notches are semi-circular notches along a fracture line (Figure 29) left by the direct impact of the hammer stone (Pickering and Egeland 2006: 462). None of the chop marks created with the experimental stone axes have percussion notches along the fractured edge. Instead, the fracture lines at the place of impact are relatively straight, as they reflect the shape of the tool that caused the breakage. A relatively straight line at the place of impact is often paired with a stepped kerf fracture at the exit point (Figure 29 and 30).

Figure 29: Schematic drawing of one side of stone chop mark and hammer stone percussion notch ©Tiffany Okaluk.

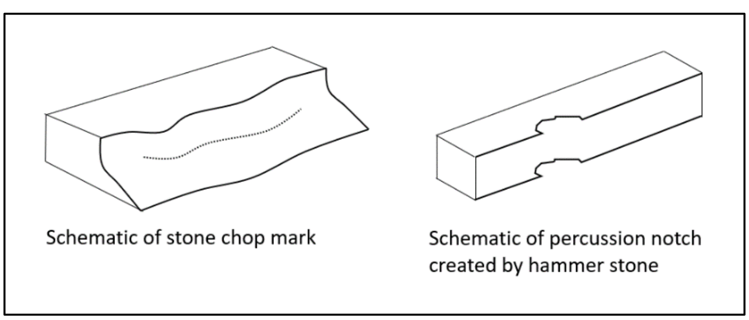
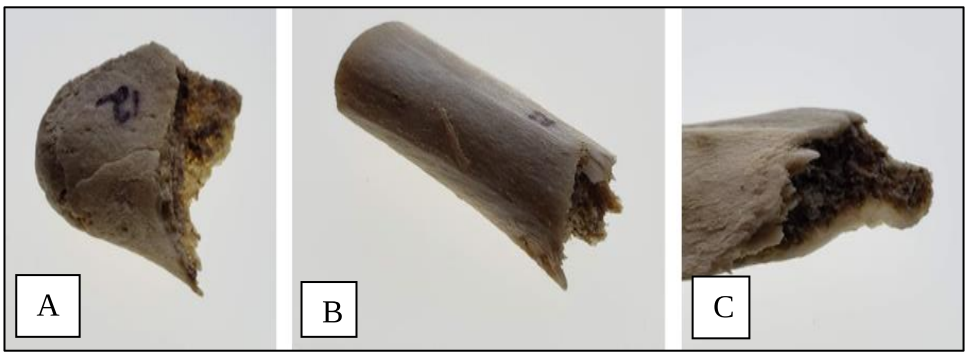


Figure 30 shows three separate ground stone chop marks on *Sus scrofa* transverse processes and vertebra. The relatively straight edge along the line of impact and stepped kerf fracture of A and B make these chop marks clearly identifiable as chop marks. However, these features are less definite in C, and makes this chop mark, classed as a 1, difficult to identify as a chop mark outside of an experimental setting. All of the chop marks in Figure 30 were created by the ground stone axe, yet both the copper and bronze axe have the ability to create similar marks. The difference is that the ground stone axe always produces these types of marks, whereas the metal axes produce a combination of these marks and sheared marks.

Figure 30: Photographs of examples of ground stone chop marks on *Sus Scrofa* vertebrae ©Tiffany Okaluk.



iv. Chop mark characteristics in relation to axe morphology

Late Chalcolithic and Early Bronze Age Anatolian ground stone axes are quite thick, (Massa 2014: 81) with a steep pitch leading to the sharpened edge (Figure 31). Thus, this tool can be very successful in splitting the bone but cannot cut through the bone without causing splintering and fragmentation on both sides of the chop. A thinner and sharper stone axe may have the ability to penetrate further into the bone as demonstrated by the thin Knife River Flint experimental axe. However, the thin and sharp cutting edge was too unstable to handle the high-speed impact needed for chopping and shattered almost immediately. Although untested, a very thin ground stone axe would likely also be at risk for significant damage while chopping. As ground stone axe takes a significant amount of time and effort to create, and breakage of the tool would be highly undesirable. A ground stone axe cannot easily be sharpened or re-shaped and damage to the cutting edge would render this high-time investment tool useless. Therefore, the functional form of the tool must be dictated by the structural integrity of the material.

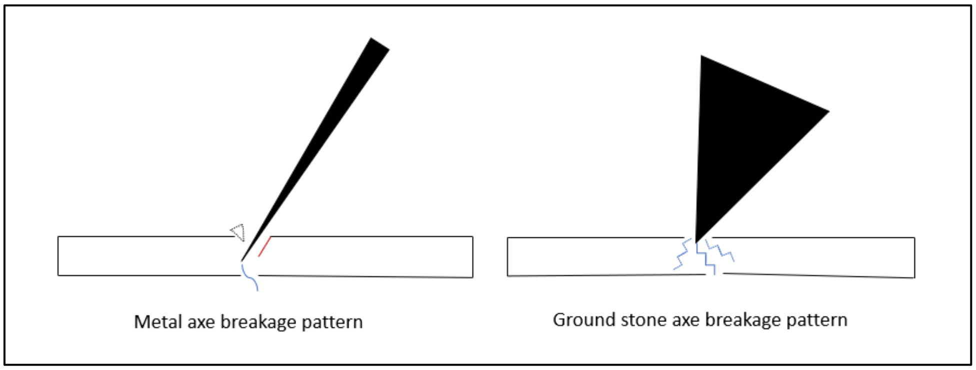
Metal axes have the ability to be both sharp and thin while maintaining their structural integrity. Unlike a ground stone axe, damage to the cutting bit of a metal axe can easily be ground out or simply re-sharpened. Early Bronze Age metal axes are significantly thinner than ground stone axes (Figure 31) and this allows them the ability to cleanly cut through the bone instead of splitting it.

Figure 31: Photograph of Bronze Age bronze axe and mould (left), and Chalcolithic ground stone axe heads (right) from the Sanliurfa Archaeology and Mosaic Museum, Turkey © Tiffany Okaluk.

The characteristics of compete chops reflect the shape of the tool rather than specific material type. Hence, thick and wide-edged (and consequently dull) axes produce fragmented chops with no shearing. Thin and narrow-edged (and consequently sharp) axes can also produce this type of mark when directed into the bone at a 90˚ angle. But, even at a slight angle, thin sharp edged axes produce marks with significantly less fragmentation and a sheared surface on the obtuse angle.

In this study and in antiquity, axe shape strongly correlates with material type (Figure 32). Wenham (1989) also concluded that axe thickness is the major variable for determining the amount of crushing at the surface and the depth the axe can penetrate the bone before fracture occurs. As such, it is important to understand the tool variation of the period in question before applying the results of this or any experimental study to an archaeological faunal assemblage.

Figure 32: Schematic drawing of metal axe vs. ground stone axe fragmentation patterns (thin/sharp vs. thick/dull) ©Tiffany Okaluk.



v. Directionality and fragmentation pattern

Axe force trauma to bone is the result of both shearing and compression forces (Lynn and Fairgrieve 2009: 786). Lynn and Fairgrieve (2009: 786) found that shearing occurred only when an axe is directed into the bone at a 45˚ angle. The experimental results of this study generally support that conclusion. This study found that shearing will only occur with metal axes and is more likely to occur when the bone is stuck at a 45˚angle. However, shearing can also occur when the bone is struck at a 90˚ angle, but only when stuck at a 90˚ angle parallel to the long axis of the bone along a previously cut edge. As most of the experimental bones came from a butcher's shop, many of the bones were sawn at transverse angles. When struck perpendicular to the saw marks at a 90˚ angle, the metal axes created very clean, deep chops. This did not occur with the stone axes, and instead, created heavy fragmentation and crushing.

The *Sus scrofa* ribs demonstrated the best examples for directionality and fragmentation pattern. The metal axes did not create any sheared chop marks when directed into the bone at a 90˚ angle perpendicular to the long axis of the bone, yet produced a sheared mark almost every time a chop was directed into the bone at a 45˚ angle. The ground stone axe did not produce shearing when directed into the bone at either a 90˚ or 45˚ angle. However, there was notably less complete fragmentation when struck at a 45˚ angle

vi. Shearing results of dull vs. sharp metal axes

The metal axes were tested in both 'dull' and 'sharp' states. The bronze axe was sharpened only once with a simple hand-file before the beginning of Test 3 (*Sus scrofa* vertebra). The copper axe was also sharpened before the beginning of Test 3 and then again before the beginning of test 6 (*Sus scrofa* ribs). While the general pattern remained the same for both dull and sharp metal axes, the characteristic traits of metal axe chop marks were heightened when the axes were sharp. Shearing with no crushing occurs more often with a sharp metal axe, whereas a dull metal axe is more likely to create some surface crushing as it enters the bone. However, shearing can occur with a 'dull' metal axe.

vii. Experimental axe durability

The chipped stone axes suffered from durability issues. Axe #5, a relatively thin biface made from Knife River Flint, fractured upon the second impact (left image of Figure 32). The thin, sharp cutting edge penetrated the bone on the initial strike very well, but the angle of the second strike caused the sharp edge of the bit to snap off, and hence, rendered this tool useless for the remainder of the experimental chops. Chipped stone Axe #4, the thicker chert biface, also suffered from significant damage to bit throughout the experiments, but remained intact enough to continue through most of the tests. It was the haft that failed in the end for the chert biface. Without the use of resin to secure the blade to the haft, the tool consistently slipped back within the haft with each chop until the tool could no longer be used (see right side of Figure 32). The damage to the cutting bit on both the chipped stone axes illustrates the need for a thick, structurally sound axe to handle the high impact forces. Thin stone axes cannot deal with the high-impact force without compromising the integrity of the tool. Therefore, it is unlikely that thin chipped or ground stone axes would have functioned as butchery tools for chopping bone.

Figure 33: Photograph of damaged Knife River Flint (left) and chert (right) chipped stone axe heads ©Tiffany Okaluk.

The copper and ground stone axe also suffered some damage to their cutting bits. The cutting edge of the copper axe was dented fairly quickly and this tool required more care to maintain the integrity of the cutting bit throughout the experiments (left side of Figure 34). The damage did not prevent the copper axe from further testing. The bit of the ground stone axe quickly became pitted (right side of Figure 34), but did not inhibit further chops. The bronze axe bit suffered no significant damage from the experimental chops.

Figure 34: Photograph of damaged copper (left) and ground stone (right) axe bits ©Tiffany Okaluk.

VIII. Conclusion

This chapter describes the experimental study and identifies the macroscopic morphological patterning of chop marks made by different types of axes on bone. The results presented in this chapter describe multiple patterns found in the experimental assemblage. The results are divided between complete and incomplete chops as these marks exhibit different characteristic and have different diagnostic criteria that are not comparable.

Incomplete surface marks are highly identifiable for chipped stone, ground stone, and metal axes. Surface marks are the most identifiable when struck into the bone at a 90˚ angle as opposed to a 45˚ angle as the angle can obscure visibility of the apex line. The morphology of the surface mark is different for each type of axe. Chipped stone surface marks are wavy with a 'pecked' and inconsistent apex line. Ground stone surface marks are either a wide U or V-shape with a pitted apex line. Metal axe surface marks take the form of a deep V-shape with a straight, smooth, and consistent apex line. There is no discernible macroscopic difference between copper and bronze surface marks. Identifying the material type for incomplete chop marks does not require any specialist equipment and is extremely simple. Although these marks are highly indicative, the marks themselves are rarer than complete chop marks.

The indicative criteria for determining axe material of compete chops is less straight forward, and once again, there is very little macroscopic morphological difference between the copper and bronze axe marks. However, there is a clear distinction between the group of chop marks made by metal axes and group of chop marks created by stone axes. Stone axes produce complete chop marks that are always fragmented. The edges of the mark often exhibit crushing around the entry point and the chopped surfaces are jagged from breakage. Metal axes produce significantly less crushing, and the blade often penetrates far into the surface of the bone leaving a cleanly cut flat surface on one side of the chop mark. The cleanly cut (or sheared) surfaces only appeared on between (approx.) 20-50% of all experimental complete chop made by metal axes, and this characteristic is not associated with stone chop marks. Shearing will only appear when the force is directed into the bone at an angle less than 90˚.

The metal chop marks created in this experimental study are very similar to the axe marks described in the forensic literature (Wenham 1989, Lynn and Fairgrieve 2009, Humphrey and Hutchinson 2001). However, both chipped stone and ground stone chop marks are not. Chop marks are difficult to identify with certainty when the mark is highly fragmented, and this creates a strong bias for the identification of metal chop marks as opposed to stone chop marks. Chipped stone axes create a unique pattern of peck marks and uneven step fractures that should not be confused with any other axe type. Ground stone axes have the potential to be invisible within a chopped assemblage if the assemblage was chopped with both metal axes and ground stone axes. According to the experimental results, an assemblage that displays more than 20% sheared chop marks was likely created using only metal axes (the copper axe assemblage produced 17% sheared marks and the bronze axe assemblage exhibited 47% sheared marks). If a chopped assemblage contains no sheared marks, it very unlikely that it was created by metal axes. The only evidence for the use of ground stone axes is the absence of evidence for either chipped stone or metal axes. Supplementing the complete chop mark data with the surface mark data can strengthen the argument for the use of ground stone axes, as ground stone axes produce a unique type of surface mark, as do the chipped stone and metal axes.

The assumption that metal axes “leave rather obvious marks” (Binford 1981: 143) is conceptually flawed, yet not wholly untrue. Metal axes can leave very obvious marks, but they can also leave marks that are frustratingly similar to marks made by ground stone axes. The most reliable method for determining axe material types used on archaeological assemblages is the analysis of both incomplete surface marks and complete chops from an entire assemblage. The analysis of a single (or few) mark(s) as representative of an entire assemblage would undoubtedly lead to incorrect interpretations.

The methods and identification criteria for chop mark analysis described in this chapter are applied to the Göltepe chopped assemblage in the following chapter. Detailed description is provided for the archaeological chopped assemblage including species, element, age, condition, and chop mark analysis.

Chapter 7: The Göltepe chopped assemblage

I. *Introduction to the archaeological sample*

The chopped assemblage from EBA Göltepe is comprised of 779 individual chop marks found on 512 specimens. Many specimens exhibit more than one chop mark as it may have taken more than one blow to sever the bone, or the dismemberment process required chops in multiple locations along the bone. All primary and secondary context EBA faunal material from Göltepe were examined for evidence of chopping, and of this material, 8.86% of the Number of Identified Specimens (NISP) exhibit one or more chop mark(s). Chop marks are found across all EBA Periods (2, 3, and 4) at Göltepe. The chop marks from Period 1 (Iron Age) are not included in this analysis.

This chapter describes the chopped assemblage from Göltepe with detailed attention to element frequency, species frequency, trends through time, fragmentation patterns of the chop marks, and finally bone and antler tool production. NISP values from only the chopped assemblage are used, and percentages do not refer to the entire faunal assemblage from Göltepe. cNISP (Number of Identified chopped Specimens) counts are used for discussion regarding element, species, and age of the chopped assemblage. Chop mark frequency, or total number of chop mark incidences (cBI) refers to the number of chop marks identified and may be higher than cNISP counts. Chop mark frequency (cBI) is used when discussing fragmentation patterns for individual chop marks.

II. *Method of analysis*

Analysis of the faunal material took place at the University of Manitoba's Near Eastern and Biblical Archaeology Laboratory (NEBAL) under the supervision of Prof. Haskel Greenfield. All specimens were surface cleaned (without immersion) with water to make the marks visible. They were then subjected to traditional standard zooarchaeological identifications (taxon, element, sex, age, taphonomy, etc.), as well as chop mark analytical methods developed in this thesis and described in Chapter 6. These analyses include the examination of each bone by eye for both incomplete and complete chop marks. The apex of incomplete marks were examined under a low power (6X) microscope for evidence of pitting. Complete marks were assigned a number along the fragmentation scale to describe the degree of crushing, splintering, fragmentation, and shearing. When visible, depth of chop mark before kerf fracture was recorded. The slice mark assemblage has already been described elsewhere (Greenfield and Chaput in press).

III. General description of the chopped assemblage

The high frequency of sheared chop marks are immediately apparent when sorting through the Göltepe faunal assemblage. The majority of the chop marks are in good condition (84% light weathering and 87% none-light root etching) with only a few chop marks distorted by either root etching or weathering. Any chop mark that was significantly affected by post depositional taphonomic forces was not assigned a number on the fragmentation scale and therefore can-not be classed as either metal or stone. All chop marks were recorded in the same way as to examine position and location on the bone, total number of chop marks, level of fragmentation, depth of mark, and the raw material of butchering implement. Many bones exhibit extremely clean and straight chops that go completely through the bone. Only 4% of the total number of chop marks have crushing associated with the marks. This means that 96% of the chop marks have no crushing at all. Bias for the non-recognition of crushed chop marks was noted in Chapter 6 in the discussion of the experimental sample. This is also likely the case for the Göltepe material. If it could not be proven beyond a reasonable doubt that the breakage was caused by a chopping implement, it was not recorded as a chop mark.

IV. Elements and placement of chops

The majority of the chop marks are found on a limited number of elements at placement locations related to dismemberment butchery. The most common chopped elements are: (i) the crania, which make up 32% of the chopped assemblage, (ii) vertebra (17%), (iii) rib (15%), (iv) innominate (7%), (v) scapula (6.5%), and (vi) humerus (3.5%). For a full listing of chopped elements see Table 6.

i. Crania

The largest proportion of the chopped Number of Identified Specimens (cNISP) are from the crania, specifically the posterior frontal and the parietal bones. Of the entire faunal assemblage, 25% of all cranial specimens exhibit chop marks. The chop marks on the crania occur at regular locations with the goal of separating the individual horn cores, or the top of the crania to expose the brain using multiple chops. Of the 289 chop marks found on crania specimens, 82% of the marks appear around the bases of the horn cores. The cranial chops are precision chops, with the majority of marks occurring at exactly the same location and at the same angle across multiple specimens. See Figure 35 for a schematic image of chop mark placements on the crania and appendix for additional images.

Figure 35: Photograph showing placement of most common chop marks on the crania.

ii. Vertebra

Chop marks found on the vertebra, including the atlas and epistropheus, make up 17% of the chop marks in the assemblage. The chop marks found on the vertebra functioned to divide the carcass of the animal into more manageable pieces. The majority of the marks occur through the centre of the vertebra along the sagittal plane, or through the coronal plane at either the cranial or caudal face. The chop marks found on the vertebra appear haphazard, and few occur in precisely the same locations on different specimens. The chops on the vertebra indicate that the carcass was not always divided axially in the exactly the same manner. Of the total vertebra in the faunal assemblage, 23.64% exhibit one or more chop marks. Although the majority of the chop marks divide the bone through the centre along the sagittal plane, some are only chopped along the caudal or cranial face. A combination of these chop mark placements is also present. This identifies the division of the axial carcass as not standardized. As only 23.64% of vertebrae exhibit chop marks, it is likely that the carcass was more often divided perpendicular to the long axis of the body between the vertebrae than split down the centre axis.

iii. Ribs

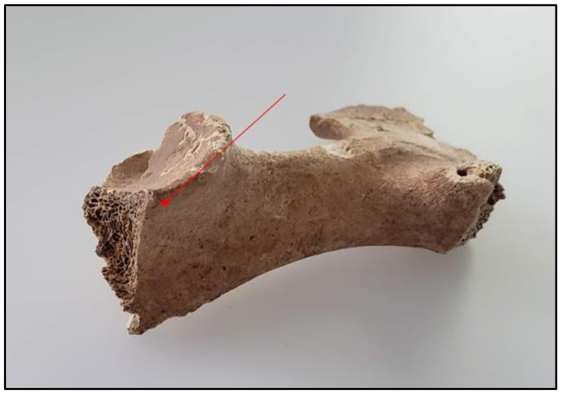
Ribs are the third most common element to exhibit chop marks and make up 15% of the cNISP. Chop mark placements are fairly standard, and occur across the head, neck, and tubercle, and also across the mid and distal shafts. Chops found on the rib shafts are always directed into the lateral face, with chops found on the head and neck entering from the lateral-superior angle (see Image 36). The chop mark placement represents standard dismemberment practices of the meaty rib sections from the vertebra and costal cartilage area.

Figure 36: Photograph of common chop mark placement and direction on *Ovis/Capra* rib from Göltepe FCN C02-0200-007, MRN 3780, Bone 6 ©Tiffany Okaluk.

iv. Innominate

The innominate is the fourth most common chopped element and make up 7% of the cNISP. However, 24.38% of all innominate bones in the faunal assemblage exhibit chop marks. The majority of the chop marks found on the innominate go directly through the acetabulum with the blow directed into the lateral face (see Figure 37). These chops are not haphazard and appear highly standardised. This chop mark would serve to sever the lower limb and caudal pelvis from the rest of the carcass. See appendix for additional images.

Figure 37: Photograph of common chop mark placement and direction on *Ovis/Capra* innominate from Göltepe FCN C02-0200-007, MRN 3780, Bone 11 ©Tiffany Okaluk.



v. *Scapula*

Scapulae make up 6.5% of the cNISP. The vast majority of the chop marks transect the scapula perpendicular to the long axis or at a slight diagonal angle. Very few chop marks divide the scapulae parallel to the long axis on the bone, and those that do are all located on the head of the bone. The chops located on the scapulae are clearly related to dismemberment activities and occur on the head, neck, and all parts of the body. The chops are not precisely placed but are mainly directed into the bone from the lateral face likely in an effort to remove the anterior limb. See appendix for scapulae chop mark images.

vi. *Tibia*

Tibiae make up 3.8% of the cNISP. Chop marks on the tibiae are primarily found on the proximal or distal ends and rarely on the mid shaft. The chops represent dismemberment activities as they transect the bone perpendicular to the long axis. See appendix for tibia chop mark image.

vii. *Humerus*

Thirty-nine chop marks (cBI), or 3.6% cNISP, are located on humeri. Of all identified humeri within the faunal assemblage, 19.2% have chop marks. The majority of these marks are located at either the proximal or distal ends and represent dismemberment and disarticulation activities. However, a small percentage of the chop marks split the bone down the long axis and are likely associated with marrow extraction. The chop marks on the humeri do not represent precision butchery as they regularly occur at random angles and are not standardized across the chopped assemblage.

Table 6: cNISP absolute and relative (%) frequency of chopped elements from Göltepe (all EB periods).

Element	Raw frequency (cNISP)	cNISP (%)
Crania	164	32%
Rib	73	14%
Vertebra	76	15%
Innominate	37	7%
Scapula	34	6.5%
Tibia	18	3.5%
Humerus	17	3%
Metacarpus	15	3%
Metatarsus	14	2.7%
Radius	14	2.7%
Epistropheus	12	2%
Antler	10	2%
Phalanx	5	1%
Mandible	5	1%
Ulna	5	1%
Femur	4	1%
Atlas	3	0.5%
Astragalus	2	0.5%
Patella	1	0.2%
Flat bone	1	0.2%
Total	**512**	**100%**

V. Taxonomic distribution

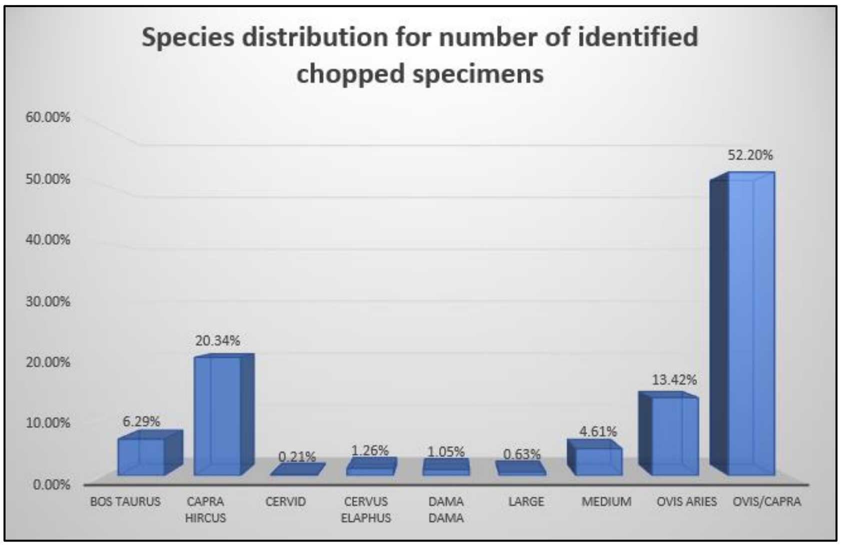
Chop marks are strongly associated with domestic species. The chop marks show that domesticates, rather than wild species, were the main source of meat protein in the diet. This is also demonstrated by the species distribution within the overall faunal assemblage which also has a very high percentage of domestic species.

The combined caprine (indeterminate *Ovis/Capra*) taxa category makes up the highest percentage of chop marks (52%). This is due to the fact that commonly chopped elements such as the ribs and vertebra can often not be credibility designated as either *Ovis aries* or *Capra hircus*. See Figure 38 for species distribution within the total Number of Identified chopped Specimens.

Of those that can be identifies as either *Ovis* or *Capra*, *Capra hircus* stands out in comparison to all other domesticates with the highest frequency of chop marks. *Capra hircus* represents 20% of the total number of the cNISP, while *Ovis aries* only has 13%. This is a 7% difference that is not accounted for in the species distribution of the faunal assemblage.

A small portion of the chopped assemblage is made up of wild cervids (*Cervus elaphus* and *Dama dama*). The majority of the wild cervidae material is antler and likely associated with tool production. No chopped axial elements were identified as *Cervus elaphus* and very few are identified as *Dama dama*. The frequency of wild cervidae is extremely small in comparison to the domestic species and it is unlikely that these wild species contributed to the diet in a substantial way.

Figure 38: Graph showing taxonomic distribution for cNISP across all time Periods ©Tiffany Okaluk.



VI. *Chop marks by age class*

The determination of age was based on fusion, porosity, and dental eruption. In general, adults make up the majority of the cNISP assemblage with 41%. Subadults make up slightly less with 37% of the assemblage, juveniles 21%, and infants only make up 1%.

When the domesticates (*Bos*, *Ovis*, *Capra*) are considered individually, the age groupings shift only slightly from the general pattern (see Table 7). Chop marks are fairly evenly distributed amongst the juvenile to adult age categories for *Bos*, with 37% adult, 33% subadult, 27% juvenile, and 3% infant. This is somewhat similar to *Capra* with 36% adult, 43.5% subadult, 20% juvenile, and only 1% infant. *Ovis* has a slightly higher adult percentage at 48.5%, 33% subadult, 16% juvenile, and 1.5% infant. Indeterminate Ovis/Capra is comprised of 42% adult, 37% subadult, 20.5% juvenile, and 0.5% infant. These patterns change slightly within each individual time period and will be discussed below (see Table 8).

The wild species, specifically *Cervus elaphus* and *Dama dama* are dominated by adults, with only a single subadult *Dama dama* specimen.

Table 7: Species and age group categories for cNISP across all EBA time periods (relative % /absolute frequency).

Species	**Infant**	**Juvenile**	**Subadult**	**Adult**	**Grand Total**
Ovis/Capra (sheep/Goat)	0.4% /1	20.5% /51	36.9% /99	42.2% /109	100% /260
Capra hircus (goat)	1.0% /1	19.6% /21	43.3% /44	36.1% /40	100% /106
Ovis aries (sheep)	1.6% /1	15.9% /10	33.3% /24	49.2% /32	100% /67
Bos taurus (cow)	3.3% /1	26.7% /18	33.3% /11	36.7% /10	100% / 40
Cervus elaphus (red deer)	0% /0	0% /0	0% /0	100% /8	100% /8
Dama dama (fallow deer)	0% /0	0% /0	40% /1	60% /3	100% /4
Large	0% /0	0% /0	66.7% /2	33.3% /1	100% /3
Medium	9.1% /1	22.7% /5	31.8% /7	36.4% /7	100% /20
Grand Total	1.3% /5	19.5% /105	36.9% /188	42.2% /210	100% /508

VII. Patterns through time

Early Bronze Age Göltepe is divided into three periods. Period 4 corresponds to the later Late Chalcolithic and the EBA I. During this time the settlement was a small seasonal metal production site. Period 3 corresponds to the EB II. The Period 3 settlement was much larger than in the previous Period, but it remains unknown if the settlement was inhabited on a permanent year-round basis. Period 2 corresponds to the EBA III. This Period experienced changes in architectural styles and appears to be inhabited on a year-round basis. Metal production remained the major economic activity throughout the entire EBA (see Chapter 3 for further information). The chop mark data indicate some variation in species and frequency of chopped specimens through time. See Table 9 and 10 for a breakdown of Number of Identified Specimens by species, age class, and period.

Table 8: Taxonomic distribution (relative % and absolute frequency) by EBA period of cNISP from EBA Göltepe.

Species	**Period 2**	**Period 3**	**Period 4**	**Grand Total**
Ovis/Capra	57.4% /119	64% /137	3.5% /3	51% /260
Capra hircus	19% /40	9.4% /19	52% /45	20.8% /105
Ovis aries	14.4% /30	10.8% /22	17.4% /15	13.3% /68
Bos taurus	4.3% /9	4.2% /9	25.6% /22	7.8% /40
Cervus elaphus	0.5% /1	3.3% /7	0% /0	1.8% /8
Dama dama	1.4% /3	0.5% /1	0% /0	0.8% /4
Large	0.5% /1	1% /2	0% /0	0.6% /3
Medium	2.4% /5	6.6% /14	1.2% /1	4% /20
Grand Total	100% /209	100% /213	100% /86	100% /508

Table 9: Age class distributions by period (relative % and absolute frequency) of cNISP from EBA Göltepe[15].

Age Class	**Period 2**	**Period 3**	**Period 4**	**Grand Total**
Adult	44.2% /92	44.8% /95	24.5% /21	41% /208
Subadult	38.9% /81	38.2% /81	30.3% /26	37.15% /188
Juvenile	14.9% /31	16.5% /35	45.5% 39	20.8% /105
Infant	1.9% /4	0.5% /1	0% /0	1% /5
Grand Total	100% /208	100% 212	100% /86	100% /506

i. Period 4

[15] The total cNISP counts are slightly different for age and taxon listing due to weathering and root etching that inhibited age determination on a few of the specimens. The degraded specimens are included in the overall counts.

Period 4 is limited in terms of taxonomic distribution and is the only period with no chop marks found on wild species. The Period 4 material comes from a small number of contexts, as the site itself was quite small during this period. From Period 4, the cNISP count that have one or more chop marks is 86, and the number of individual identified chop marks is (cBI)174.

Capra hircus dominates the chopped assemblage and makes up 52% of the Period 4 (see Table 8) chopped assemblage (cNISP). All *Capra* chop marks, except for one located on an innominate, are located on the crania. The vast majority of the chop marks found on *Capra* crania are located as to isolate the top of the crania with both horn cores intact, or to isolate individual horn cores including a small portion of the surrounding frontal bone.

Ovis aries makes up 17% of the Period 4 chopped assemblage. All chops on *Ovis* specimens are located on the crania and are concentrated around the horn cores, except for one located on a radius.

The *Bos taurus* chop marks (25% of the chopped assemblage) are also all located on the crania and are found in very similar distribution on the crania to *Capra* and *Ovis*. The indeterminate *Ovis/Capra* category is comprised only of a small number (3 cNISP) of ribs and vertebrae.

The age of the chopped specimens of Period 4 is younger than the average overall, particularly for *Bos*. Only 4.5% of the chopped *Bos* crania were of adult age, with the majority being juveniles (77%) and subadults (18%). See Table 10 for a breakdown of Period 4 species by age Class.

The culling pattern for chopped *Capra* specimens is similar to the overall assemblage averages at 31% adult, 40% subadult, and 28% juvenile. *Ovis* is different from both *Bos* and *Capra* with 33% adult, 26% subadult, and 40% juvenile. The very small number of indeterminate Ovis/Capra specimens are 33% adult and 67% juvenile.

Table 10: Breakdown of taxon by age Class (absolute and relative frequency) of cNISP from Period 4 Göltepe.

Taxon by age class	**cNISP absolute frequency**	**cNISP relative frequency (%)**
Bos taurus	**22**	**25.58%**
Adult	1	4.55%
Subadult	4	18.18%

Juvenile	17	77.27%
Capra hircus	**45**	**52.33%**
Adult	14	31.11%
Subadult	18	40%
Juvenile	13	28.89%
Ovis aries	**15**	**17.44%**
Adult	5	33.33%
Subadult	4	26.67%
Juvenile	6	40%
Ovis/Capra	**3**	**3.49%**
Adult	1	33.33%
Juvenile	2	66.67%
Medium	**1**	**1.16%**
Juvenile	1	100%
Grand Total	**86**	**100%**

The large quantity of butchered crania and very small number of chopped axial elements for this period may indicate that the majority of butchered axial elements were disposed of away from the main living areas and were never recovered in excavation. The four contexts from which all Period 4 chopped material originated are pits within the main habitation area of the site. The excellent preservation of the crania and horn cores suggests that the pits were not left open and exposed for any length of time, and may be an intentional deposit rather than a random collection of refuse material.

ii. Period 3

In Period 3, a limited number of wild taxa are introduced into the chopped assemblage, including *Cervus elaphus* and *Dama dama*, See Table 11 for species and age class distributions. The number of identified chop marks dramatically increased in this period. However, this increase is also reflected in the NISP counts of the entire faunal assemblage (from 264 in Period 4 to 3880 in Period 3). The cNISP from Period 3 is 211, while the number of individual identified cBI (chop mark butchering incidents) is 309.

The majority of specimens that exhibit chop marks from Period 3 are identified as *Ovis/Capra* (65%). The highest percentage of chop marks identified to species come from *Ovis aries* (10.5%), followed by *Capra hircus* (9%), *Bos taurus* (4%), *Cervus elaphus* (3%), and *Dama dama* (0.5%).

Contrary to the previous period, the chop marks found in Period 3 are distributed over a wider range of elements, although crania still dominate the assemblage (17%). Commonly found chopped elements from domestic taxa are: crania, vertebra, ribs, radius, scapula, innominate and humerus. *Capra hircus* is distinct from the other taxa in that 75% of the *Capra hircus* chop marks are found on the crania. For all other domestic species, the chop marks are not concentrated on a specific element.

The majority of material from the only two wild taxa with chop marks, *Cervus elaphus* and *Dama dama*, are restricted to antler. No axial elements identified as *Cervus elaphus* are present, and only a single chopped tibia is identified as *Dama dama*.

In terms of age distribution in Period 3, *Bos taurus* and *Ovis aries* are primarily culled as adults with no examples of juvenile specimens. *Bos taurus* is represented by adults (55%) and subadults (44%). *Ovis aries* has the greatest (by only a small advantage over *Bos*) number of adult specimens with 60% adult and 40% subadult. This is very different from the previous period where both *Bos* and *Ovis* are mainly represented by juveniles and subadults. *Capra hircus* has far fewer adults in Period 3 and is similar to the pattern from the to the previous period with 41% adults, 47% subadults, and 12% juveniles. All wild specimens are of adult age. The dramatic shift in the culling age of chopped *Bos* and *Ovis* from Period 4 to Period 3 may also signal a shift in heard management practices where it became more economical to keep both species well into adulthood before they are slaughtered and consumed. See Table 11 for a breakdown of taxa by age class categories.

The deposition of the chopped assemblage from Period 3 is also dramatically different from the previous period. The chopped material is clearly refuse material and comes from a wide variety of contexts including Pit houses, pits, outdoor activity areas, Terraced buildings, and stratified fill layers.

Table 11: Breakdown of taxon by age Class (absolute and relative% frequency) of cNISP from Period 3 Göltepe.

Taxon by age class	cNISP absolute frequency	cNISP relative frequency
Bos taurus	**9**	**4.27%**
Adult	5	55.56%
Subadult	4	44.44%
Capra hircus	**19**	**9.00%**
Adult	7	36.84%
Subadult	10	52.63%
Juvenile	2	10.53%
Ovis aries	**22**	**10.43%**
Adult	13	59.09%
Subadult	9	40.91%
Ovis/Capra	**137**	**64.93%**
Adult	55	40.15%
Juvenile	52	21.90%
Subadult	30	37.96%
Cervus elaphus	**7**	**3.32%**
Adult	7	100%%
Dama dama	1	**0.47%**
Adult	1	100.00%
Large	2	**0.95%**
Adult	1	50.00%
Subadult	1	50.00%
Medium	14	**6.64%**
Adult	5	35.71%
Subadult	5	35.71%
Juvenile	3	21.43%
Infant	1	7.14%
Grand Total	**211**	**100.00%**

iii. Period 2

The chopped assemblage from Period 2 is very similar to the chopped assemblage from Period 3. Two hundred and eight (208) chopped specimens (cNISP) are identified from Period 2 with a total of 289 chop mark incidences (cBI). Relative to the overall NISP of the Göltepe faunal collection, it is strikingly similar to Period 3 (2880 NISP for Period 3 and 2785 NISP for Period 2), and a slight decrease in the number of chopped specimens is to be expected.

Once again, the largest identified taxonomic grouping is *Ovis/Capra* at 58%, followed by *Capra hircus* with 17%, *Ovis aries* at 14%, *Bos taurus* at 4%, *Dama dama* at 2%, and *Cervus elaphus* at 0.5% (see Table 12). If all the caprines are combined, then they completely overwhelm the other taxa in the assemblage – 89%. Notably, Period 2 has very few wild specimens, with three specimens identified as *Dama dama* and only one *Cervus elaphus* antler.

Crania continue to be the most commonly represented element (24%) for domestic species. The next most common elements in descending order, other than the crania, across all taxonomic categories are vertebrae, ribs, innominates, scapulae, and humeri.

Period 2 sees slightly more variation in age categories than in the previous period, specifically in the infant age group that is almost completely absent in the previous two periods (see Table 12). *Capra hircus* is comprised of 40% adult, 42% subadult, 15% juvenile, and 3% infant. *Ovis aries* is comprised of 44% adult, 33% subadult, 15% juvenile, and 4% infant. *Bos taurus* is comprised of 50% adult, 12.5% juvenile, and 12.5% infant. The small proportion of wild species are all adult except for a single subadult *Dama dama* vertebra.

It is interesting to note that chop mark patterns and animal exploitation are more similar between Periods 2 and 3 than either are with Period 4. Period 4 has only domestic species made up primarily of juvenile (45%) and subadult crania (30%). Whereas, both Period 2 and 3 are comprised of approximately 44% adult, 38% subadult, and 14-16% juvenile specimens. Both Periods 2 and 3 are comprised of a range of elements and includes a small percentage of wild taxa, which is not present in Period 4. Heard exploitation strategies seems to have shifted to a preference for older domestic animals between Periods 4 and 3, and remained fairly constant between Periods 3 and 2.

Table 12: Breakdown of taxon by age Class (absolute and relative% frequency) of cNISP from Period 2 Göltepe.

Taxon by age class	cNISP absolute frequency	cNISP relative frequency (%)
Bos taurus	**9**	**4.33%**
Adult	4	44.44%
Subadult	3	33.33%
Juvenile	1	11.11%
Infant	1	11.11%
Capra hircus	**40**	**19.23%**
Adult	17	42.5%
Subadult	16	40%
Juvenile	6	15%
Infant	1	2.5%
Ovis aries	**30**	**14.42**
Adult	13	43.33%
Subadult	11	36.67%
Juvenile	4	13.33%
Infant	1	3.33%
Ovis/Capra	**119**	**57.21%**
Adult	53	44.54%
Subadult	46	38.66%
Juvenile	19	15.97%
Infant	1	0.84%
Cervus elaphus	**1**	**0.48%**
Adult	1	100%
Dama dama	**3**	**1.44%**
Adult	2	66.67%
Subadult	1	33.33%
Large	**1**	**0.48%**
Subadult	1	100%
Medium	**5**	**2.40%**

Adult	2	40%
Subadult	2	40%
Juvenile	12	20%
Grand Total	**208**	**100%**

VIII. Fragmentation patterns within the chopped assemblage

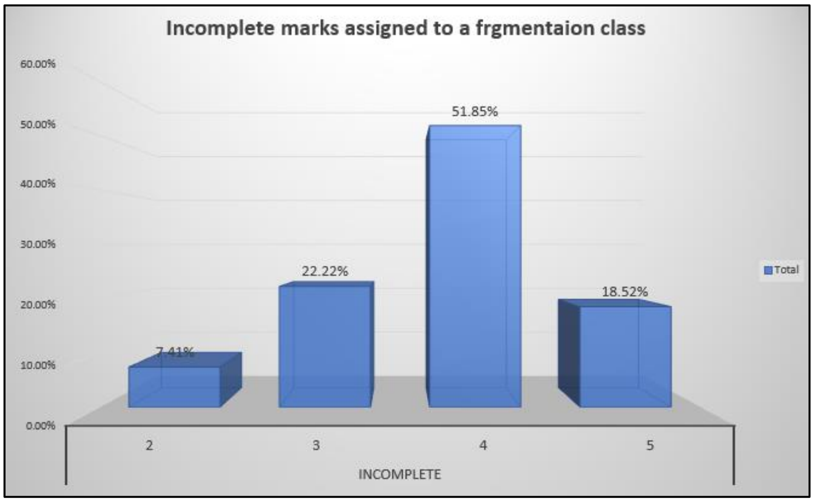
The Göltepe chopped assemblage is characterised by high frequencies of complete chop marks, extensive shearing, and low levels of crushing. In this section, the absolute and relative frequencies refer to number of individual chop mark incidences and not to NISP counts – chop Butchering Incidence (**cBI**).

i. Incomplete chop marks

The chopped assemblage contains a low percentage of incomplete marks. A very small number of cBI's (13%) did not fully penetrate through the hard outer layer of bone by cutting through it, causing it to break apart, or a combination of both. Of these incomplete marks, 68% are deep enough to be assigned to a fragmentation class: 52% are Class 4, 22% are Class 3, 18.5% are Class 5, and 7.5% are Class 2 (see Figure 39).

Class 5 marks exhibit no crushing at the point of impact and an extremely smooth cut surface that extends into the bone for at least 5 mm. Class 4 marks exhibit very little or no crushing and a sheared face that continues into the bone for at least 3 mm. Class 3 marks exhibit light or no crushing at the place of impact and controlled breakage into the surface of the bone instead of cutting/shearing. Only a few marks are Class 2. Class 2 marks have light to moderate crushing at the place of impact and uncontrolled breakage into the surface of the bone. No incomplete marks are Class 1.

Figure 39: Graph showing incomplete chop marks assigned to a fragmentation class ©Tiffany Okaluk.



Due to the depth as well as the 45˚ angle rather than a 90˚ angle of many of the incomplete chop marks, the apex line is only visible on only 3.6% of the incomplete marks. Of the visible apex lines, the vast majority are straight, narrow, and very clean with no macroscopic or microscopic pitting. Some apex lines are distorted due to root etching.

ii. Complete marks

The majority of the chopped assemblage is composed of complete chop marks (87%). Of the complete mark incidences, only 6% fall below a 3 on the fragmentation scale. See Image 40 for fragmentation class frequencies of complete chop mark incidences.

Two percent (2%) of the chopped assemblage are Class 1, and 4% are Class 2. These marks have moderate to high degrees of crushing at the place of impact and uncontrolled breakage that divides the bone. Chop marks classed between a 1 and a 2 occur across all the major chopped elements with the highest concentrations found on the crania, ribs and vertebrae (see Table 13). Marks classed as a 1 and 2 are found across all age groups with no significant patterning. No Class 1 marks are found in Period 3. Class 2 marks are found evenly distributed across all other time Periods (see Figure 41)

Figure 40: Complete chop mark incidences by fragmentation class for all Periods.

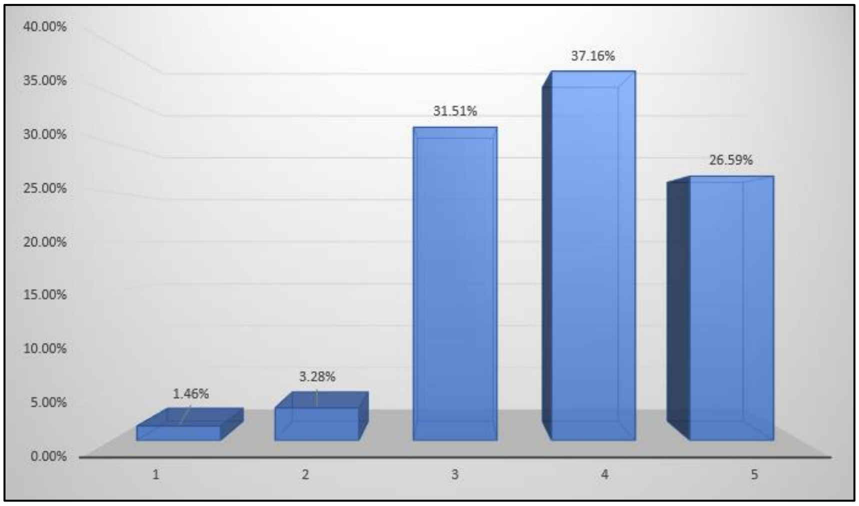


Table 13: cBI absolute and relative frequency of all chopped elements from Göltepe (all EB periods).

Element	Raw frequency (cBI)	cBI (%)
Crania	300	39%
Vertebra	108	14%
Rib	84	11%
Innominate	48	6%
Antler	40	5%
Scapula	39	5%
Humerus	39	5%
Epistropheus	23	3%
Tibia	19	2.5%
Metacarpus	16	2%
Metatarsus	14	2%
Radius	14	2%
Phalanx	6	1%
Ulna	6	1%

Femur	4	0.5%
Mandible	5	0.5%
Astragalus	3	0.5%
Atlas	5	0.5%
Patella	1	0.1%
Flat bone	1	0.1%
Total	**779**	**100%**

An incredible 94% (cBI 523) of the complete chop marks are Class 3 and above. Of these, 31.5% (cBI 173) are assigned to Class 3. Many of these chop marks exhibit no crushing and highly controlled breakage. Although these chop marks consist fully of breakage rather than cutting, it is sometimes possible to see the location/depth of the kerf fracture. This means that the axe entered into the surface of the bone before causing the bone to split from wedge action pressure, and that the bone did not completely fracture immediately upon contact. The distance from the point of entry to the location of the kerf fracture was measured when visible. This distance varies from 4-10 mm, but is only measurable in 5% of the Class 3 marks. Class 3 chop marks occur most frequently on the crania, vertebrae, and ribs, although they also occur infrequently on a wide range of elements. All age categories are represented within this group with no significant patterning. Class 3 chop marks are also found within all time Periods at around 30% distribution for all time Periods. See Figure 41 for comparison of fragmentation pattern to time Period.

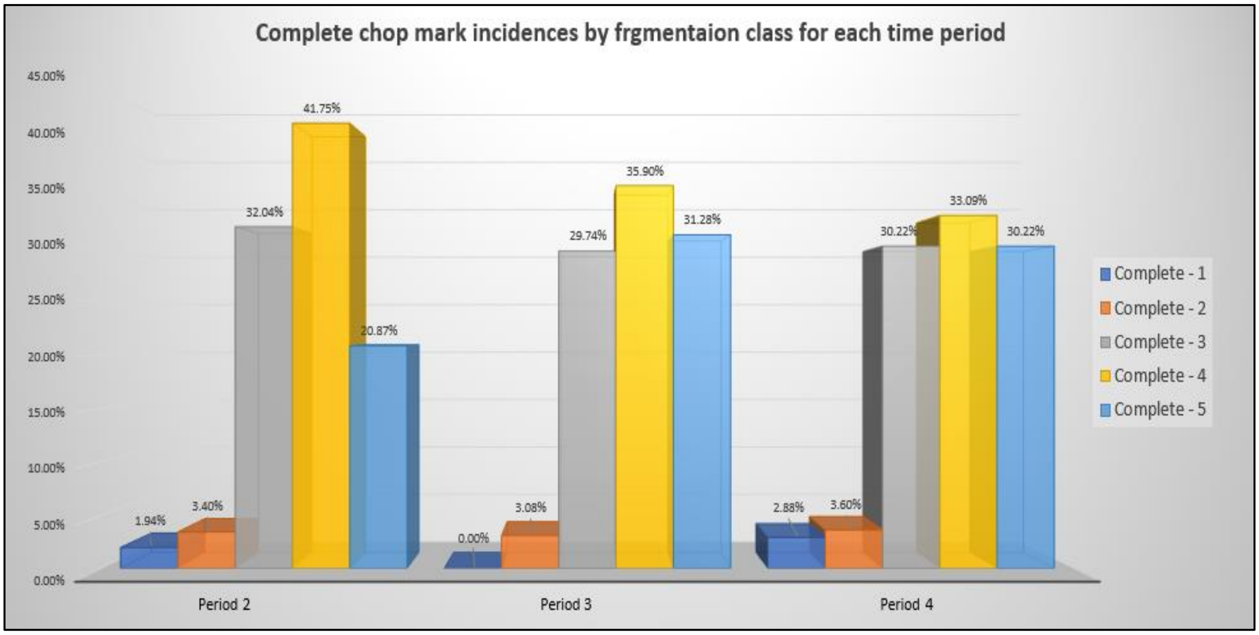
Complete chop marks categorised as a Class 4 of the fragmentation scale constitute 37% (cBI 204) of the total complete chop mark incidences and are the largest class of chop marks (Figure 40). The marks are highly recognisable as the bone exhibits a clean cut surface with a kerf fracture extending from the final penetration point of the axe. Only two chop marks in this group have light crushing at the place of impact, whereas, the majority have an almost perfectly clean entry point. Depth from point of impact to kerf fracture (sheared surface) was visible in 34% of the marks. Depth is not visible on all chop marks due to the location, position, and condition of some of the marks. A chop often shears off the edge of a small process and leaves no kerf fracture, and thus, no measurable depth. Chop marks can also be broken in antiquity and only leave partial depths that are not quantifiable. Of the quantifiable depth measurements, the Class 4 chop marks range between 3 and 17 mm.

The majority of the Class 4 marks are found on the crania, ribs, and vertebrae, but also occur on 13 different elements and include the widest variety of elements of any fragmentation class. No significant patterning is observed between element or age class within this group as all major age categories are represented and are fairly evenly distributed. Class 4 chop marks are the most common fragmentation class found across all time periods.

The third largest fragmentation group is Class 5 (26%; N=146). This class group is defined by an extremely controlled mark with no crushing and an exceptionally clean sheared surface that continues into the bone for five or more millimetres. Chop marks on the crania represent almost 50% of the Class 5 marks. Marks on the vertebra are also significantly more frequent (18%) than other elements. The remainder of the Class 5 marks are distributed across the commonly chopped elements. All age group are represented with adults only slightly more common than in other class groups. The higher number of adult specimens may be due to the dense structure and fused nature of the bone which is less likely to fragment along weak suture or fusion lines on impact allowing for a clean, deep chop mark. This is also a pattern that was noted in the experimental sample.

Depth of the sheared surface before kerf fracture was measurable on 35.5% of the complete Class 5 chop marks. Some of these chop marks are exceptionally deep. The depths ranged from 4 mm up to 30 mm and averaged anywhere from 8-15 mm. This is well beyond depths created by the experimental sample and indicate than an extremely thin and sharp axe created these chop marks.

Figure 41: Graph showing complete chop mark incidences by fragmentation class for each time period.



IX. Bash marks

A limited number of hammer stone percussion marks were identified on the assemblage, although they are not common. Hammer stone percussion marks (semi-circular notches) (Pickering and Egeland 2006) are found mainly on long bone shafts and are likely associated with marrow extraction (see Figure 42).

Figure 42: Photograph of hammerstone percussion mark on an *Ovis/Capra* metatarsus from Göltepe FCN E70-0100-003, MRN 2297, Bone 109, Period 2 ©Tiffany Okaluk.

X. Chop marks versus chisel marks in relation to tool production

All chop marks found on wild cervidae antler are associated with tool production. The antler fragments are often hollowed out with multiple chop/chisel marks that encircle the tine and produce a smooth edge around the circumference of the tine or beam section (see appendix for additional images). These specimens were likely parts of handles, or scrap material from handle production. Multiple, deep marks are visible on almost all antler material. While many of the marks are complete marks, some are incomplete marks. Often, incomplete marks do no accurately represent the full length of the cutting bit due to the irregular shape of most bones. However, some flatter sections of the antler along the main beam have incomplete marks that are too short to have been made by an axe. These incomplete marks average 13 mm in length across a flat surface. Incomplete marks found on other elements measure an average of 25 mm across an uneven or broken surface and only represent a portion of the length of the cutting bit. Figure 43 is an image of metal chisel mark and Figure 44 are two separate incomplete axe marks on the same epistropheus. The axe marks in Figure 44 do not represent the total length of the tool as the mark on the left is broken, and the mark on the right (lower right hand corner) hit the edge of the bone. The incomplete axe marks shown in in Figure 44 are both longer than the chisel mark. The mark in Figure 43 was made by a different tool than the marks in Figure 44 as the lengths of the tool bits are different. Both bones come from the same Period 3 context.

In all other aspects, the small incomplete marks found on antler appear as Class 4 or 5 chop marks. The obtuse angle is always sheared and mirrored by a rougher side that may, or may not have an acute angle wedge fracture. The apex of these marks are narrow and straight. Rosen (1997: 93) identifies bit length as the distinguishing characteristic between an axe and a chisel. The archaeological record shows that EBA axe bits were much longer than 13mm, and thus, some of the marks associated with tool production are identified as metal chisel marks.

It is not unique to find metal EBA metal chisel marks on antler. In her study of Early Bronze Age tool manufacture in England, Olsen (1988) found that metal chisels as well as metal axes were used on antler material. Olsen (1988: 349-350) identified her chisel marks from a series of striated gouges. Striated chisel gouges were also identified on Göltepe antler remains (see Image 45).

Figure 43: Photograph of metal chisel mark in *Cervus Elaphus* antler FCN B05-0700-000, MRN 4819, Bone 9, Period 3 ©Tiffany Okaluk.

Figure 44: Photograph of two separate incomplete metal axe chop marks on opposite sides of the same *Ovis aries* epistropheus FCN B05-0700-000, MRN 4819, Bone 3, Period 3 ©Tiffany Okaluk.

Figure 45: Photograph of striated metal chisel gouges on Cervus elaphus antler FCN E69-0100-008, MRN 2210, Bone 10, Period 3 ©Tiffany Okaluk.

XI. *Discussion*

The chopped assemblage from Göltepe was analysed for taxonomic patterning, culling strategies, and fragmentation patterning to better understand how and why the animal resources from EBA Göltepe were butchered.

i. *Heard management strategies*

The majority of the chop mark incidences are found on domestic species throughout all EBA Periods and suggests a heavy reliance on domestic, pastoral species, especially sheep and goats. The shift in age class frequencies between Period 4 and Period 3 strongly suggests that heard management strategies for both *Bos taurus* and *Ovis aries* shifted from a reliance on their primary products to more diversified herd management strategies that likely included the utilization of more secondary products as many more individuals were kept into adulthood with less culled as juveniles. The consistency between Period 3 and Period 2 for age group categories, element distribution, and taxa is strikingly similar and suggests that there was very little change in heard management strategies and butchery practices between these two later Periods.

The excavators of Göltepe remain unsure if the Period 3 settlement was seasonal as it was in Period 4, or inhabited on a year round basis as it was in Period 2 (Yener in press). The faunal data suggests that a shift in pastoral practices took place between Periods 4 and 3, and not between Periods 3 and 2. This may indicate that Period 3 was occupied on a year-round basis or at least in a very similar way to Period 2. Overall NISP and cNISP counts are actually highest in Period 3 and slightly decrease in Period 2. Full analysis of the entire Göltepe faunal assemblage will be published elsewhere.

ii. Fragmentation patterning and metal axe use

The high percentage of chop marks that exhibit shearing, no crushing, and a depth measurement over 5 mm (64%) demonstrate that the majority of chop marks found on the Göltepe assemblage were made by thin, sharp axes. Experimentation proves that sheared surfaces can only be created by metal axes, as stone axes that are strong enough to handle high-speed impact forces are too wide and dull to cut into the bone before significant fragmentation occurs (wedge action). Moreover, the experimental samples created by both the copper and bronze axes found that an assemblage that exhibits over 17% sheared marks (Class 4 and 5 on the fragmentation scale) can be solely created by metal axes. The depth of many of the sheared marks is remarkable and far exceeds any of the depths created by the experimental metal axes. The depth of the Göltepe sheared marks averaged between 3-15 mm, but reached up to 30 mm. The experimental sheared surfaces ranged between 3-10mm, and averaged between 3-7 mm. The extensive shearing on the Göltepe marks is likely due to the skill and strength of the butcher and possibly the sharpness of the axe. The Göltepe chopped assemblage exhibits shearing on 64% of the identified marks, leaving no doubt that the majority of chop marks were created by metal axes. While it is not impossible that some of the lower Class marks (1-3) were created by ground stone axes, it is unlikely. Metal axes will not always produce shearing depending on the angle of the chop, structure of the bone, and side of the chop recovered (obtuse vs. acute). Shearing on 100% of chopped material chopped with a metal axe is impossible, as even if every chop with a metal axe creates a sheared surface, and both sides of each chop mark are recovered, shearing would only be present on 50% of the chopped assemblage. The fact that shearing is present on 64% (<50%) of the Göltepe assemblage is likely due to the recognition bias for sheared chop marks as well as preservation and recovery methods. Stone axes are incapable of creating the majority of the chop marks found on the Göltepe assemblage.

iii. Tool production on Cervidae antler

The use of chisels as a means to break apart bone in a controlled manner seems to be isolated to tool manufacture, however, this can-not be definitely proven as metal chisel marks leave many of the same signatures as metal axes, including no significant crushing, a sheared obtuse surface, and an acute angle wedge fracture. Due to the varied lengths of many of the incomplete marks not associated with tool manufacture that measure over 13 mm in length, is very unlikely that the marks were created by metal chisels.

XII. Conclusion

The axe was an important dismemberment butchery tool at EBA Göltepe. The Göltepe chopped assemblage shows that the axe was the primary tool used in dismemberment of the limbs from the torso, and the reduction of the axial portions into smaller portions. Axes were less often used in disarticulation, but chops are found across the transverse plane of a limited amount of distal humeri and proximal tibia suggesting that axes were used to further divide the animal at the joints. Axes were also used for splitting the bone, likely for marrow extraction, although once again, this is not as common as dismemberment (Binford 1981).

There is very little variation between periods in regard to fragmentation patterns within the chop marks and shows that metal axes were consistently used in butchery from at least the transitional Late Chalcolithic/EB I through the end of the EB III at Göltepe. The following chapter will further explore and elaborate on these data from Göltepe within the context of Anatolian metal production and previous slice mark data.

Chapter 8: Axes before knives: the use of metal axes in butchery at EBA Göltepe

I. *Introduction*

The study of ancient butchery tools and the marks they leave behind on bones is not a new concept in archaeology (Walker and Long 1977, Greenfield 1999, Olsen 1988). However, the primary focus of butchery studies in archaeology is, and always has been slice marks (Greenfield 1999, Pickering and Hensley-Marschand 2008, Courtenay et al. 2019). Chop mark studies are rare in the history of zooarchaeology (Shipman 1981), but are essential as chop marks often constitute a significant proportion of the butchered assemblage (Greenfield, Cheney, and Galili 2016, Greenfield and Horwitz 2012, Greenfield, Galili, and Horwitz 2006). The Göltepe faunal assemblage is unique as both the chop marks and slice marks have been extensively analysed to reveal differential patterns of material use in regard to slicing and chopping implements. Slice mark analysis was conducted by Greenfield and Chaput (in press) using SEM imaging that followed Greenfield's (1999) method on the differentiation between stone and metal slice marks.

The differentiation between metal and stone butchery for both slice marks and chop marks is an essential line of evidence for tracking and understanding the adoption of metal butchery tools, particularly in the EBA. Both metal and stone axes are a relatively rare find in EBA Anatolia with the majority recovered in funerary contexts. As they are rarely discovered in occupational deposits, denoting specific tool function can be problematic. The use of butchery marks to connect a specific tool and material type to an action is important and enables a functional designation as so many tools were likely 'multi-purpose'.

This chapter explores how the use of metal axes in butchery at EBA Göltepe relates to previous research on the adoption of metal blades in Near Eastern butchery practices. Differential rates of adoption are suggested by these data for the axe and knife in south central Anatolian butchery practices.

II. *Longitudinal slice marks data for the introduction of metal blades in butchery*

The rise in the number of metal axes recovered archaeologically dramatically increases from the Chalcolithic to the EBA in Anatolia (Stos-Gale, Gale, and Gilmore 1984, Efe and Fidan 2006), however, until now it remained unknown if metal axes were used in butchery. There is also a dramatic increase in the number of metal daggers and knives archaeologically recovered from the Chalcolithic to the EBA in Anatolia (Arcan 2012), but research suggest that it is unlikely these blades were used in butchery. A *Longue Durée* study of the slice marks found on the Çatalhöyük

East faunal assemblage by Greenfield and Marciniak (2019) found that metal blades did not commonly function as butchery tools before the Hellenistic period. Only one metal slice mark was found from EBA levels. Even in the Hellenistic period, only 29% of the slice marks were found to be made by metal knives. Rather than metal, chipped obsidian implements were the preferred slicing material used in butchery. These slice mark data suggest that the pattern for the adoption of metal knives into butchery practices was later at Çatalhöyük when compared to the southern Levant.

To understand the adoption rate of metal blades in the southern Levant, Greenfield (2013) conducted a longitudinal study that looked at 27 assemblages across Israel ranging in time from the proto-Neolithic through to the Roman and Islamic Periods. With over 3000 samples analysed, a very clear pattern emerged. With the exception of a few outliers, no metal knives or slicing implements were used in butchery before the Early Bronze Age in the southern Levant. Throughout the Early Bronze Age, there are very low frequencies (c. 10%) of metal slice marks on bone in the southern Levant with the exception of Jericho which exhibited 41% metal blade use. Greenfield notes that the results for Jericho are unusual and clearly do not fit the pattern seen at all other sites. He suggests this may be due to stratigraphic issues, and this discrepancy may be resolved as the material from Jericho is currently under reassessment. The consistent, low usage of metal blades indicates that even though metal blade technology was available by the EB III, it was not adopted as a common butchery tool at any point during the EBA.

Metal blade usage in the Middle Bronze Age (MBA) increased substantially, averaging 60-80% of slice marks at some sites (Greenfield 2013). This indicates true adoption of metal blade technology and metal was the preferred butchery material in the MBA. The jump in metal blade usage is extraordinary, and curiously, without any evidence of a gradual intermediate or transitional Period. Greenfield (2013) suggests that the transitional Period likely took place in the EBA IV/Intermediate Bronze. Recently, he has concluded analysis of assemblages in Jordan where EB IV/IB strata are present and there is no evidence for an increase in metal slicing marks there (Greenfield, Beller, and Gaastra 2021). This is important since the EBA IV is the time period when 10% tin-bronze is introduced to the southern Levant (Rosenfeld, Ilani, and Dvorachek 1997: 857). Bronze is a much more effective cutting tool than pure copper due to its ability to retain a sharp edge. Whether or not the introduction of bronze technology was a contingent factor in this process is yet to be determined.

Frequency patterns remained fairly constant for both the Late Bronze Age (c. 89%) and slightly higher (95-100%) in the Iron Age. It is important to note that stone blades do not completely go out of use, and even in the modern Arab samples analysed less than 10% of all slice marks are shown to be made by stone blades. Greenfield (2013) observes that the adoption process for metal blades in butchery is not gradual, but punctuated, with long periods of consistency and sudden jumps in frequency that possibly correlate with the introduction of new technologies. This pattern coincides with the decline of stone tool production and reduction of types found across the southern Levant from the beginning of the EBA on (Rosen 1997: 151).

This type of longitudinal study is rare in butchery analysis, yet the results emphasize the value of butchery mark analysis beyond its use in subsistence studies. Technological transitions are an important part of archaeological inquiry, yet are very difficult to track when relying on tool frequency alone. Greenfield (2013: 174) notes that the majority of stone slice marks from the EBA are made with simple unifacial flakes, yet in lithic studies these types of *ad-hoc* tools never get more than a brief mention with little discussion of the importance they played in everyday activities (cf. Rosen 1997). Butchery analysis allows the archaeologist to see what tools were actually used for different tasks and their relative frequency in everyday butchering activities.

III. Slice marks at Göltepe

A sample of slice marks from all four (EBA and Iron Age) occupational time periods at Göltepe were previously analysed by Greenfield and Chaput (in press). Their analysis found no evidence for metal slice marks on bone in either Periods 4 or 3 (EB I and II), and very low frequencies of metal blade use in Period 2 (EB III). This pattern changes to a more even frequency distribution of metal and stone slice marks during the Iron Age occupation (Period 1). The majority of the stone slice marks were found to be made by simple, unifacial obsidian flakes/blades (Greenfield and Chaput in press).

The slice mark data from Göltepe do not fit the patterns seen at Çatalhöyük East or many sites from the southern Levant and re-enforces the need for more butchery studies across Anatolia. The use of obsidian as a cutting tool is not unexpected as it can be exceptionally sharp when broken (Greenfield and Marciniak 2019), was readily available around Göltepe, and was recovered from the excavations (Yener in press: 96). Greenfield and Chaput (in press: 471-472) argue that efficiency was a key aspect for retaining stone technologies for slicing as slice mark frequency actually increases with the use of metal blades. This can be interpreted as indicating that more slices were needed to complete the same butchering task. Stone blades were accessible, economic, and efficient. Therefore, they retained an active role in butchery activities well after metal blades became available. Stone axes however, are not as efficient as metal axes (Mathieu and Meyer 1997).

IV. *Chop marks at Göltepe*

The chop marks from Göltepe were consistently created by metal axes in all EBA time periods. The extreme depth and low levels of fragmentation of the bone from many of the Göltepe chop marks shows that they could have only be created by very sharp and thin axe. The experimental study demonstrates the fragility of thin, sharp stone axes wielded at high speeds. The force needed to cut dense bone to the depths seen on the Göltepe assemblage could only be completed by a tool that is thin, sharp, and structurally stable. The ability for pure copper to create the kinds of chop marks found on the Göltepe assemblage is questionable in light of the experimental results, and it is more likely the chop marks were created by bronze or arsenical-copper axe heads. As Göltepe is a tin production site, it is not unreasonable to suggest that the chop marks may have been made by bronze axe heads as 54% of all metal artefacts found at Göltepe are made from bronze.

Stone axes are considerably less efficient than metal axes. This was noted by Mathieu and Meyer (1997) in relation to experimental tree felling. Stone axes are also less efficient butchery tools as found by the current study. Stone axes create high levels of fragmentation and uncontrolled breakage. Multiple chops with stone axes are often needed to sever the bone and results in many bone splinters that become embedded into the consumable meat and makes consumption unpleasant. This is evident from our chopping experiments with ground stone axes. The meat from all chopped pig ribs was consumed. The meat was removed from the rib bones as part of the processing and then consumed 'for dinner'. The meat chopped by the ground stone axe experiments was difficult and unpleasant to consume due to tiny bone splinters imbedded in the meat that were impossible to remove through visual inspection. Both the copper and bronze axe did not create this problem. Ground stone axes are not *ad-hoc* tools, in contrast to simple chipped stone slicing blades. Although the material (stone) may be readily available, a ground stone axe requires a considerable time investment to create (Clark 1965). At a site such as Göltepe where metal was likely readily available, stone axes may not have been a more economical option.

No metal axes were recovered from the Göltepe excavations, although two axe moulds were recovered from Period 3. A fragment of a ground hematite axe was also recovered from a Period 3 pit house floor. This indicates that both metal and stone axes were present at the site, but that they were not haphazardly discarded and were likely valuable objects. No chop marks were confirmed as created by stone axes and shows that ground stone axes did not regularly function as butchery tools at Göltepe even though both types of axes were available. Interestingly, the use of metal axes at EBA Göltepe does not increase through time. This suggests that the adoption process for the preferred use of metal axes in butchery took place before the Chalcolithic/EB I transition in south central Anatolia.

V. The use of metal tools at Göltepe

The recovered metal finds from Göltepe are not overly impressive, nor do they suggest that metal tools were extensively used in everyday situations. The EBA metal finds mainly consist of small items of personal adornment, such as pins, rings, and bracelets. The only functional items recovered were two metal chisels, an awl and a needle. However, 54% of the metal items from EBA contexts were made of bronze with the majority of bronze artefacts dating to between 2900-2400 bce (Yener in press). The enormous quantity of ground stone tools found across the site from all EBA Periods (mainly grinding stone and pounders) and obsidian flakes would suggest that stone tools were the preferred utilitarian tool material. Slice mark analysis on the faunal assemblage supports the hypothesis that metal tools were not extensively used in the EBA, nor were they integrated as a part of everyday butchery activities. However, analysis of the chop marks found on the faunal material from all EBA periods indicates that this was not the case. Metal axes and chisels were extensively used in butchery and tool production. Metal chop marks on butchery remains were found across all periods and were not reserved to specific contexts. Metal chop marks on faunal material were found in Pit Houses, dirt and stone lined pits, outdoor activity areas, Terraced Buildings 1 and 2, stone foundation buildings, stone installations, thermal installations, and middens. This indicates that all butchers had access to metal axes and that metal axes were an everyday tool available to the general population of EBA Göltepe, even though metal axes are physically not present in the archaeological record at the site.

The extensive use of metal tools in butchery provides new evidence for how metal functioned and was used within EBA Anatolian society. While metal was clearly a prestige material used by the elite classes to differentiate themselves as powerful leaders, metal was not exclusively reserved for the elite class. Metal was used, traded, and consumed by both elite and non-elite individuals. However, investigation into the use of metals by the non-elite requires more detailed research methods such as butchery analysis, as it may not be self-evident in the material culture.

VI. Trade networks

The production of metal objects has a long history in Anatolia. Although a dramatic increase in the volume, diversity, and skill of metal production took place in the EBA, the technological systems had been slowly developing since the Neolithic. EBA funerary deposits across Anatolia demonstrate the importance of metals to both elite and non-elite individuals, with copper, arsenical-copper, and bronze axes and knives (along with many other metal items) found in many EBA funerary deposits (Geniş and Zimmermann 2014, Massa, McIlfatrick, and Fidan 2017, Massa 2014). By the Anatolian EB III, metal objects had permeated Anatolian culture. The metal objects removed from circulation and found in funerary contexts likely represent only a fraction of the available metal resources (Stork 2015). The technological systems associated with metal production grew exponentially throughout the EBA and is probably related to the emergence of local elites, social stratification, and increased trade (Sagona and Zimansky 2009: 144, Efe 2007).

The degree to which metal production was (or was not) an attached specialisation is difficult to assess. No evidence for administration was recovered from Göltepe, although it is theorised that Göltepe was connected to a lager regional centre in the Niğde area (Yener et al. 2015, Yener in press). The presence of many stone weights that fit the standard Mesopotamian measurement system at Göltepe (Yener in press: 375) supports the idea that there was some internal regulation of commodities and connection to Mesopotamian trade networks. The multiple ingot moulds found at Göltepe as well as the archaeological evidence for a wide geographic dispersal of bronze artefacts originating from the Bolkardağ region suggests the trade networks connected to Göltepe stretched from the southern Levant (Garfinkel et al. 2014), Mesopotamia (Massa and Palmisano 2018: 16-17), Cyprus (Webb et al. 2006), and western Anatolia (Efe 2007).

The use of metal axes (possibly bronze) in everyday butchery activities at Göltepe demonstrates that metal tools were readily available at EBA Göltepe. This suggests that metals were not reserved only for export and that there was also an inflow of finished metal products (or copper ingots) along with their tin exports.

VII. Comparative evidence

There is approximately a millennium between the adoption of metal axes and the introduction of metal knives in butchery at Göltepe. However, we do not know if this pattern is a local or regional phenomenon. Although Göltepe had unique access to metal resources as a metal production site, it is unlikely that the residents of Göltepe existed in a social bubble. Period 4 Göltepe was a seasonal metal production site, and for part of the year, the residents must have resided elsewhere. Since metal axes were used in butchery at Göltepe during Period 4 (EB I), then metal axes were presumably also in use at other (nearby?) sites as well.

Preliminary chop mark evidence from the butchered assemblage at Tell eṣ-Ṣâfi/Gath (Area E), Israel suggests a somewhat similar pattern to Göltepe was developing in the EB III. Tell eṣ-Ṣâfi/Gath is an EB III urban settlement located in the Shephelah of the southern Levant (Greenfield, Shai, and Maeir 2016). Slice mark analysis from EB III material recovered in Area E has found no evidence for the use of metal blades in butchery (Greenfield, Shai, and Maeir 2016: 485). However, chop mark analysis found some evidence for the use of metal axes in butchery throughout the EBA strata. While the use of metal axes at Safi (cBI 17) is not as prevalent as at Göltepe (cBI 779), the presence of a limited number of metal chop marks from the earliest EBA strata onward is undeniable. The chop marks interpreted as metal exhibit little to no crushing on the a sheared surface, and have a thin straight apex line (see Figure 46 and image appendix). The chop marks from Tell eṣ-Ṣâfi/Gath are not as deep as the Göltepe marks. Of the measurable depths, the Tell eṣ-Ṣâfi/Gath marks average 5-10 mm in depth, with the deepest being 15 mm. As there is no evidence for bronze in the southern Levant EB III, these marks have to have been made by either a pure-copper or arsenical-copper axe head. The meagre depths of the marks suggest the marks were more likely made by a pure-copper rather than an arsenical-copper axe head. A copper axe head was recovered from the alleyway of the EB III residential neighbourhood in Area E (Haskel Greenfield, personal communication).

Figure 46: Photograph of multiple incomplete metal chop marks on a Ovis/Capra vertebra from EBA Tell Tell eṣ-Ṣâfi/Gath. ©Tiffany Okaluk.

Metal chop marks are found only sporadically scattered throughout the Tell eṣ-Ṣâfi/Gath EB III strata even though the number of chop marks in general were not great (cBI 17). The low number of identified chop marks may be due to the difficulty of recognising highly fragmented chop marks on as they often resemble natural breakage (Class 1 and 2). The faunal assemblage itself also suffered from high levels of fragmentation. This is problem particularly evident in southern Levantine EBA assemblages where preservation is often poor. Therefore, the evidence does not suggest that metal axes were a common butchery instrument used throughout the EBA at Tell eṣ-Ṣâfi/Gath. However, it is apparent that they were used occasionally indicating that the residents had at least occasional access to metal axes and that they made the active choice not to fully incorporate them as a butchery tool.

The occasional use of metal axes paired with the exclusive use of stone blades in butchery in Tell eṣ-Ṣâfi/Gath is different from the pattern seen at Göltepe. Yet, it still provides evidence for the earlier use of metal axes in butchery when compared to metal blades. Research and analysis of the chop marks at Tell eṣ-Ṣâfi/Gath is ongoing and will be fully reported upon and published elsewhere.

VIII. Technological choice

The decision of an individual to use one technology instead of another is rarely based solely on functionality (Dobres and Hoffman 1994, Dobres 2000, Lemonnier 1992). However, a functional argument for the early adoption of metal axes should not be avoided either. The evidence for the superior functionality of metal axes is strong (Mathieu and Meyer 1997) and is reaffirmed by this experimental study, but social reasons likely also played a roll.

Beginning in the Neolithic, axes straddled the divide between a ceremonial and functional object. Ground stone axes are a high-time investment object and are found deposited as unused objects often in ceremonial contexts, but they are also found broken and well used in occupational strata (Özkaya 2009). Stone axes are found made from both exotic (jade) (Hansen 2013: 141) and common materials (basalt and flint), and were at no point confined to a single material type. Early experimentation with a new material type (metal) is therefore not unexpected nor out of character for this object. Whether or not the earliest metal axes were exclusively ceremonial or prestige objects remains unknown. The superior functionality of metal axes could not have gone unnoticed and likely contributed to the early adoption of the new material type. However, the retention of older technologies through the EBA once again suggests the cultural fluidity of axe material type. It seems that it was not the material that defined an axe as an "axe", but rather its form and function. Similar to Neolithic and Chalcolithic ground stone axes, metal axes in the EBA are also found both used and unused in funerary deposits, suggesting the cultural significance of the tool did not change with the introduction of the metal form.

Bronze metal knives are not necessarily functionally superior to stone knives because this depends on the level of alloying. Also, obsidian blades can be much sharper than even 10% tin-bronze and have been used in surgical procedures in the recent past. They cut very finely and produce less dramatic surgical scars (Buck 1982, Crabtree 1972, Disa, Vossoughi, and Goldberg 1993). Yet, by the Middle Bronze Age in the southern Levant, the Iron Age at Göltepe, and the Hellenistic at Çatalhöyük, metal knives began to replace stone in butchery practices (Greenfield 2013, Greenfield and Marciniak 2019, Greenfield and Chaput in press). If this cannot be explained by superior function, why did the change occur? For a society to adopt a new technology, it must be deemed as socially acceptable by that society. Ethnographic research shows that a functionally superior technology will never replace an inferior technology if the superior technology does not fit with acceptable social ideals of what that technology 'should be' (Lemonnier 1992). Changes to butchery tool types and materials may also suggest a shift in dietary practices, food preparation methods and/or culinary trends. Improved dismemberment tools may have stimulated heightened the use of heavy tools in butchery

Unlike the metal axe, which is functionally superior to stone (Mathieu and Meyer 1997), the eventual adoption of metal blades in butchery is puzzling from a functional perspective. Why would individuals choose to use a less efficient tool? Metal knives are found in Chalcolithic/EBA burial and occupational contexts in Anatolia (Massa, McIlfatrick, and Fidan 2017), the southern Levant (Oakberg, Levy, and Smith 2000), and Cyprus (Webb et al. 2006). Yet the evidence from Göltepe and Tell eṣ-Ṣâfi/Gath suggests the use of metal knives in butchery commenced significantly later than the use of metal axes in butchery. This means that there were cultural factors and preferences that either (a) halted the early use of metal knives in butchery or (b) stimulated it significantly later than axes and chisels. It seems more likely that the use of metal blades in butchery was stimulated by deep permeation of metals into social contexts, and not by functionality.

It appears as though the adoption process for metal tools in butchery was unique to each tool type and geographic region, as already noted for the complementary abandonment pattern of lithics (Rosen 1997). While it is impossible to know the 'true' social reasons why new technologies were adopted at specific points in time, the investigation into functional capability, availability, and actual use patterns offers feasible lines of investigation to frame interpretive arguments. Butchers at Göltepe had choice in their butchery tools, and they chose to use metal axes and chisels, stone blades, and hammer stones.

IX. Conclusion

The time disparity between the sustained use of metal axes in butchery and the introduction of metal blades into butchery practices at Göltepe is substantial. Although metal tools and objects are often part of the same technological and social systems, it is clear that individuals and groups choose how and when to integrate or replace accepted technologies. Why and when this takes place is determined by a combination of social and functional factors. The early adoption of metal axes into butchery practices offered a functional improvement to animal carcass dismemberment. The axe was also one of the earliest smelted metal objects, appearing significantly earlier than the dagger or knife in Anatolia (Zimmermann 2004-2005, Yener 2000: 32, Caneva, Palumbi, and Pasquino 2012: 369), which may have been a contributing factor for its early adoption in butchery. The axe was also clearly an object that was socially acceptable in many different forms regardless of material type. If technological adoption is punctuated rather than gradual as suggested by Greenfield (2013), the adoption of metal axes in butchery took place before the EB I in south central Anatolia, almost a millennium before the introduction of metal blades into butchery practices across the Near East.

Unlike the stone blade industry which continued to thrive throughout the Early Bronze Age, stone axe production in the Early Bronze Age is rare. Stone axes that are found in EBA contexts look significantly different than the abundant flat stone axes found throughout the Neolithic and early Chalcolithic. EBA stone axes are predominantly shaft-hole style with a wide body and steep pitch leading to a dull cutting bit (Massa 2014). In the Late Chalcolithic both stone and metal axes are both commonly found, but by the EBA stone axes are rare (Rosen 2013: 146, Stos-Gale, Gale, and Gilmore 1984, Şahoğlu and Tuncel 2014). While stone axes do not totally disappear from Anatolia during the EBA, they do completely disappear in the southern Levant after the EB I (Rosen 1997: 98, 2013: 146). Rosen points out this change within the lithic industry many times (Manclossi, Rosen, and Böeda 2019, Rosen 1997, 2013). He also attributes the disappearance of stone axes to the rise of their metal counterparts .

The findings within the study are therefore, not unexpected. The dominant material type for axes in the Early Bronze age was metal (Shalev and Braun 1997, Stos-Gale, Gale, and Gilmore 1984: 38-40, Massa, McIlfatrick, and Fidan 2017). Axes were primarily made from copper, arsenical-copper, and bronze, depending on the region. While it is important to test all the possible chopping implements to understand the marks they create, it is also very important to understand the context and variation within the archaeological record for the region and time period to support interpretation.

Chapter 9: Conclusions

I. *Research aims*

This thesis aims to identify the raw material of the axes responsible for creating the chop marks found on the Göltepe faunal assemblage. This was accomplished through a series of experiments using replicas Bronze Age axes on multiple types and size classes of animal bone. The study identified the signature criteria of different axe material types (chipped stone, ground stone, copper, and bronze) and allows for the differentiation of metal and stone axes marks on archaeological bone. This thesis also created explicit criteria for the identification chop marks on bone in general.

II. *Research findings*

The residents of EBA Göltepe chose to use the tools that they deemed to be appropriate for specific tasks. These ancient people chose to butcher using metal axes and stone blades. Although no metal axes were recovered from Göltepe, two axe moulds were recovered which hints at the local production of metal tools (Yener in press: 370). A single ground hematite axe fragment was also recovered, which shows that the residents at Göltepe had choice in their chopping tools, although they likely exclusively used metal axes for butchery (Yener in press: 203).

It is significant that the metal axe usage does not increase through time at Göltepe. The earliest faunal deposit from the site dates to the Late chalcolithic/EB I transition. This rather unique deposit of horn cores are covered with Class 4 and 5 chop marks. Sheared chop marks strongly outweigh non-sheared marks in all periods, meaning that this was not a transitional period between the use of stone and metal axes. If an archaeologically visible transitional period exits for stone and metal axes, it took place earlier than the Late Chalcolithic/EB I transition in Bolkardağ region of Anatolia.

The time discrepancy of almost a millennium between the sustained use of metal axes and the beginning of the use of metal knives in butchery fits with the material culture of the period. Metal axes are one of the earliest cast metal tools, appearing around 4600 BCE in Anatolia (Caneva, Palumbi, and Pasquino 2012, Yener 2000), and stone axe production begins to significantly taper off around 3000 BCE (Rosen 2013). From experimentation, we know that metal axes are much more efficient than stone axes as they create less fragmentation with fewer blows needed to sever the bone. Stone knives however, are just as efficient as metal knives, as well as requiring less complex chains of production. Therefore it is important to recognize that each tool type will likely have its own historical trajectory and reasons why the preferred material type might change through time.

III. *Summary of the method*

Experimentation found that chop marks are incredibly variable and can range from completely fragmentary to an exceptionally smooth cut surface. Chop marks can also take the form of a complete or incomplete mark.

i. *Incomplete chop marks*

An incomplete mark does not sever the bone, but instead leaves either a shallow or deep U/V shape depending on the material of the axe. Chipped stone axes create an uneven, wavy, and pitted incomplete chop mark. Ground stone axes create a U-shaped incomplete chop mark with a slightly pitted apex. Metal axes create strong V-shaped incomplete marks with one smooth side and a slightly more fragmented opposing side. The apex of a metal mark is always straight and narrow with no significant pitting.

ii. *Complete chop marks*

All complete chop marks can be classed according to the level of fragmentation within the mark. Both Class 1 and 2 are highly fragmented marks. Class 1 is difficult to identify as the mark has often broken into many pieces upon impact, which can obliterate evidence of chopping activity. Class 2 are more recognisable chop marks and have a definable point of impact, but often suffer from uncontrolled breakage. Class 3 marks are recognisable as chop marks and have a clear point of impact and controlled breakage continuing all the way through the bone. A Class 4 chop mark has a lightly cut surface (extends for at least 3 mm) where the axe has cut through the bone instead of splitting it. This mark often has a severe kerf fracture due to the short length of the sheared surface. The sheared surface must be flat, with no undulation or striations running either down or across the mark that might indicate multiple impacts, or an uneven blade surface. Class 5 chop marks have an exceptionally clean cut sheared surface that extends into the bone for more than 5 mm. Class 4 and 5 marks often have no crushing at the place of impact.

Stone axes (chipped and ground) create marks that fall between a 1-3 on the fragmentation scale. Stone axes cannot create Class 4 or 5 chop marks, or cleanly sheared surfaces. Metal axes (copper and bronze) are capable of creating marks between Class 1-5 on the fragmentation scale, however, metal axes are more likely to create marks that fall between a 3-5. Copper axe marks tend to cluster between Classes 3-4, and bronze axes cluster between Classes 3-5. The experimentation showed that chopped assemblages (cNISP) that exhibit more than 20% sheared (Class 4 & 5) marks can be solely created by metal axes unless analysis of incomplete marks indicates otherwise.

iii. Hypotheses

This study provides evidence to both support and deny the original research hypotheses. Chop mark analysis shows that metal axes were the preferred chopping tool throughout the entire EBA at Göltepe with no definitive evidence for the use of stone axes in butchery.

Hypothesis 1

Hypothesis 1 states that chipped stone axes will fracture upon high-speed impact. Experimentation found this to be true as both experimental chipped stone axe heads suffered significant damage during the chopping procedure. The sharp and thin Knife River Flint biface was rendered unusable by the second chop. This suggests that such a thin biface would not have been used as a high-speed impact butchery tool. The thicker chert biface suffered extensive damage to the cutting bit, and without retouch, functioned more as a bashing tool rather than a chopping tool, although it was still able to divide the bone through fracture. Hence, the hypothesis is supported.

Hypothesis 2

Hypothesis 2 states that ground stone axes will create significantly more crushing at the place of impact compared to metal axes. Experimentation found this to be true. The relatively dull cutting bit (needed for structural stability) of the ground stone axe pushed the surface of the bone into the chop mark before dividing the bone. Metal axes produce very little to no crushing at the place of impact as the cutting bit is extremely narrow and the force is driven into the bone instead of extending across the surface of the bone. Hence, the hypothesis is supported.

Hypothesis 3

Hypothesis 3 states that metal axes will cut deeper into the bone tissue than ground stone axes. Experimentation found this to be true as ground stone axes do not cut into the bone to a significant degree. For a stone axe to have the structural integrit, it needs to handle high-speed impact forces, and the stone axe needs to be thicker than a traditional metal axe. A thick (2-3 cm) ground stone axe cannot cut deep into the bone tissue before it acts as a wedge and splits the bone. Hence, the hypothesis is supported.

Hypothesis 4

Hypothesis 4 states that metal chop marks will be 'more obvious' than stone chop marks (Binford 1981: 143). Experimentation created evidence to both support and deny this hypothesis. Metal axes can create very 'obvious' chop marks with a smooth sheared surface that extends deep into the bone that finish in a kerf fracture. However, metal axes can also create highly fragmented marks depending on the angle of the axe, age of the animal, and side of the chop recovered. If only the acute side of a metal chop mark is recovered the chop mark will appear jagged and fragmented as both the acute and obtuse sides of a ground stone chop mark would. It is imperative that an entire assemblage of chop marks be analysed to mitigate recovery bias. Only then, can the analyst see the full range of chop marks within an assemblage before assessing if individual chop marks were made by stone, metal or a combination of both tool types. Hence, the hypothesis is not supported.

Hypothesis 5

Hypothesis 5 states that the degree of fragmentation within a chop mark will correlate to the width and sharpness of the axe (Wenham 1989). Experimentation found this to be true. Both the width and sharpness of an axe bit (cutting edge) are co-related variables as a sharp axe bit necessarily has a low gradient pitch leading from the bit to the body. This is the reason why ground stone axes that are sturdy enough to withstand high-impact force can never be as sharp as their metal counterparts and will always create more fragmentation and little to no shearing. Hence, the hypothesis is supported.

Hypothesis 6

Hypothesis 6 states that the presence of both crushed and sheared chop marks at Göltepe represents the use of both metal and stone axes. Experimentation does not support this hypothesis. Metal axes have the ability to create both sheared and fragmented marks. Only the analysis of incomplete surface marks can confirm the use of stone axes when shearing is present within a chopped assemblage. If no shearing is present within an entire chopped assemblage, it is highly likely that the assemblage was chopped using only stone axes. Hence, the hypothesis is not supported.

Hypothesis 7

Hypothesis 7 states that the use of metal axes in butchery will follow a similar trajectory of adoption to metal knives in the Early Bronze Age. If metal axes were used on the Göltepe assemblage, an increase through time should be detected. Analysis of the Göltepe chopped assemblage does not support this hypothesis. The adoption of metal axes does not follow a similar trajectory to metal knives in butchery as metal axes were the primary chopping tools from the first occupation level on at Göltepe (Late Chalcolithic/EB I). No change in the frequency of metal chops marks was detected and suggests that the adoption process for the integration of metal axes into butchery practices (whether gradual or punctuated) took place before the earliest occupation level at Göltepe. Hence, the hypothesis is not supported.

Hypothesis 8

Hypothesis 8 states that if the smooth chop marks found on the Göltepe faunal assemblage were created by metal axes, then the use of metal axes predates the use of metal blades in butchery by almost a millennium. Analysis of the Göltepe material according to the experimental results demonstrates that this hypothesis is supported. Stone axes are not capable of producing the level of shearing found on the vast majority of chop marks in the chopped assemblage through the entire EBA at Göltepe. Metal slice marks are not found at Göltepe until the EB III, and are only found in very low frequencies. This evidence strongly suggests that metal axes were the preferred dismemberment tool for almost a millennium before the introduction of metal blades in butchery at Göltepe. Hence, the hypothesis is supported.

IV. Significance of research

This thesis demonstrates the importance of chop marks as an avenue of study in butchery research. Individual butchery tools have their own histories as object types and material types. Different tool types have their own trajectories in how, when, and why they were incorporated into butchery practices. The identification and definitions of chop mark characteristics in this thesis helped to identify previously unrecognised chop marks and processing patterns in the zooarchaeological assemblage. As the variability of chop marks can lead to the under-identification of this type of butchery mark, the results of this study have important implications for other butchering studies. Identifying axe material type from chop marks is relatively simple, low-cost, and requires no specialist equipment. The chop mark identification criteria and material type signature characterises can be applied to any faunal assemblage and provides information about carcass processing and tool usage that would otherwise remain undetected within the fragmentary archaeological record.

This research also complements previous research on the process of abandonment of lithic types. Changing lithic types during the EBA are often cited as due to increasing availability and usage of metal counterparts (Rosen 1997: 153). However, in the absence of complementary evidence, this can be difficult to prove. Lithics are only one side of the coin. Use of the zooarchaeological record can fill in the other side of the equation since it preserves evidence for both metal and stone butchering implements. Most metals are not visible within the archaeological record and preservation conditions (not the record itself) is biased against them. Stone and bones, in contrast, are abundant within the archaeological record. Patterns of usage between stone and metal axes in everyday butchery contexts at Göltepe and Tell eṣ-Ṣâfi/Gath show that metal axes were used in butchery during the EBA, and therefore supports the argument the decline and eventual disappearance of lithic axes was likely due to the availability and use of new metal types.

The application of the methods outlined in this thesis contributes to the study of ancient metal technologies in revealing how and if metal axes were actually used by ancient communities, as the tools themselves often reveal frustratingly little about how they functioned within society. Tracking metal axe usage in butchery has been heretofore nearly impossible. By using butchery mark analysis, the accessibility, desire for, and acceptance of new metal material types at pivotal times of technological advancement can now be recognised.

V. Avenues for future research

The emerging pattern of early metal axe usage in butchery in comparison to metal knives is deserving of further research. Both Chalcolithic and EBA faunal assembles across Anatolia and the Levant should be analysed for the presence of both stone and metal chop marks in an effort to isolate the transitional period between metal and stone axes in butchery practices. A survey of Chalcolithic and EBA chop marks across Anatolia and the southern Levant would produce detailed information on differential pattern of adoption, acceptance and availability of metal axes at the dawn of key metallurgical advancements and complement existing research on the adoption of metal blades in butchery (e.g. Greenfield 2013).

VI. Concluding remarks

Analysis of the Göltepe chop marks demonstrates the deep permeation of metal tools into the everyday lives of individuals of south central Anatolia in the EBA. There is very little evidence for such an interpretation based solely on the physical presence of the tools themselves. The continued presence of stone knives in butchery shows that the residence of Göltepe chose to structure their physical world with the tools that they deemed to be socially acceptable, locally available, and appropriate for specific tasks.

Göltepe, and the Bolkardağ region in general, was clearly an important part of the interregional EBA metals production and distribution network and a nucleus for bronze production during the EBA (Webb et al. 2006). This may have influenced the early adoption of metal axes and chisels in butchery due to the availability of metallic resources and copper alloys in the Bolkardağ region and from the nearby mining site of Kestel. However, evidence from Tell eṣ-Ṣâfi/Gath suggests the early use of metal axes in butchery in comparison to metal knives may not only be a Bolkardağ regional phenomena. Hopefully, future research will extend our knowledge of early metal axe usage in butchery practices across the Near East.

Appendix of images

This appendix contains supporting images from the experimental and archaeological chopped assemblages. All images were created by the author and are owned by the author (myself). Not every bone is photographed with a scale due to the difficulty of capturing the slope of the chop mark in a photograph.

I. Experimental chop marks

Figure 47: Experimental incomplete chop marks of all five axes on a pine wood plank © Tiffany Okaluk.

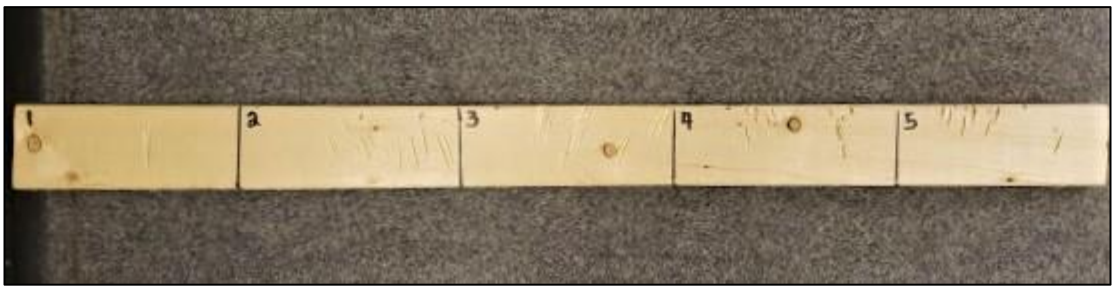


Figure 48: Experimental bronze axe chop mark on *Sus scrofa* rib (Class 3) © Tiffany Okaluk.

Figure 49: Experimental bronze axe chop mark on *Sus scrofa* rib (Class 5) © Tiffany Okaluk.

Figure 50: Experimental bronze axe chop mark on *Sus scrofa* rib (Class 3) © Tiffany Okaluk.

Figure 51: Experimental bronze axe chop mark on *Sus Scrofa* rib (Class 5) © Tiffany Okaluk.

Figure 52: Experimental bronze axe chop mark on *Sus scrofa* sternum (Class 4) © Tiffany Okaluk.

Figure 53: Experimental bronze axe surface chop marks on *Sus scrofa* radius © Tiffany Okaluk.

Figure 54: Experimental copper axe chop marks on *Sus scrofa* rib (Class 3) © Tiffany Okaluk.

Figure 55: Experimental copper axe chop mark on *Sus scrofa* rib (Class 2) © Tiffany Okaluk.

Figure 56: Experimental copper axe chop mark on *Sus scrofa* rib (same bone as Figure 55) © Tiffany Okaluk.

Figure 57: Experimental copper axe chop mark on *Sus scrofa* rib (Class 4) © Tiffany Okaluk.

Figure 58: Experimental copper axe chop marks on *Sus scrofa* rib (Class 3) © Tiffany Okaluk.

Figure 59: Experimental copper axe chop marks on *Sus scrofa* rib (Class 2 right) © Tiffany Okaluk.

Figure 60: Experimental ground stone axe chop mark on *Sus scrofa* vertebra (Class 3) © Tiffany Okaluk.

Figure 61: Experimental ground stone axe surface chop mark on *Sus scrofa* vertebra (imbedded in sawn surface) © Tiffany Okaluk.

Figure 62: Experimental ground stone axe chop mark on *Sus scrofa* rib (Class 1) © Tiffany Okaluk.

Figure 63: Experimental ground stone axe chop mark on *Sus scrofa* rib (Class 2) © Tiffany Okaluk.

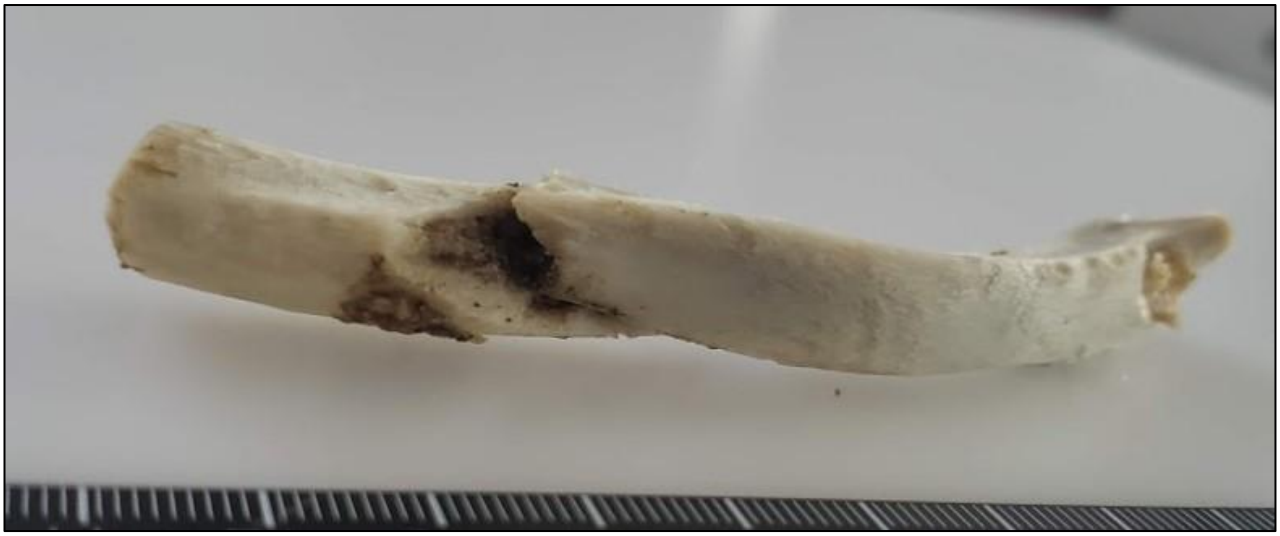


Figure 64: Experimental ground stone axe chop mark on *Sus scrofa* rib (Class 2) © Tiffany Okaluk.

Figure 65: Experimental ground stone axe chop mark on *Sus scrofa* rib (Class 1) © Tiffany Okaluk.

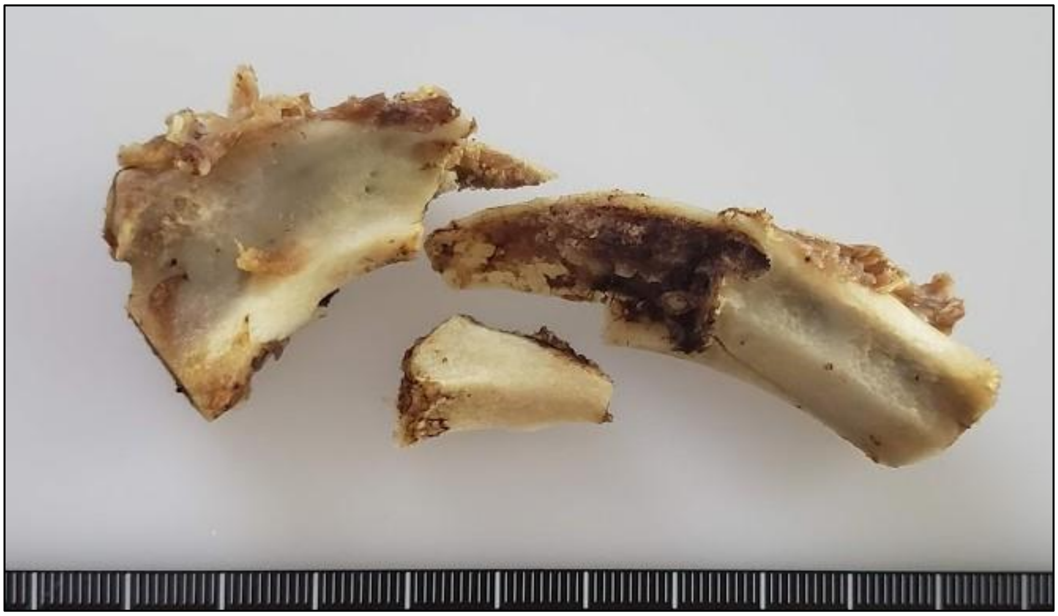


Figure 66: Experimental ground stone axe chop mark on *Sus scrofa* rib (Class 2) © Tiffany Okaluk.

Figure 67: Experimental ground stone axe chop marks on *Odocoileus virginianus* radius (Class 3) © Tiffany Okaluk.

Figure 68: Experimental ground stone axe chop marks on *Odocoileus virginianus* radius (same bone as Figure 67) © Tiffany Okaluk.

Figure 69: Experimental ground stone axe chop marks on *Bos taurus* rib © Tiffany Okaluk.

II. Göltepe chop marks

Figure 70: Complete (Class 5) chop mark on *Capra hircus* occipital segment of the cranium FCN B08-0300-011, MRN 4773, Bone 2, Period 3 © Tiffany Okaluk.

Figure 71: Complete (Class 5) chop mark on *Ovis/Capra* horn core FCN E69-0100-003, MRN 1485, Bone 60, Period 2 © Tiffany Okaluk.

Figure 72: Complete chop (Class 5) mark through *Ovis aries* occipital and parietal with two incomplete marks on (central) parietal FCN E69-0100-003, MRN 1485, Bone 60, Period 2 © Tiffany Okaluk.

Figure 73: Complete (Class 4) chop mark on *Ovis/Capra* vertebra FCN E70-0100-003, MRN 2299, Bone 12, Period 2 © Tiffany Okaluk.

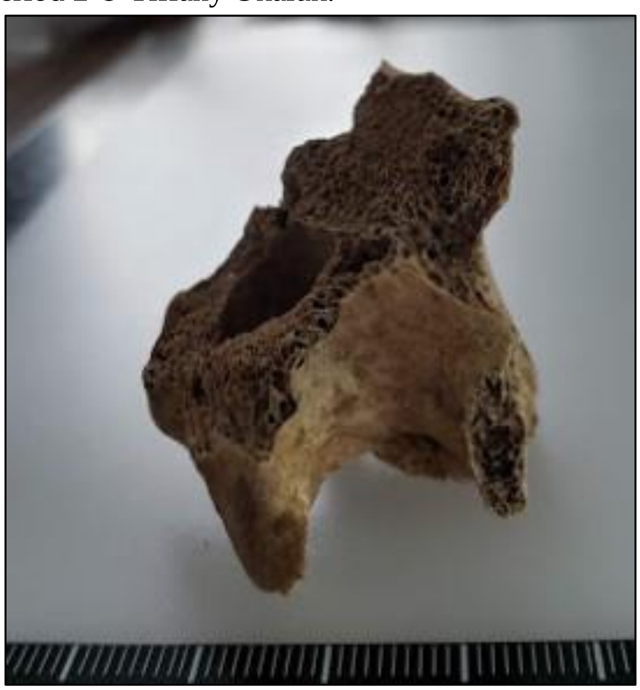


Figure 74: Complete (Class 5) chop mark on *Ovis/Capra* vertebra FCN E70-0100-003, MRN 2299, Bone 13, Period 2 © Tiffany Okaluk.

Figure 75: Incomplete (right) and Class 4 complete (left) chop mark on *Ovis/Capra* acetabulum FCN E70-0100-003, MRN 2299, Bone 96, Period 2 © Tiffany Okaluk.

Figure 76: Complete (Class 5) chop mark on proximal *Ovis/Capra* tibia FCN B09-0700-000, MRN 4836, Bone 1, Period 3 © Tiffany Okaluk.

Figure 77: Complete (Class 4) chop mark through head of *Capra hircus* scapula FCN E69-0100-003, MRN 3569, Bone 18, Period 2 © Tiffany Okaluk.

Figure 78: Complete (Class 4) chop mark on *Ovis/Capra* vertebra FCN E69-0100-003, MRN 3569, Bone 79, Period 2 © Tiffany Okaluk.

Figure 79: Complete (Class 5) chop mark on base of *Capra hircus* horn core FCN E63-0100-035, MRN 3433, Bone 35-4, Period 4 © Tiffany Okaluk.

Figure 80: Complete (Class 5) chop mark on base of *Capra hircus* horn core FCN E63-0100-035, MRN 3433, Bone 35-19, Period 4 © Tiffany Okaluk.

Figure 81: Complete (Class 3) chop mark on *Ovis/Capra* scapula FCN E69-0100-003, MRN 3599, Bone 102, Period 2 © Tiffany Okaluk.

Figure 82: Complete (Class 5) chop mark on *Ovis/Capra* vertebra FCN E69-0100-003, MRN 3599, Bone 12, Period 2 © Tiffany Okaluk.

Figure 83: Incomplete Class 5 chop mark on *Capra hircus* epistropheus FCN E69-0100-003, MRN 3569, Bone 78, Period 2 © Tiffany Okaluk.

Figure 84: Incomplete Class 5 chop mark on *Capra hircus* atlas FCN E69-0100-003, MRN 3583, Bone 8, Period 2. © Tiffany Okaluk

Figure 85: Incomplete chop mark on (central) *Bos taurus* frontal and Class 3 chop marks (foreground) FCN E63-0100-035, MRN 3438, Bone 5, Period 4 © Tiffany Okaluk.

Figure 86: Incomplete metal chop mark (background) and Class 3 complete chop mark (foreground) on *Ovis aries* frontal FCN E63-0100-035, MRN 3438, Bone 24, Period 4 © Tiffany Okaluk.

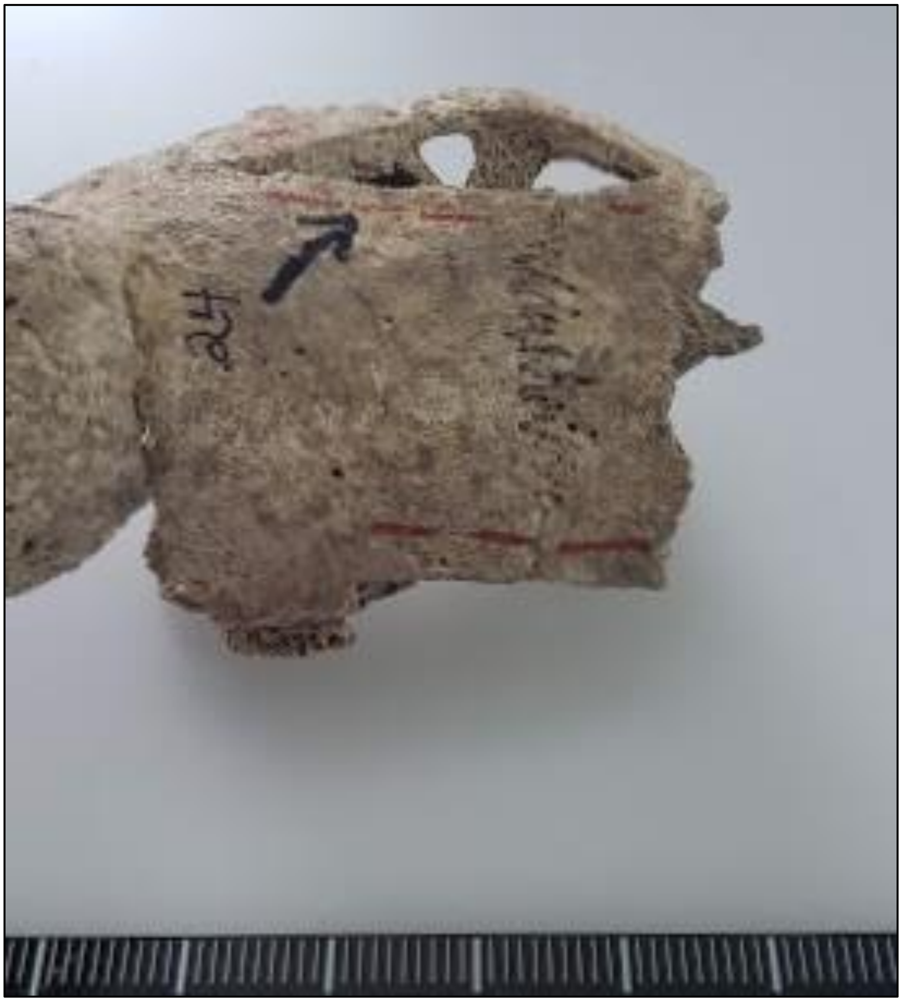


Figure 87: Complete (Class 1) chop mark on *Capra hircus* frontal FCN E63-0100-035, MRN 3438, Bone 48, Period 4 © Tiffany Okaluk.

Figure 88: Complete (Class 2) chop mark on *Ovis aries* frontal/parietal suture FCN E63-0100-035, MRN 3438, Bone 56, Period 4 © Tiffany Okaluk.

Figure 89: Metal chisel marks on *Cervus elaphus* antler FCN B06-0300-016, MRN 1808, Bone 1, Period 3 © Tiffany Okaluk.

III. *Chop marks from Tell es-Safi/Gath, Area E*

Figure 90: Complete (Class 4) chop mark on *Ovis aries* horn corn base from Area E, Locus 20E83D05, Basket 20E83D116, Bone 2, Phase E7 © Tiffany Okaluk.

Figure 91: Complete Class 3 (left) and incomplete chop mark (right) from Area E, Locus 19E83B070, Basket 19E83B091, Bone 47, Phase E6 © Tiffany Okaluk.

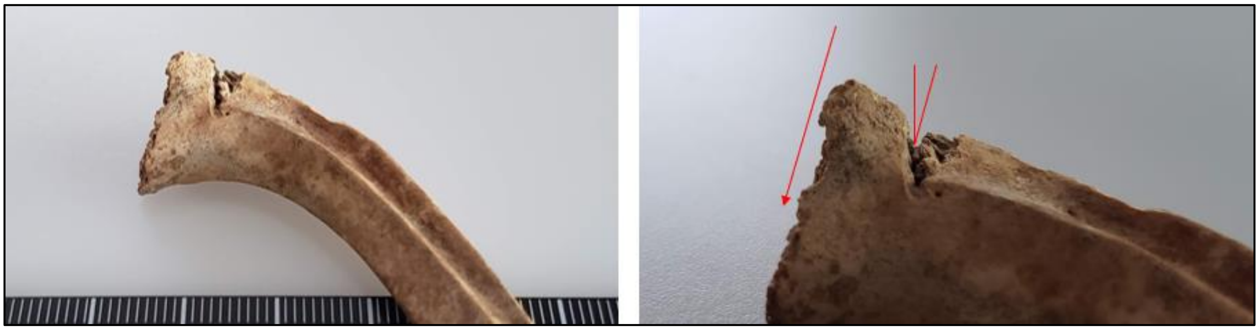


Figure 92: Complete Class 4 chop mark on *Ovis/Capra* vertebra from Area E, Locus 104303, Basket 1043075, Bone 2, Phase E5A © Tiffany Okaluk.

Figure 93: Incomplete Class 5 chop mark on *Ovis/Capra* vertebra from Area E, Locus 19E93A04, Basket 19E82D051, Bone 2, Phase E5B © Tiffany Okaluk.

Figure 94: Complete Class 4 chop mark on vertebra from Area E, Locus 20E83D06, Basket 20E83D139, Bone 3, Phase E7 © Tiffany Okaluk.

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