Journal of Ancient Egyptian Interconnections

Metal as a Mechanism for Understanding Social Complexity during the Third millennium BCE: A Comparative Zooarchaeological Perspective on Egypt and the Southern Levant

Eleutério Abreu De Sousa
Macquarie University

Haskel J. Greenfield
University of Manitoba

Abstract
Most studies of the spread of copper and bronze metallurgy across the Near East rely upon the relatively few surviving metal artifacts, most of which originate in mortuary contexts and thus indicate little about daily life activities. In recent years, a new method that circumvents the biased metallurgical record has been developed using microscopic groove analysis of animal butchering on zooarchaeological remains. In this paper, we present and compare our data from the southern Levant and Egypt to assess the spreading of copper and bronze metallurgy in the two regions. Our analysis allows for an initial assessment of the relative importance of metal versus stone tools for quotidian activities during the third millennium BCE in different parts of the eastern Mediterranean. Furthermore, the results have demonstrated that access to copper and metal tools for even such quotidian activities as meat processing in the eastern Mediterranean was differentiated by social status.

Introduction
Little is known about the rate of change from lithic- to metal-based (copper and bronze) technologies and how this has affected our interpretations of ancient societies. The role of metallurgy in the development of early complex societies has long been studied from an artifactual perspective. The presence of copper and bronze objects in archaeological contexts, such as needles, daggers, axes, and mirrors, in sites dating from the period of early-state formation societies across the Near East, has long been used to point to the intensification of resources, craft specialization, and social differentiation, all characteristics of a complex society (Childe 1930, 1934, 1950; Johnson 1977; Philip 1988, 1989, 2003; Philip, Clogg, and Dungworth 2003; Sanders, Wright, and McCormick Adams 1984; Wenke 1989; Wright, Neely, and Johnson 1975; Wright 1986). The focus on metal objects is, in fact, part of the bias that archaeologists working in the region have toward elite and public contexts and associated artifacts. Given that non-elite (lower) strata of early state societies in the eastern Mediterranean had limited access to goods signaling higher status affiliation (e.g., metals), only part of the picture is archaeologically visible.

There is a growing number of studies across the Near East, Europe, and elsewhere in the eastern Mediterranean, which demonstrate that stone tools continue to be of great importance during the Bronze Age and later periods, particularly in non-elite quotidian activities (e.g., Blitzer 1995; Carter 2004a, b; Dierckx 2008; Eriksen 2010; Greenfield 2017;

Khalaily 2008; Rosen 1997). This begs the question: what types of raw materials used for making tools commonly served utilitarian purposes during this critical time in the evolution of complex societies in the eastern Mediterranean region?

The quantity and range of ancient metal goods having survived degradation processes are likely a low fraction of the original deposited amount (Greenfield 1999, 2013; Olsen 1988a). This is concerning since most studies of the origins and spread of metallurgy rely upon the few metal artifacts recovered from archaeological context (Chernykh 1992; Levy and Shalev 1989; Moorey 1988, 1994a; Shephard 1980; Tylecote 1986, 1987, 1992). In fact, metal finds are recovered within a very restricted range of depositional contexts, such as hoards and burials. (Harding 2000; Philip 1988; Tadmor et al. 1995). Moreover, very few metal objects come from living floors in settlements where they were used in daily life (Philip 1989, 2008; Taylor 1993). It is thus difficult to document social changes (i.e., complex society) based only on evidence from copper objects (Eriksen 2010) when stone tool use evidence suggests continued use by the majority of the population (Greenfield 2013).

The frequency of metal objects in domestic contexts, particularly from the Early Bronze Age, is exceptionally lower than that of stone tools. For example, the excavations at Tell eṣ-Ṣâfi/Gath recovered only two pieces of copper objects among hundreds of chipped stone tools from the same Early Bronze Age levels at the site (Manclossi and Rosen in press; Manclossi and Rosen 2017; Eliyahu-Behar and Yahalom-Mack in press). In Egypt, only 5% of copper objects from the Old Kingdom derive from settlement contexts, while 95% were recovered from tomb contexts (Abreu de Sousa 2020, 86–87; Odler 2016).

An alternative approach has been pioneered over the past two decades to explore the impact of the development or adoption of metal tools for use in quotidian activities in emerging complex societies in the Near East. This twofold approach includes evaluating and combining the archaeological evidence (including objects, text, and iconography) with zooarchaeology (analysis of animal remains from archaeological contexts). In this approach, the ancient evidence of tool use for animal butchery is reconstructed through microscopic examination of butchering marks on animal bones. These are utilized as a proxy measure for the frequency of stone versus metal butchering implements (Greenfield 1999, 2006, 2013). The advantage of this method is that it allows for investigating whether metal or stone butchering tools were used to service all or only some elements of society. By investigating such a quotidian activity as animal carcass processing (i.e., slaughtering, skinning, dismemberment, disarticulation, and filleting), it is possible to investigate whether stone or metal was widely used even among the lower strata of society in Egypt and the Levant. The results allow for contemplating the effect (or lack) of the introduction of metallurgy into local societies, as well as for an increased understanding of the role that bronze metallurgy played in the development of complex societies.

In this paper, we use a microscopic zooarchaeological approach to document the continued use of stone and/or its replacements by metal tools for quotidian activities in Old Kingdom Egypt and Early Bronze (EB) southern Levant. Slice marks on animal bones are employed as a proxy measure for the use of either chipped stone or metal (copper-based) blades for animal butchery. Previously collected data from the EB of the southern Levant are compared with newly collected data from the Old Kingdom in Egypt to assess the use of copper-based tools for animal butchery during the Egyptian Old Kingdom. This is the first time such analyses have been conducted on Egyptian material. Data from the Fourth Dynasty pyramid builders' complexes (i.e., the Kromer Dump) are compared with the data from contemporary assemblages in the southern Levant. The Kromer Dump is used as a case study to evaluate the adoption of metallurgy at a state level as it is a "company town" designed for support of elite state-level activities (i.e., to build the pyramid complexes of the Fourth Dynasty).

Zooarchaeology and Slice Mark Analysis: A Method for Monitoring the Use of Metal and Retention of Stone Tools

Slice Mark Morphology

One available way to examine the development of metallurgy is through the faunal remains. Slice marks on animal bones can be identified as a butchering-related slicing activity made with a sharp tool, and their criteria have long been defined and tested by various analysts (Fig. 1) (Greenfield 1999; Olsen 1988b; Potts and Shipman 1981; Shipman 1981; Walker 1978; Walker and Long 1977).

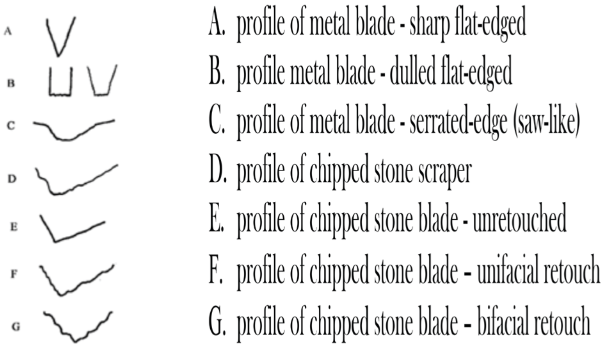

Figure 1: Greenfield's protocols for stone and metal slice mark morphology (cf. Greenfield 2013).

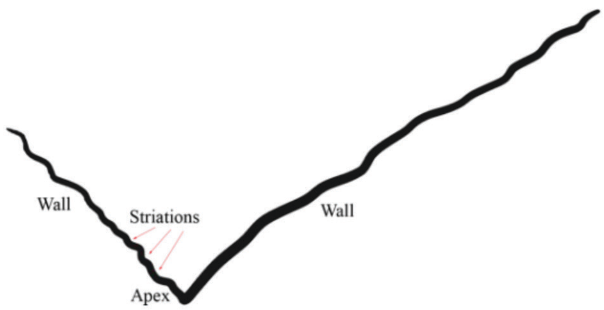

Figure 2: Example of a slice mark profile with the walls, apex, and striations.

Also, the criteria for identifying tool types, based upon the microscopic morphology of butchering slice marks, are fairly straightforward and are now being replicated with AI and other quantitative studies (Abe et al. 2002; Bello, Parfitt, and Stringer 2009; Cifuentes-Alcobendas and Domínguez-Rodrigo 2019; Courtenay et al. 2018; Domínguez-Rodrigo et al. 2021; Domínguez-Rodrigo et al. 2020; Kooi and Fairgrieve 2013; Maté-González et al. 2018). Simply put, there are clear morphological differences between slice marks caused by chipped stone or metal tools. The impression created by a metal or stone knife blade (or flake) on the bone can be distinguished by differences in several characteristics: apex, wall, and lateral striations (Fig. 2).

Metal-based tool implements leave a clear, straight, deep, V-shaped or |_|-shaped (if dull) impression on the bone (Fig. 1A–B). The apex is usually straight, and there are few (if any) lateral striations. In contrast, chipped stone tools create a greater variety of shapes since they are more complex (Fig. 1E–G). Thus, they display a variety of characteristics depending on the type of tool used in the butchering process. Generally, chipped stone tools have shallow apexes with rough, wavy, and irregular walls. There are invariably one or more lateral striations on one or both walls, depending on whether it is unifacially or bifacially produced and retouched. The variety of shapes among chipped stone implements that can be used for animal butchery leaves an equal variety of impressions on the bone. Stone tool production methods (i.e., unifacial, bifacial, unretouched, and retouched) will result in different morphological characteristics in the groove as they slice into bones.

Microscopic Approach to Zooarchaeology

All bones discussed in the present analysis were visually examined through an optical microscope for any evidence of slice marks. Samples with slice marks were further subject to microscopic and SEM analysis to identify the morphology of these marks. Following the protocols set by Greenfield (1999), the method was applied to bones from the Levant and Egypt to determine if stone or metal-based tools were adopted in animal butchery during the Early Bronze Age.

Two forms of microscopic analyses were adopted to achieve accurate results. First, a light optical microscope was used to initially identify the morphology of the slice mark following established guidelines (Walker and Long 1977; Walker 1978). Next, another level of microscopic analysis was conducted using a Scanning Electron Microscope (SEM). The SEM provides a depth of field and resolution that allows for a much more accurate identification of tool type (Olsen 1988b, 358; Potts and Shipman 1981; Shipman 1981; Shipman and Rose 1988).

Without microscopy, identifying tool type in slice marks is mostly guesswork; this is particularly true when fine-grained chipped stone tools (e.g., those made from obsidian) are used (Greenfield and Marciniak 2019). Greenfield's (1999) results not only refined earlier research but also demonstrated that this analysis method can be applied to answer broad questions, such as the transition from stone to metal tools in butchering across sites within a region (e.g., Greenfield 2013) and also between regions and continents (e.g., Greenfield 2018). Thus, this method is useful for investigating the development of metallurgy for quotidian purposes on a regional scale.

Based on a series of previous research, it is now understood that the transition from stone to metal tools for butchering began to occur on a large scale only during the Middle Bronze Age in the Levant and central Balkans (Greenfield 1999, 2002, 2008, 2013, 2017, 2021; Greenfield and Brown 2016; Greenfield, Brown, and Miroschedji 2021; Greenfield and Marciniak 2019), and in the Late Bronze Age in central Poland (Greenfield 2018; Marciniak and Greenfield 2013). However, certain areas of the Near East (i.e., Anatolia) lagged in the transition to metal tools for butchering since obsidian was easily available and sharper than metal (Greenfield and Chaput 2021; Greenfield and Marciniak 2019). Thus, it is clear that the transition did not occur uniformly throughout the Early Bronze Age but that each region must be investigated separately.

Previous Studies on Utilitarian Metallurgy in the Southern Levant

Early copper-based metallurgy in the Near East has its origins in the shaping of metal objects, such as beads, during the Pre-pottery Neolithic. Such early metal items were largely used for display purposes and quickly spread throughout the Near East (Greenfield 2008; Muhly 1980, 1988, 2011; North 1955; Tylecote 1992). During the Chalcolithic, a local copper mining and smelting industry developed in the southern Levant, allowing for new shapes (Garfinkel et al. 2014; Hauptmann 2007; Levy and Shalev 1989; Shalev 1994; Shugar and Gohm 2011). It has been suggested that the development of the early copper industry in Egypt had its roots in the Levant and neighboring areas of Sinai, where large copper mines are located (Adams 1997, 2002; Adams and Genz 1995; Ben-Yosef et al. 2016; Golden 2002, 2010; Hauptmann et al. 2015; Levy et al. 2002; Philip, Clogg, and Dungworth 2003; Rosenberg et al. 2020). However, early copper objects have been found in Egypt dating to the Chalcolithic, suggesting that a local industry had already developed concurrently with the Early Bronze Age (Odler 2015).

While the alloying of copper with other metals is an innovation of the Early Bronze Age, most copper objects from this period are not yet alloyed with tin or arsenic (Hauptmann and Pernicka 2004; Moorey 1988, 1994b). Alloying strengthens the material and makes it more widely usable for daily quotidian tasks. Consequently, it was during the Early Bronze Age in the Levant that the presence of metal for quotidian tasks began to increase and displace chipped stone tools. However, it was not until the Middle Bronze Age that metallurgy began to be truly quotidian in the southern Levant, across the Near East, and beyond (Greenfield 2008, 2013; Greenfield 2017; Greenfield and Greenfield 2018; Greenfield and Marciniak 2019; Manclossi, Rosen, and Lehmann 2018; Rosen 1984, 1997;).

The transition from stone-based to metal-based quotidian technology can be a slow or rapid process that differs between cultures. The adoption of bronze metallurgy in the Levant has proven to have occurred much later than previously expected; it took over a millennium from the earliest bronze objects for chipped stone tools to be replaced. Other types of stone tools for quotidian purposes continued in use throughout the Bronze Age (Greenfield 2013, 2017; Manclossi, Rosen, and Böeda 2019; Rosen 1997; Rosenfeld, Ilani, and Dvorachek 1997). While traditional methods of tool use (i.e., chipped stone, such as flint) continued well into the latter parts of the Bronze Age across the Near East, the ratio between stone and metal objects changed over time. In some domains, stone tools were rapidly replaced (e.g., prestige or display items), while in others, there was a slow replacement over time (e.g., food processing) (Greenfield 2013, 2017; Manclossi, Rosen, and Böeda 2019; Rosen 1997).

Studies of stone versus metal use focusing on the Levant involved well-curated and temporally controlled samples (Greenfield 2013, 2017). Over 20000 bones from various settlement contexts were examined. Initially, the data were not well separated within the Early Bronze Age. Reanalysis of the stratigraphic associations of remains from older excavations (e.g., from Tell es-Sultan/Jericho) and addition of new data from more modern scientific and systematic excavations (Tall Zirāʻa, Tell eṣ-Ṣâfi/Gath) suggest that while a few metal slice marks appear early in the EBA, it is only toward its end (during the latter half of the EB IV) that metal slice marks begin to appear consistently, but in very small quantities (Table 1) (Eliyahu-Behar and Yahalom-Mack 2018; Greenfield et al. 2022). Metal chop marks are consistently found only for the MB, and in small frequencies until the Iron Age (e.g. Tall Zirāʻa, Jordan, Greenfield et al. 2022). While daggers and axes appear prior to this EBA phase, they are clearly not used for animal butchery since they are made of copper. Tin-bronze daggers begin to appear in the Intermediate Bronze (Nigro et al. 2018). Metal knife marks become more common

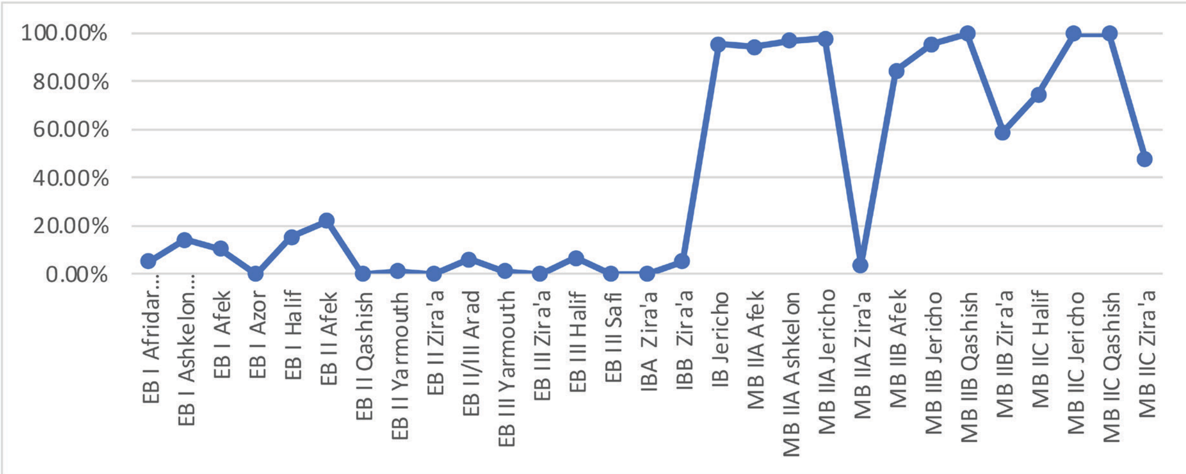

Figure 3: Histogram showing the quantitative distribution of metal butchering marks from southern Levantine sites during the Early and Middle Bronze Ages. Current reanalysis of the Jericho material suggests that the high frequency of metal in the IB is not supported.

during the Middle Bronze (MB), where there is a c. 50% average distribution between metal and stone marks (Greenfield, Beller, and Gaastra 2021; Greenfield et al. 2016). This pattern coincides with the development of bronze knives late in the EB (Moorey 1994b). This temporal pattern makes sense, given that a bronze knife is much harder and more durable than a copper one (Greenfield 1999).

The Development of Metallurgy in Pre-Dynastic to Old Kingdom Egypt (2592–2153 BCE)

The Old Kingdom (OK) marks a period of major advancement for Egypt, when massive monumental architecture requiring plentiful resources and a large labor force is commissioned by the kings. Also, foreign missions expand borders and supply luxury items and resources (e.g., copper ingots) through trade resources (Baud 2010, 70; Muhs 2016, 8; Odler 2015; Rosińska-Balik et al. 2015; Wengrow 2005, 14, 138). These projects are associated with innovative technologies, such as the development of a local copper industry to make fine objects for the elites to display, both in life and death (Cowell 1986; Garland and Bannister 1927, 33; Lucas 1927; for a corpus of objects see Odler 2016; Ogden 2000; Richards 2005; Scheel 1989, 34–46).

Unlike in the southern Levant, visual and textual evidence of copper production in Egypt abound and suggest that production of copper in Egypt was multi-layered. It involved individuals at various levels of society, including miners, metalsmiths, overseers, administrators, and transporters (Abreu

EB I Afridar combined	5.26%
EB I Ashkelon marina	14.29%
EB I Afek	10.53
EB I Azor	0
EB I Halif	15.38
EB II Afek	22.22
EB II Qashish	0
EB II Yarmouth	1.15
EB II Zira'a	0
EB II/III Arad	6.08
EB III Yarmouth	1.15
EB III Zira'a	0
EB III Halif	6.64
EB III Safi	0
IBA Zira'a	0
IBB Zira'a	5.26
IB Jericho	95.45
MB IIA Afek	94.29
MB IIA Ashkelon	97.06
MB IIA Jericho	97.87
MB IIA Zira'a	3.81
MB IIB Afek	84.62
MB IIB Jericho	95.45
MB IIB Qashish	100
MB IIB Zira'a	59.09
MB IIC Halif	74.7
MB IIC Jericho	100
MB IIC Qashish	100
MB IIC Zira'a	48.05

Table 1: Frequency distribution of metal slice marks on animal bones from southern Levantine sites. Data are derived from each of Greenfield's many studies (summarized in Greenfield 2013; Greenfield and Brown 2016; Greenfield, Beller, and Gaastra 2021). Data from Jericho are currently being reanalyzed with finer chronological control than previously published (Greenfield 2005). Hence, the Jericho data reported here are preliminary and not reliable.

de Sousa 2020, 72–87). Recent studies on the smelting practices of the later Middle Kingdom suggest that a variety of fuel types were used in copper manufacturing (Verly et al. 2021), which would have required several individuals at different social strata to manage logistically. On top of these activities (Delage 2017; Hauptmann 2007, 8), the King's administration oversaw the production of precious resources, including copper, and heavily guarded its copper stores (likely in a centralized treasury), at least in the later periods of Egyptian history (Cour-Marty 1997; Desplancques 2006, 157, 396).

The *Chaîne Opératoire* of copper development in Egypt during the Pre-Dynastic and until the Old Kingdom demonstrates that mining, production, and distribution efforts were administered by the crown and its officials, who oversaw the entire operation (Klemm and Klemm 2013; Odler and Kmošek 2020, 152). The earliest mining expedition recorded for the Eastern Desert and Sinai regions is from the late Pre-Dynastic period (Abdel-Motelib et al., 2012; Tallet, 2018; Tallet and Laisney, 2012). Another early mining expedition occurred in the First Dynasty (likely by Semerkhet) in the Sinai region (Lucas 1927, 167; Tallet 2010). Inscriptions from mining or production sites suggest extensive mining operations occurred through Dynasties 1–6 (Emery 1963; Klemm and Klemm 2008, 1685; Lucas 1927). Copper became a highly desired commodity by the First Dynasty, and by the Third Dynasty the Egyptian court secured *"control over the copper mines of south-western Sinai"* (Wengrow 2005: 147; see also Stager 1992, 35). A large number of sites in the Sinai and Eastern Desert yielded archaeological evidence of early copper working (Odler and Kmošek 2020, 196). The evidence for smelting and copper production in the Nubian site of Buhen, suggests that areas to the south were also controlled by the Egyptian state, where a copper smelting production area comprising three furnaces was found (Lucas 1927, 163–165; Muhly 1999, 630). However, despite the location of mining in Egypt, the royal agenda during the Old Kingdom included the control of copper mining, production, storage, and circulation (Cour-Marty 1997; Desplancques 2006; Wengrow 2005, 146–147). Rare resources, including copper, were purposefully reserved for royal officials and individuals from the higher strata of society (Baud 2010, 72; Tillmann 1999, 314).

The consumption of copper during the Early Dynastic and Old Kingdom is materially evident from artifacts in both household and funerary contexts. The first uses of copper in Egypt were cosmetic (Lucas 1959, 245–249). Slowly, the range of uses expanded also to include more functional quotidian tasks (e.g., copper chisels for stone working). The earliest metal objects appear among grave goods during the Neolithic Badarian period (c.4500–3500 BCE) (i.e., copper beads recovered from Grave 596 at el-Mustagidda; Muhly 1999, 629; Scheel 1989, 8), Chalcolithic Naqada I–II cultures (c. 4000–3200 BCE) (i.e., axes, adzes, chisels, razors, knives) (Needler 1984, 280–282, cat. 180–183), and Early Dynastic, Old Kingdom, and later periods (for a corpus of Old Kingdom copper objects see Kobusiewicz 2015, 1–2; Odler 2016). Copper knives resembling those used in animal butchery iconography are found in tombs dating from the Early Dynastic and Old Kingdom periods (Maddin et al. 1984; Muhly 1999; Odler 2016, 66–69; Petrie 1913). The question is whether they were used only to service the elite (particularly in mortuary contexts) or for more quotidian tasks among the general population. It is even questionable whether objects, such as knives, were used in the same manner that their name suggests, considering that unalloyed copper knives would have been relatively soft and easily damaged.

The adoption of metal-based tools for quotidian tasks in Egypt is similar to that in neighboring regions in that it was a slow transition over time (Graves-Brown 2010, 97). In Egypt, alloyed copper (bronze) metallurgy is thought to have been adopted for quotidian purposes during the Middle and New Kingdoms (Graves-Brown 2010, 83; Ikram 1995, 65–69; Kobusiewicz 2015, 13). However, chipped stone (flint) tools continued being used alongside copper tools throughout the Old and Middle Kingdoms. It is only in the New Kingdom that bronze technology is widely adopted for quotidian tasks (Graves-Brown 2010, 97). This study is the first of its kind conducted on Egyptian faunal remains and is only representative of a non-elite context organized for and supplied by the Egyptian state (i.e., a company town). Despite an increase of copper objects from the Old Kingdom, compared to earlier periods, it cannot be assumed that the increased use of copper reflects the replacement of stone tools, particularly in quotidian activities such as animal butchery.

The disparity in copper finds between elite and lower stratum contexts is a gap that must be studied to understand the impact of metallurgical

Element	Bovines	%	Caprines	%
Calcaneus	0	0.00%	1	0.61%
Cranial	2	3.39%	0	0.00%
Femur	0	0.00%	3	1.82%
Fibula	0	0.00%	0	0.00%
Humerus	0	0.00%	14	8.48%
Innominate	1	1.69%	9	5.45%
Long bone fragment	19	32.20%	1	0.61%
Mandible	4	6.78%	11	6.67%
Metacarpal	2	3.39%	6	3.64%
Metatarsal	0	0.00%	11	6.67%
Phalanx	0	0.00%	1	0.61%
Radius	0	0.00%	23	13.94%
Rib	19	32.20%	44	26.67%
Scapula	6	10.17%	8	4.85%
Tibia	0	0.00%	18	10.91%
Ulna	0	0.00%	4	2.42%
Vertebra	6	10.17%	11	6.67%
Total limbs (bNISP)	**59**	100.00%	**165**	100.00%

Table 2: Frequency distribution of osteological elements for each taxon (bNISP).

development and consumption upon the development of Old Kingdom society. Most copper objects from the Early Dynastic and Old Kingdom periods derive from funerary contexts in tombs (Maddin et al. 1984; Muhly 1999; Odler 2016, 66–69; Petrie 1913), while evidence for household consumption of copper is limited to a few isolated finds from the Pre-Dynastic to the Old Kingdom (Odler 2016, 66–69). While it can be argued that the absence of copper objects in settlement contexts may be due to melting, reuse, or degrading over time, its absence or minimal presence in household contexts raises the question of what the lower strata of society used for quotidian purposes, such as food processing. This question is discussed below from the perspective of the workers' settlement at Giza.

Case Study: Giza and the Kromer Dump in Context

The zooarchaeological assemblage from the Kromer Dump (KRO) found during excavations at Giza, Egypt, is used as a case study to investigate the above questions. Austrian prehistorian Karl Kromer excavated the site between 1971 and 1975 and cleared 1550 cubic meters (up to a depth of 6.5 meters) of a settlement that contained a 4500-year-old trash dump (midden) on the high western slope of the Gebel el-Qibli (Southern Mound), south of the Heit el-Ghurab (HeG) (Kromer 1978). The mound is composed of trash dumped by the workers who built the Fourth Dynasty pyramids on the Giza Plateau. It includes pottery, flint blades, mud bricks, faunal remains, bone implements, mud sealings, and copper implements (Kromer 1978).

In 2018, AERA re-excavated Kromer's Dump (Sondage 185=Kromer Dump=KRO) and determined that it contained the rubbish from the nearby seasonal camp of the workers who built the pyramids of Pharaoh Khafre, and possibly Menkaure, of the Fourth Dynasty, representing over a 60-year time span (Lehner 2018).

Data and Sample Size

The faunal remains from KRO provide a rich source of information on animal consumption and butchery practices (Redding 2020, 51–54). A vast number of mammal bones (35512 fragments) were unearthed (Redding 2020, 51). A large share of these included proximal and distal limb shaft fragments (femur, humerus, tibia, radius, metapodia).

Sample #	Taxa	Element	SEM raw material identification	Stone Tool production type	Stone tool retouch type	Blade type	bNISP	Type of butchering mark	Type of slicing instrument
16a	Caprine	Femur	Stone	Unifacial	Not = |/	Unifacial	1	Slice	Blade
16b	Caprine	Femur	Stone	Unifacial	Not = |/	Unifacial		Slice	Blade
144	Caprine	Vertebrae	Stone	Unifacial	Not = |/	Unifacial	1	Slice	Blade
145	Caprine	Vertebrae	Stone	Unifacial	Not = |/	Unifacial	1	Slice	Blade
148	Caprine	Vertebrae	Stone	Unifacial	Not = |/	Unifacial	1	Slice	Blade
172a	Bovine	Vertebrae	Stone	Unifacial	Not = |/	Unifacial	1	Slice	Blade
172b	Bovine	Vertebrae	Stone	Unifacial	Not = |/	Unifacial		Slice	Blade
172c	Bovine	Vertebrae	Stone	Unifacial	Not = |/	Unifacial		Slice	Blade
174	Bovine	Vertebrae	Stone	Unifacial	Not = |/	Unifacial	1	Slice	Blade
192	Bovine	Rib	Stone	Unifacial	Unidentifiable	Unifacial	1	Slice	Blade
193	Bovine	Rib	Stone	Unifacial	Not = |/	Unifacial	1	Slice	Blade
199	Bovine	Rib	Stone	Unifacial	Not = |/	Unifacial	1	Slice	Blade
204a	Bovine	Rib	Stone	Unifacial	Bifacial - V	Bifacial	1	Slice	Blade
204b	Bovine	Rib	Stone	Unifacial	Bifacial - V	Bifacial		Slice	Blade
204c	Bovine	Rib	Stone	Unifacial	Bifacial - V	Bifacial		Slice	Blade
205	Bovine	Long bone	Stone	Unifacial	Bifacial - V	Bifacial	1	Slice	Blade
208	Bovine	Long bone	Stone	Unifacial	Bifacial - V	Bifacial	1	Slice	Blade
220a	Bovine	Long bone	Stone	Unifacial	Bifacial - V	Bifacial	1	Slice	Blade
220b	Bovine	Long bone	Stone	Unifacial	Bifacial - V	Bifacial		Slice	Blade
220c	Bovine	Long bone	Stone	Unifacial	Bifacial - V	Bifacial		Slice	Blade
220d	Bovine	Long bone	Stone	Unifacial	Bifacial - V	Bifacial		Slice	Blade
220e	Bovine	Long bone	Stone	Unifacial	Bifacial - V	Bifacial		Slice	Blade

Table 3: Detailed information on each of the butchering incidences examined in the SEM (BI). Note the difference between the initial identification under Dino-Lite and the confirmed SEM identification.

Many of the faunal specimens displayed some evidence of butchery, such as slices, chops, and/or skinning (butchered individuals=bNISP). Over 5000 specimens were examined (50% of the total faunal mammalian assemblage), of which only 224 specimens had slice marks (Table 2). The 224 specimens (bNISP) were examined under an optical binocular microscope, and those thought to bear metal slice marks (a total of 13 specimens) were selected for further examination under SEM.

Such butchery extent makes the Kromer Dump a valuable assemblage for the study of slice marks to determine the nature of tool types utilized in the animal butchery process at Giza. In fact, it has been suggested that the workers from the quarries consumed the proximal and distal parts of the animal in a highly nutritious stew similar to *the* "*Kawar*eh" consumed in Egypt today (Ahmed and Redding 2021; Redding 2011). The study of the vast number of butchered animal bones from KRO has provided valuable information on animal consumption at Giza during the Fourth Dynasty, particularly by those individuals who worked in the quarry and may have resided in a settlement within the Tafla Bowl.

Results

Based on the light optical microscopic and SEM levels of analysis, only chipped stone tools, such as blades and flakes, accounted for each of the slice marks on the specimens. No metal slice marks were present on the specimens identified. Furthermore, a variety of stone blade types appeared: the butchery of sheep and goats was conducted with unifacially produced chipped stone blades, while cattle were butchered using larger bifacially produced chipped stone blades (Table 3).

The samples studied under SEM demonstrated clear characteristics of chipped stone-tool-based slice marks. These included the presence of lateral striations (either on one or both sides), uneven apex, and asymmetrical profiles characteristic of unifacially or bifacially produced chipped stone blades (Greenfield 2006; Greenfield and Brown 2016; Shipman 1981). Lateral striations were present on one or both sides of the slice marks in all the samples examined under SEM. Their presence suggests that most of the chipped stone tool flakes or blades employed in animal butchery were made by unifacial production, without retouch (Fig. 4). A small number of marks also exhibited bifacial retouch, but these were for butchering of larger animals (i.e., cattle).

Two interesting conclusions can be drawn from the current study of slice marks. First, the absence of metal-based slice marks on the faunal remains suggests an exclusive use of a stone-based tool technology in animal butchery by the pyramid workers at the quarry settlement at Giza during the Old Kingdom. Second, a variety of stone-based tool types were adopted in animal butchery. These two observations shed light on the tool types and their raw material adopted in the animal butchering process during the Old Kingdom.

The raw material of the blades depicted in two-dimensional animal butchery scenes from the Egyptian Old and Middle Kingdoms has previously been suggested to be flint (Ikram 1995, 63–69). The

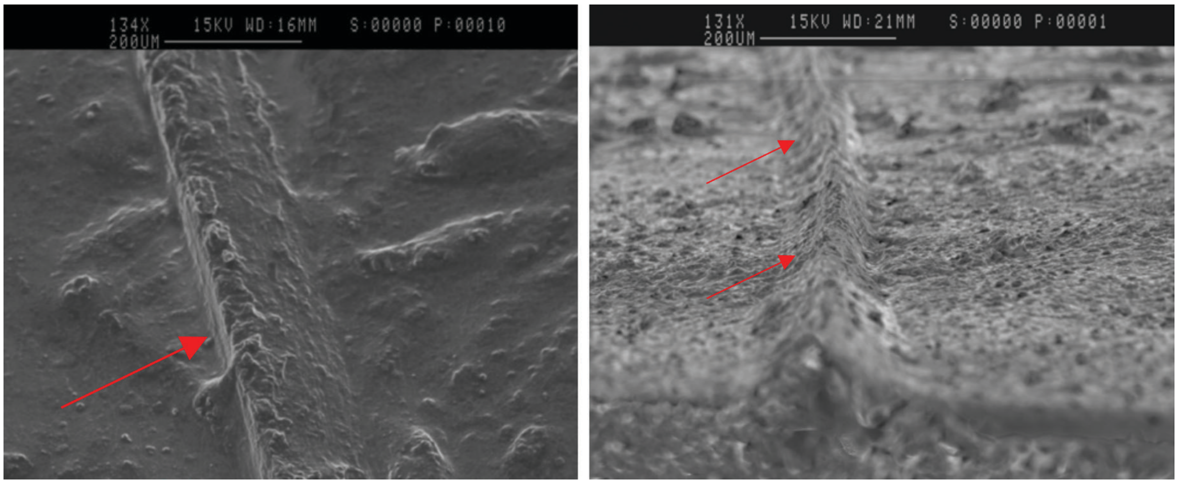

Figure 4: SEM Micrography of a unifacially produced slice mark. LEFT: KRO sample 174, Bos taurus, slice mark found on the spinous process fragment, thoracic vertebra. 200μ side angle. Note the clear steep slope on one side (red arrow). RIGHT: SEM Micrography of a unifacially produced slice mark. KRO sample 144, Ovis/Capra, slice mark found on the spinous process fragment, thoracic vertebra. 200μ side angle. The striations (denoted by the arrows) are present in these images and are reflective of a stone unifacial retouched knife.

knife blade in the Old Kingdom scenes that depict the slaughter of cattle with a knife is believed to be a chipped stone knife (e.g., Tomb of Nianchenesut, Saqqara. Old Kingdom, AS5967, Tomb 67, PM III. II: 696). The KRO case study data corroborates the ancient evidence and overwhelmingly demonstrates that butchering was also conducted using chipped stone tool blades in non-religious contexts.

Conclusions and Discussion

In the southern Levant, the distribution of metal objects vastly differs from that in neighboring Egypt during the third millennium BCE. In the latter, metal objects are largely recovered in mortuary contexts (Odler 2016, 66–69). During this time, copper use was limited to elite activities (which is why it shows up mainly in funerary deposits) or by the state for the construction of Pharaonic projects. However, whether the consumption of copper objects was restricted to these parameters is unknown.

In the southern Levant, by contrast, mortuary contexts are few and far between (Greenberg 2019, 336–338; Richard 2003, 175; Steiner and Killebrew 2014, 270), and most metal objects are recovered from settlements (Montanari 2015). While the aggregate data from the southern Levant allows us to infer the behavior of the lower strata, the data from Egypt also allows inference of elite behavior. Hence, the data from the two regions complement each other.

Metal as a Mechanism for Change

> "Technological change…is not always a progressive sequence of innovations but can also be characterised by continued use of traditional methods or artefacts, and even the surprisingly frequent re-introduction of techniques that might be assumed to become outmodeled" (Shaw 2012:1).

This statement by Ian Shaw stresses how technological advancements can be heavily influenced by traditional *and* progressive viewpoints. Indeed, in Egypt and the Levant, chipped stone tools continue to be extensively used through the development and rare consumption of copper tools. This pattern concurs with what is known about the relationship between technological innovations that ultimately replace older technologies (Edgerton 2008, 212). In fact, according to the evidence, the adoption of newer technologies (in this case, copper tools) in the Early Bronze Age was limited to high-status individuals or their administrators.

The Implications of Restricted Access to Metal in the Development of Early Complex Societies

Individuals who reside in a complex society typically have "differential access to and/or control of economic, productive, or symbolic resources and the mechanisms of enhancing socioeconomic status and the methods of displaying it …" (Richards

2005, 13). The shift from a socially egalitarian to a stratified, complex society is driven by several factors or mechanisms that serve as agents for change. Differential access to metal goods reinforces changes happening in the larger society. Metal enhances socioeconomic status through differential access to resources. Moreover, the distribution of copper objects in burials differs among the ranks of Egyptian officials (Kmošek et al. 2018, 205). The development of metallurgy and the adoption of metal-based tools enhances the social changes occurring in Egypt and the Levant—it supports and enhances the status quo among the higher-status individuals and differentiates them from the lower strata of society.

Social Differentiation in the Southern Levant

Evidence for social differentiation in the EB of southern Levant and metal consumption appears to play a role in the development of early complex society. In his description of EB II–III Jericho, for instance, Nigro stated that

> "The emergence of a distinguished ruling class, basically evidenced by funerary customs in tombs, as well as the functional differentiation of public areas within the city … point to an increased social complexity within, however, the framework of a strong concentration of wealth, power and ideology in the hands of the emerging elite" (Nigro 2014a, 71).

This may explain why the IB Jericho butchering data is so out of sync with that of most of the region. Differential access to goods, such as tin-bronze (Nigro et al. 2018), seems to occur much earlier at Jericho than in nearby settlements in the Jordan Valley drainage (e.g., Tall Zirāʻa) (Greenfield, Beller, and Gaastra 2021). Others discussing changes in the Levant from a social perspective also recognize that society became more complex socially during the EB II and III, particularly in larger cities (Chesson 2019). However, given the dearth of EB tombs across most of the southern Levant beyond the Jordan Valley, it is difficult to make pan-regional comparisons with Jericho. Each major settlement has yielded various copper artifacts, but they are found in both elite (Nigro et al. 2018; Greenberg 2019) and non-elite residential contexts, such as at Tell eṣ-Ṣâfi/Gath (Eliyahu-Behar and Yahalom-Mack, in press; Greenfield 2021). The absence of a pan-regional study of EB copper and bronze metal tools across the southern Levant impedes any definitive comparison with Egypt. The lack of EB I–III iconography or tomb contexts in the southern Levant does not allow for an in-depth understanding of how the use of early metal objects coincided with the development of early state-level societies. Contrary to Egypt, with its rich mortuary archaeological record, it is difficult to distinguish between elite and non-elite use of metal in the southern Levant. It is not yet clear if Jericho is an exception or the rule. If Jericho is the rule, the use of copper by elite members of society, as exemplified in Old Kingdom society, also becomes apparent in the Levant (Nigro 2019, 93).[1]

Interconnections and Metallurgy

The presence of exchange, particularly of prestige items to and from the Levant and Egypt, suggests an interregional trade network that included copper (Nigro 2014b). Nigro stated that at Jericho,

> "Increasing wealth, reflected into technological progress, material culture standardization and functional specialization supported the city interaction on an extra-regional scenario, enhancing exchange of typical Jericho products with prestigious items both from Egypt (on a route active since EB I), and Northern Levant (Syria and the Lebanese coast)" (Nigro 2014a).

From this perspective, Nigro suggests a world-systems view of copper distribution routes (Nigro 2014b), similar to what Algaze (1993) proposed for Chalcolithic Mesopotamia. The Levant served as the periphery of the copper world (supplier). In fact, the recent metallurgical studies of copper objects from Early Dynastic and Old Kingdom Egypt (Martin Odler, this volume, and previous work) suggest that some early copper objects came from as far as Anatolia (Kmošek et al. 2018; Odler and Kmošek 2020, 69). While the use of archaeometallurgy to understand the interconnections between Egypt, the Levant, Anatolia, and elsewhere in the Eastern Mediterranean has proven useful for tracing exchange routes, the adoption of a zooarchaeological perspective (as presented here) complements this perspective—it furthers our understanding by being more socially inclusive, being able to see that access to non-local goods was socially differentiated. Thus, in conclusion, we suggest that such resources were more likely to be available to the "state," elite individuals, and/or officials or individuals with the capabilities of procuring them in early complex societies (e.g., merchants acting on behalf of the state). As can be seen in our discussion above, the spread of new technologies (e.g., metallurgy) is a more complex process than previously conceptualized. It requires rethinking basic concepts within archaeology about the transmission of new knowledge across time and space (Straub 2009).

Based on the results of this analysis from Egypt and previous research in other regions, the transition from stone to metal tools for butchering began, on a large scale, only during the Middle Bronze Age, in the Levant and the central Balkans (Greenfield 1999, 2002, 2008, 2013, 2017, 2021; Greenfield and Brown 2016; Greenfield, Brown, and Miroschedji 2021; Greenfield and Marciniak 2019), and, in the Late Bronze Age, in central Poland (Greenfield 2017; Greenfield and Marciniak 2021; Marciniak and Greenfield 2013). Certain areas of the Near East (i.e., Anatolia) lagged in the transition to metal tools for butchering since obsidian was easily available and sharper than metal (Greenfield and Chaput 2021; Greenfield and Marciniak 2019). It is clear, thus, that one cannot assume the transition occurred broadly in the Early Bronze Age and that each region must be investigated separately.

Acknowledgments

The authors gratefully acknowledge the multitude of archaeologists and zooarchaeologists working in or from the southern Levant who opened their laboratories and collections for analysis here. We also gratefully acknowledge the AERA project for permission to analyze and report our analysis of the butchered faunal remains from the Kromer Dump. In particular, we would like to thank Mark Lehner and Richard Redding for making this research possible. Funds for this research were granted by the Social Science and Humanities Research Council of Canada to Haskel J. Greenfield. We also gratefully acknowledge the support provided by the University of Manitoba and St. Paul's College for making it possible to analyze the data in the Near Eastern and Biblical Archaeology Laboratory. Any errors in this paper are the responsibility of the authors.

References

Abe, Yoshiko, Curtis W. Marean, Peter John Nilssen, Zelalem Assefa, and Elizabeth C. Stone. 2002. "The Analysis of Cutmarks on Archaeofauna: A Review and Critique of Quantification Procedures, and a New Image-Analysis GIS Approach." *American Antiquity* 67(4): 643–663.

Abreu de Sousa, Eleutério. 2020. "On the Chopping Block: Animal Butchery Technologies in Old Kingdom Egypt." MA Thesis, Anthropology Department, University of Manitoba, Winnipeg (35088).

Adams, Russell B. 1997. "On Early Copper Metallurgy in the Levant: A Response to Claims of Neolithic Metallurgy." In Hans Georg K. Gebel, Zeidan Kafafi, Gary O. Rollefson (eds.), *The Prehistory of Jordan II: The Perspectives from 1997*, 651–655. Berlin: ex Oriente.

———. 2002. "From Farms to Factories: The Development of Copper Production at Faynan, Southern Jordan, during the Early Bronze Age." In Barbara S. Ottaway and Emma C. Wager (eds.), *Metals and Society: Papers from a Session Held at the European Association of Archaeologists Sixth Annual Meeting in Lisbon 2000*, 21–32. Oxford: Archaeopress.

Adams, Russell B., and Hermann Genz. 1995. "Excavations at Wadi Fidan 4: A Chalcolithic Village Complex in the Copper Ore District of Feinan, Southern Jordan." *Palestine Exploration Quarterly* 127: 8–20.

Ahmed, Mohamed Hussein, and Richard Redding. 2021. "Faunal Remains from Excavations at the Menkaure Valley Temple (MVT-W), 2019." *Journal of the American Research Center in Egypt* 56: 17–34. DOI: https://doi.org/10.5913/jarce.56.2020.a002.

Algaze, Guillermo. 1993. *The Uruk World System: The Dynamics of Expansion of Early Mesopotamian Civilization*. Chicago: University of Chicago Press.

Baud, Michel. 2010. "The Old Kingdom." In Alan B. Lloyd (ed.), *A Companion to Ancient Egypt*, 63–80. Chichester West Sussex: Wiley–Blackwell.

Bello, Silvia M., Simon A. Parfitt, and Chris Stringer. 2009. "Quantitative Micromorphological Analyses of Cut Marks Produced by Ancient and Modern Handaxes." *Journal of Archaeological Science* 36:1869–1880.

Ben-Yosef, Erez, Aaron D. Gidding, L. Tauxe, Uri Davidovich, Mohammed Najjar, and Thomas

E. Levy. 2016. "Early Bronze Age Copper Production Systems in the Northern Arabah Valley: New Insights from Archaeomagnetic Study of Slag Deposits in Jordan and Israel." *Journal of Archaeological Science* 72: 71–84.

Blitzer, Harriet. 1995. "The Chipped Stone Industry (CS 1-96)." In Joseph W. Shaw and Maria C. Shaw (eds.), *Kommos I: The Kommos Region and Houses of the Minoan Town, Part 1: The Kommos Region, Ecology, and the Minoan Industries*, 488–496. Princeton: Princeton University Press.

Carter, Tristan. 2004a. "The Chipped Stone." In Jeffrey S. Soles (ed.), *Mochlos IC: Period III. Neopalatial Settlement on the Coast: The Artisans' Quarter and the Farmhouse at Chalinomouri*, 91–107. Philadelphia: INSTAP Academic Press.

———. 2004b. "Transformative Processes in Liminal Spaces: Craft as Ritual Action in the Throne Room Area." *British School at Athens Studies* 12: 273–282.

Chernykh, Evgeniĭ Nikolaevich. 1992. *Ancient Metallurgy in the USSR: The Early Metal Age.* Cambridge: Cambridge University Press.

Chesson, Meredith S. 2019. "The Southern Levant during the Early Bronze Age I–III." In Assaf Yasur-Landau, Eric H. Cline and Yorke Rowan (eds.), *The Social Archaeology of the Levant: From Prehistory to the Present*, 163–182. Cambridge: Cambridge University Press.

Childe, V. Gordon. 1930. *The Bronze Age.* Cambridge: Cambridge University Press.

———. 1934. *New Light on the Most Ancient Near East.* London: Routledge & Kegan Paul.

———. 1950. "The Urban Revolution." *The Town Planning Review* 21(1): 3–17.

Cifuentes-Alcobendas, Gabriel, and Manuel Domínguez-Rodrigo. 2019. "Deep Learning and Taphonomy: High Accuracy in the Classification of Cut Marks Made on Fleshed and Defleshed Bones Using Convolutional Neural Networks." *Scientific Reports* 9(1): 1–12.

Cour-Marty, M.A. 1997. "Les poids inscrits de l'Ancien Empire." In Jean-Philippe Lauer, Catherine Berger and Bernard Mathieu (eds.), *Etudes sur l'Ancien Empire et la nécropole de Saqqâra dédiées à Jean-Philippe Lauer*, 129–145. Montpellier: Université Paul Valéry-Montpellier III.

Courtenay, Lloyd A., Miguel Ángel Maté-González, Julia Aramendi, José Yravedra, González-Aguilera Diego, and Manuel Domínguez-Rodrigo. 2018. "Testing Accuracy in 2D and 3D Geometric Morphometric Methods for Cut Mark Identification and Classification." *PeerJ* 6: e5133. DOI: 10.7717/peerj.5133.

Cowell, Michael. 1986. "The Composition of Egyptian Copper-Based Metalwork." In Science in Egyptology, edited by R.A. David, 463–468. Manchester: Manchester University Press.

Delage, Christophe. 2017. "Once Upon a Time…the (hi)story of the Concept of the Chaîne Opératoire in French Prehistory." *World Archaeology* 49(2): 158–173. DOI: 10.1080/00438243.2017.1300104.

Desplancques, Sophie. 2006. *Institution du trésor des origines à la fin du moyen empire*. Paris: Presses de l'Université de Paris-Sorbonne.

Dierckx, Heidi M. C. 2008. "The Chipped Stone from Hagios Charalambos," in Excavations in the Hagios Charalambos Cave: A Preliminary Report by Philip P. Betancourt, Costis Davaras, Heidi M. C. Dierckx, Susan C. Ferrence, Jane Hickman, Panagiotis Karkanas, et al. *Hesperia* 77: 562–566.

Domínguez-Rodrigo, Manuel, Enrique Baquedano, Luciano Varela, P. Sebastián Tambusso, María Julia Melián, and Richard A. Fariña. 2021. "Deep Classification of Cut-Marks on Bones from Arroyo del Vizcaíno (Uruguay)." Proceedings of the Royal Society B 288, 1954. DOI: https://doi.org/10.1098/rspb.2021.0711.

Domínguez-Rodrigo, Manuel, Gabriel Cifuentes-Alcobendas, Blanca Jiménez-García, Natalia Abellán, Marcos Pizarro-Monzo, Elia Organista, and Enrique Baquedano. 2020. "Artificial Intelligence Provides Greater Accuracy in the Classification of Modern and Ancient Bone Surface Modifications." *Scientific Reports* 10, 18862. DOI: https://doi.org/10.1038/s41598-020-75994-7.

Edgerton, David. 2008. *The Shock of the Old: Technology and Global History Since 1900.* London: Profile Books.

Eliyahu-Behar, Adi, and Naama Yahalom-Mack. 2018. "Metallurgical Investigations at Tell eṣ-Ṣâfi/Gath." In Itzhaq Shai, Jeffrey R. Chadwick, Louise Hitchcock, Amit Dagan, Chris McKinny and Joe Uziel (eds.), *Tell it in Gath: Studies in the History and Archaeology of Israel: Essays in honor of Aren M. Maeir on the Occasion of the Sixtieth Birthday*, 811–815. Münster: Zaphon.

Eliyahu-Behar, Adi, and Naama Yahalom-Mack. In press. "Copper Objects and their Provenance." In Itzhaq Shai, Haskel J. Greenfield and Aren M.

Maeir (Eds.), *Tell eṣ-Ṣâfi/Gath III: the Early Bronze Age III*. Wiesbaden: Harrassowitz.

Emery, Walter B. 1963. "Egypt Exploration Society: Preliminary Report on the Excavations at Buhen, 1962." *Kush: Journal of the Sudan Antiquities Service*. 11: 116–120.

Eriksen, Berit V., ed. 2010. *Lithic Technology in Metal Using Societies (Proceedings of a UISPP Workshop, Lisbon, September 2006, Moesgaard)*. Jutland Archaeological Society Vol. 67. Hojbjerg: Jutland Archaeological Society.

Garfinkel, Yosef, Florian Klimscha, Sariel Shalev, and Danny Rosenberg. 2014. "The Beginning of Metallurgy in the Southern Levant: A Late 6th Millennium Calbc Copper Awl from Tel Tsaf, Israel." *PLoS One* 9(3), e92591. https://doi.org/10.1371/journal.pone.0092591.

Garland, H., and Charles Olden Bannister. 1927. *Ancient Egyptian Metallurgy*. London: Griffin.

Golden, Jonathan. 2002. "The Origins of the Metals Trade in the Eastern Mediterranean: Social Organization of Production in the Early Copper Industries." In Edwin CM Van Den Brink and Thomas Levy (eds.), *Egypt and the Levant: Interrelations from the 4th through the Early 3rd Millenium BCE*, 225–238. New York: Bloomsbury Academic.

———. 2010. *Dawn of the Metal Age: Technology and Society during the Levantine Chalcolithic* (Approaches to Anthropological Archaeology Series). Edited by Thomas E. Levy. London: Equinox Publishing Ltd.

Graves-Brown, Carolyn A. 2010. *The Ideological Significance of Flint in Dynastic Egypt*. Unpublished Ph.D. Dissertation. London: Institute of Archaeology, University College London.

Greenberg, Raphael. 2019. *The Archaeology of the Bronze Age Levant: From Urban Origins to the Demise of City-States, 3700–1000 BCE*. Cambridge World Archaeology. Cambridge: Cambridge University Press.

Greenfield, Haskel J. 1999. "The Origins of Metallurgy: Distinguishing Stone from Metal Cut Marks on Bones from Archaeological Sites." *Journal of Archaeological Science* 26(7): 797–808.

———. 2002. "Distinguishing Metal (Steel and Low-Tin Bronze) from Stone (Flint and Obsidian) Tool Cut Marks on Bone: An Experimental Approach." In James R. Mathieu (ed.), *Experimental Archaeology: Replicating Past Objects, Behaviors, and Processes*. British Archaeological Reports, International Series 1035, 35–54. Oxford: Archaeopress.

———. 2005. The Origins of Metallurgy at Jericho (Tel es-Sultan): A Preliminary Report on Distinguishing Stone from Metal Cut Marks on Mammalian Remains. In H. Buitenhuis, A. Choyke, L. Martin, L. Bartosiewicz and M. Mashkour, *Archaeozoology of the Near East VI: Proceedings of the 6th Sixth International Symposium on the Archaeozoology of Southwestern Asia and Adjacent Areas*, 178–186. ARC/Archeological Research and Consultancy Publications: Groningen.

———. 2006. "Slicing Cut Marks on Animal Bones: Diagnostics for Identifying Stone Tool Type and Raw Material." *Journal of Field Archaeology* 31: 147–163.

———. 2008. "Metallurgy in the Near East. A Zooarchaeological Perspective on the Origins of Metallurgy in the Near East: Analysis of Stone and Metal Cut Marks on Bone from Israel." In Helaine Selin (ed.), *Encyclopedia of the History of Science, Technology, and Medicine in Non–Western Cultures*, 1639–1647. Dordrecht: Springer Academic Publishers.

———. 2013. "'The Fall of the House of Flint': A Zooarchaeological Perspective on the Decline of Chipped Stone Tools for Butchering Animals in the Bronze and Iron Ages of the Southern Levant." *Lithic Technology* 38(3): 161–178.

———. 2017. "The Spread of Productive and Technological Innovations in Europe and Near East: An Integrated Zooarchaeological Perspective on Secondary Animal Products and Bronze Utilitarian Metallurgy." In Philipp W. Stockhammer and Joseph Moran (eds.), *Appropriating Innovations (Proceedings of the Entangled Knowledge in Late Neolithic and Early Bronze Age Eurasia Conference, Heidelberg, 15th–17th January 2015)*, 50–68. Oxford: Oxbow Books.

———. 2021. "Insufficient Evidence for Metal Butchering Marks at Tell El-Hesi during the Early Bronze Age: Critique of the Analysis of Microscopic Grooves in 'Cultural Modification Analyses on Faunal Remains in Relation to Space Use and Direct Provisioning from Field VI EBIIIA Tell el–Hesi' by Kara Larson, James W. Hardin, and Sara Cody." *Palestine Exploration Quarterly* 160(2): 144–155. DOI: 10.1080/00310328.2021.1921436.

Greenfield, Haskel J., Jeremy A. Beller, and Jane Gaastra. 2021. "Changes in Butchering Technology and Efficiency Patterns between the Early and Middle Bronze Ages from Tell Zirā´A, Jordan." In Dieter Vieweger and Jütta Häser (eds.), *Tall Zirā'a, The Gadara Region Project (2001–2011) Final Report Volume 3: Early and Middle Bronze Age (Strata 25–17)*. Wuppertal: Deutsches Evangelisches Institut.

Greenfield, Haskel J., Jeremy A. Beller, Jane S. Gaastra, and Dieter Vieweger. 2022. "Filling the Gap: A Microscopic Zooarchaeological Approach to Changes in Butchering Technology During the Early and Middle Bronze Periods at Tall Zirā´A, Jordan." *Palestine Exploration Quarterly*: 1–37. DOI: https://doi.org/10.1080/00310328.2022.2050094.

Greenfield, Haskel J., and Annie Brown. 2016. "'Making the cut': Changes in Butchering Technology and Efficiency Patterns from the Chalcolithic to modern Arab Occupations at Tell Halif, Israel." In Nimrod Marom, Reuven Yeshurun, Lior Weissbrod and Guy Bar-Oz (eds.), *Bones and Identity: Zooarchaeological Approaches to Reconstructing Social and Cultural Landscapes in Southwest Asia (Proceedings of the ICAZ-SW Asia Conference, Haifa, June 23–28, 2013)*, 273–291. Oxford: Oxbow Press.

Greenfield, Haskel J., Annie Brown, and Pierre de Miroschedji. 2021. "Origins of Metallurgy in the Southern Levant: Microscopic Examination of Butchering Marks on Animal Bones at Tel Yarmuth, Israel." In Umberto Albarella, Cleia Detry, Sónia Gabriel, Catarina Ginja, Ana Elisabete Pires and João Pedro Tereso (eds.), *Themes in Old World Zooarchaeology: from the Mediterranean to the Atlantic*, 95–107. Oxford, United Kingdom: Oxbow Books.

Greenfield, Haskel J., Annie Brown, Itzhaq Shai, and Aren M. Maeir. 2016. "Preliminary Analysis of the Fauna from the Early Bronze Age III Neighbourhood at Tell Eṣ-Ṣâfi/Gath, Israel." In Nimrod Marom, Reuven Yeshurun, Lior Weissbrod and Guy Bar-Oz (eds.), *Bones and Identity: Zooarchaeological Approaches to Reconstructing Social and Cultural Landscapes in Southwest Asia (Proceedings of the ICAZ-SW Asia Conference, Haifa, June 23–28, 2013)*, 170–192. Oxford: Oxbow Press.

Greenfield, Haskel J., and Talisha Chaput. 2021. "Butchering Technology at the Early Tin Metal Producing Site of Göltepe." In K. Aslihan Yener (ed.), *Tin Production at Göltepe: Excavations at an Early Bronze Age Mining Town in the Central Taurus Mountains, Turkey*, 160–176. Philadelphia: Institute for Aegean Academic Press.

Greenfield, Haskel J., and Tina L. Greenfield. 2018. "Butchering Technology in Middle Bronze Age Ashkelon." In Lawrence E. Stager, Daniel M. Master, and J. David Schloen (eds.), *Final Reports of the Leon Levy Expedition to Ashkelon: Ashkelon 6: The Middle Bronze Age Ramparts and Gates of the North Slope and Later Fortifications*, 509–520. University Park, PA: Harvard Semitic Museum Publications and Eisenbrauns.

Greenfield, Haskel J., and Arkadiusz Marciniak. 2019. "Retention of Old Technologies Following the End of the Neolithic: Microscopic Analysis of the Butchering Marks on Animal Bones from Çatalhöyük East." *World Archaeology* 51(1): 76–103. DOI: https://doi.org/10.1080/00438243.2018.1525310.

———. 2021. "The Emergence and Transmission of Metallurgical Technology for Subsistence Activities in Daily Life in Northern Europe: A Microscopic Zooarchaeological Perspective." *Journal of Field Archaeology* 46: 275–288. DOI: https://doi.org/10.1080/00934690.2021.1909279.

Harding, Anthony F. 2000. "Hoards and Hoarding." In Anthony F. Harding (ed.), *European Societies in the Bronze Age*, 352–368. Cambridge University Press.

Hauptmann, Andreas. 2007. *The Archaeometallurgy of Copper: Evidence from Faynan, Jordan*. New York: Springer.

Hauptmann, Andreas, Sigrid Schmitt-Strecker, Thomas E. Levy, and Friedrich Begemann. 2015. "On Early Bronze Age Copper Bar Ingots from the Southern Levant." *Bulletin of the American Schools of Oriental Research* 373: 1–24.

Hauptmann, Harald, and Ernst Pernicka, eds. 2004. *Die Metallindustrie Mesopotamiens von den Anfängen bis zum* 2. Jahrtausend v. Chr., Orient-Archäologie. Rahden, Germany: Verlag Marie Leidorf.

Ikram, Salima. 1995. *Choice Cuts: Meat Products in Ancient Egypt*. Leuven: Peeters Press.

Johnson, Gregory A. 1977. "Aspects of Regional Analysis in Archaeology." *Annual Review of Anthropology* 6: 479–508.

Khalaily, Hamoudi. 2008. "The Flint Assemblage," in The Early Bronze Age Site of Ashqelon, Afridar – Area M by Amir Golani. *'Atiqot* 60: 36–40.

Klemm, Dietrich, and Rosemarie Klemm. 2008. "Mining in Ancient Egypt and Nubia." In Helaine Selin (ed.), *Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures*, 1685–1698. New York: Springer.

———. 2013. *Gold and Gold Mining in Ancient Egypt and Nubia: Geoarchaeology of the Ancient Gold Mining Sites in the Egyptian and Sudanese Eastern Deserts.* Heidelberg: Springer.

Kmošek, Jiří, Martin Odler, Marek Fikrle, and Yulia V. Kochergina. 2018. "Invisible Connections. Early Dynastic and Old Kingdom Egyptian Metalwork in the Egyptian Museum of Leipzig University." *Journal of Archaeological Science* 96: 191–207. DOI: 10.1016/j.jas.2018.04.004.

Kobusiewicz, Michal. 2015. *The Production, Use and Importance of Flint Tools in the Archaic Period and the Old Kingdom in Egypt.* Archaeopress Egyptology 12. Oxford: Archaeopress.

Kooi, Rebecca J., and Scott I. Fairgrieve. 2013. "SEM and Stereomicroscopic Analysis of Cut Marks in Fresh and Burned Bone." *Journal of Forensic Sciences* 58(2): 452–458. DOI: https://doi.org/10.1111/1556-4029.12050.

Kromer, Karl. 1978. *Siedlungsfunde aus dem frühen alten Reich in Giseh: Österreichische Ausgrabungen 1971–1975, Denkschriften der Philosophisch–Historischen Klasse*. Wien: Österreichische Akademie der Wissenschaften.

Lehner, Mark. 2018. "Kromer in Context: Biography of an Ancient Dump." *AERAGRAM* (Ancient Egypt Research Associates), 19(2): 2–13. https://www.aeraweb.org/wp-content/uploads/2020/04/AG19_2.pdf.

Levy, Thomas E., Russell B. Adams, Andreas Hauptmann, Michael Prange, Sigrid Schmitt-Strecker, and Mohammad Najjar. 2002. "Early Bronze Age Metallurgy: A Newly Discovered Copper Manufactory in Southern Jordan." *Antiquity* 76: 425–437.

Levy, Thomas E., and Sariel Shalev. 1989. "Prehistoric Metalworking in the Southern Levant: Archaeometallurgical and Social Perspectives." *World Archaeology* 20(3): 353–372.

Lucas, A. 1927. *Copper in Ancient Egypt*. London: Egypt Exploration Society.

———. 1959. *Ancient Egyptian Materials and Industries*. Third edition. London: Edward Arnold Publishers Ltd.

Maddin, R., Tamara Stech, James D. Muhly, and E. Brovarski. 1984. "Old Kingdom Models from the Tomb of Impy: Metallurgical Studies." *The Journal of Egyptian Archaeology* 70(1): 33–41.

Manclossi, Francesca, and Steve A. Rosen. 2017. "What We Can Learn from the Flint Industries from Tell eṣ-Ṣâfi/Gath." *Near East Archaeology* 81: 84.

Manclossi, Francesca, Steve A. Rosen, and Eric Böeda. 2019. "From Stone to Metal: The Dynamics of Technological Change in the Decline of Chipped Stone Tool Production: A Case Study from the Southern Levant (5th–1st Millennia BCE)." *Journal of Archaeological Method and Theory* 26: 1276–1326. DOI: 10.1007/s10816-019-09412-2.

Manclossi, Francesca, and Steven A. Rosen. In press. "The Early Bronze Age Lithic Assemblage from Tell eṣ-Ṣâfi/Gath." In Itzhaq Shai, Haskel J. Greenfield, and Aren M. Maeir eds.), *Tell eṣ-Ṣâfi/Gath III: The Early Bronze Age*. Wiesbaden: Harrasowitz.

Manclossi, Francesca, Steven A. Rosen, and Gunnar Lehmann. 2018. "The Decline and Disappearance of Chipped-Stone Tools: New Insights from Qubur El-Walaydah, a Late Bronze/Iron Age Site in Israel." *Lithic Technology* 42(2): 93–124. DOI: https://doi.org/10.1080/01977261.2018.1438336.

Marciniak, Arkadiusz, and Haskel J. Greenfield. 2013. "A Zooarchaeological Perspective on the Origins of Metallurgy in the North European Plain: Butchering Marks on Bones from Central Poland." In Sophie Bergerbrant and Serena Sabatini (eds.), *Counterpoint: Essays in Archaeology and Heritage Studies in Honour of Professor Kristian Kristiansen*. British Archaeological Reports, International Series 2508, 457–468. Oxford: Archaeopress.

Maté-González, Miguel Ángel, Juan Francisco Palomeque-González, José Yravedra, Diego González-Aguilera, and Manuel Domínguez-Rodrigo. 2018. "Micro-Photogrammetric and Morphometric Differentiation of Cut Marks on Bones Using Metal Knives, Quartzite, and Flint Flakes." *Archaeological and Anthropological Sciences* 10(4): 805–816.

Montanari, Daria. 2015. "Metal Weapons in the Southern Levant during the Early Bronze Age: An Overview." In Karolina Rosińska-Balik, Agnieszka Ochał-Czarnowicz, Marcin Czarnowicz and Joanna Dębowska-Judwin (eds.), *Copper and Trade in the South-Eastern Mediterranean: Trade Routes of the Near East in Antiquity*. British Archaeological Reports, International Series 2753, 67–76. England: BAR Publishing.

Moorey, P.R.S. 1988. "Early Metallurgy in Mesopotamia." In Robert Maddin (ed.), *The Beginning of the Use of Metals and Alloys: Papers from the Second International Conference on the Beginning of the Use of Metals and Alloys Zhengzhou China 21-26 October 1986*, 28–33. Cambridge Mass.: MIT Press.

———. 1994a. *Ancient Mesopotamian Materials and Industries*. Oxford: Oxford University Press.

———. 1994b. *Ancient Mesopotamian Materials and Industries: The Archaeological Evidence*. Oxford: Oxford University Press.

Muhly, James D. 1980. "The Bronze Age Setting." In Theodore A. Wertime and James D. Muhly (eds.), *The Coming of the Age of Iron*, 25–68. New Haven: Yale University Press.

———. 1988. "The Beginning of Metallurgy in the Old World." In Robert Maddin (ed.), *The Beginning of the Use of Metals and Alloys: Papers from the Second International Conference on the Beginning of the Use of Metals and Alloys Zhengzhou China 21-26 October 1986*, 2–20. Cambridge Mass.: The MIT Press.

———. 1999. "Metallurgy." In Kathryn A. Bard (ed.), *Encyclopedia of the Archaeology of Ancient Egypt*, 628–634. London: Routledge.

———. 2011. "Metals and Metallurgy." In Sharon R. Steadman and G. McMahon (eds.), *The Oxford Handbook of Ancient Anatolia (10000–323 BCE)*, 858–876. Oxford: Oxford University Press.

Muhs, Brian. 2016. *The Ancient Egyptian Economy: 3000–30 BCE*. Cambridge, United Kingdom: Cambridge University Press.

Needler, Winifred. 1984. *Pre-dynastic and Archaic Egypt in the Brooklyn Museum*. Brooklyn, N.Y.: Brooklyn Museum.

Nigro, Lorenzo. 2014a. "The Archaeology of Collapse and Resilience: Tell es-Sultan/Ancient Jericho as a Case Study." In Lorenzo Nigro (ed.), *Overcoming Catastrophes: Essays on Disastrous Agents Characterization and Resilience Strategies in Pre-Classical Southern Levant*, 55–85. Rome: "La Sapienza" Expedition to Palestine & Jordan.

———. 2014b. "The Copper Route and the Egyptian Connection in 3rd Millennium BC Jordan seen from the Caravan City of Khirbet al-Batrawy." *Vicino Oriente* 18: 39–64.

———. 2019. "Tell es-Sultan/ancient Jericho in the Early Bronze Age II–III." In Elisabetta Gallo (ed.), *Conceptualizing Urban Experiences: Tell es-Sultan and Tall al-Ḥammām Early Bronze Cities across the Jordan. Proceedings of a Workshop held in Palermo, G. Whitaker Foundation, June 19th, 2017, Rome "La Sapienza" Studies on the Archaeology of Palestine & Transjordan, vol. 13*, 79–108. Rome: La Sapienza.

Nigro, Lorenzo, Daria Montanari, Francesco Mura, and Ruggero Caminiti. 2018. "Not Invasive Analyses on a Tin-Bronze Dagger from Jericho: A Case Study." *Mediterranean Archaeology and Archaeometry* 18(1): 199–207. DOI: 10.5281/zenodo.1161359.

North, Robert. 1955. "Metallurgy in the Ancient Near East." *Orientalia Nova Series* 24(1): 78–88.

Odler, Martin. 2015. "Adzes in the Early Dynastic Period and the Old Kingdom." In Karolina Rosińska-Balik, Agnieszka Ochał-Czarnowicz, Marcin Czarnowicz and Joanna Dębowska-Ludwin (eds.), *Copper and Trade in the South–Eastern Mediterranean: Trade routes of the Near East in Antiquity*, 85–153. Oxford: Archaeopress.

———. 2016. *Old Kingdom Copper Tools and Model Tools*. Archaeopress Egyptology 14. Oxford: Archaeopress.

Odler, Martin, and Jiří Kmošek. 2020. *Invisible Connections: An Archaeometallurgical Analysis of the Bronze Age Metalwork from the Egyptian Museum of the University of Leipzig*. Oxford: Archaeopress.

Ogden, Jack. 2000. "Metals." In Paul Nicholson and Ian Shaw (eds.), *Ancient Egyptian Materials and Technology*, 148–176. Cambridge, UK: Cambridge University Press.

Olsen, Sandra L. 1988a. "The Identification of Stone and Metal Tool Marks on Bone Artifacts." In Sandra L. Olsen (ed.), *Scanning Electron Microscopy in Archaeology*, 337–360. Oxford: BAR.

———. 1988b. "The identification of stone and metal tool marks on bone artifacts." In Sandra L. Olsen (ed.), *Scanning Electron Microscopy in Archaeology*, 337–360. Oxford: BAR.

Petrie, William Matthew Flinders. 1913. *Tarkhan I and Memphis V*. London: School of Archaeology in Egypt, Univ. College.

Philip, Graham. 1988. "Hoards of the Early and Middle Bronze Ages in the Levant." *World Archaeology* 20(2): 109–208.

———.1989. *Metal Weapons of the Early and Middle Bronze Ages in Syria-Palestine*. British Archaeological Reports, International Series 526. Oxford: BAR.

———. 2003. "The Early Bronze Age of the Southern Levant: A Landscape Approach." *Journal of Mediterranean Archaeology* 16: 103–132.

———. 2008. "The Early Bronze Age I–III." In Russell B. Adams (ed.), *Jordan: An Archaeological Reader*, 2nd edition, 161–226. London: Equinox.

Philip, Graham, Philip W. Clogg, and David Dungworth. 2003. "Copper Metallurgy in the Jordan Valley from the Third to the First millennia BC: Chemical, Metallographic and Lead Isotope Analyses of Artefacts from Pella." *Levant* 35: 71–100.

Potts, Richard, and Pat Shipman. 1981. "Cutmarks Made by Stone Tools on Bones from Olduvai Gorge, Tanzania." *Nature* 291(5816): 577–580.

Redding, Richard. 2011. "Stews, Meat, and Marrow: Extracting Protein and Fat for the Lost City." *AERAGRAM* 12(2): 13.

———. Fortchoming. Cattle in Egypt.

Richard, Suzanne. 2003. "The Early Bronze Age of the Southern Levant." In Suzanne Richard (ed.), *Near Eastern Archaeology: A Reader*, 280–296. Winona Lake, IN: Eisenbrauns.

Richards, Janet. 2005. *Society and Death in Ancient Egypt: Mortuary Landscapes of the Middle Kingdom*. Cambridge: Cambridge University Press.

Rosen, Steven A. 1984. "The Adoption of Metallurgy in the Levant: A Lithic Perspective." *Current Anthropology* 25: 504–505.

Rosen, Steven A. 1997. *Lithics after the Stone Age: A Handbook of Stone Tools from the Levant*. Walnut Creek, CA: Altamira Press.

Rosenberg, Danny, Eli Buchman, Sariel Shalev, and Shay Bar. 2020. "A Large Copper Artefacts Assemblage of Fazael, Jordan Valley: New Evidence of Late Chalcolithic Copper Metallurgy in the Southern Levant." *Documenta Praehistorica* 47: 246–261. DOI: 10.4312\dp.47.14.

Rosenfeld, Amnon, Shimon Ilani, and Michael Dvorachek. 1997. "Bronze Alloys from Canaan during the Middle Bronze Age." *Journal of Archaeological Science* 24(9): 857–864.

Rosińska-Balik, Karolina, Agnieszka Ochał-Czarnowicz, Marcin Czarnowicz, and Joanna Dębowska-Judwin, eds. 2015. *Copper and Trade in the South-Eastern Mediterranean: Trade Routes of the Near East in Antiquity*. England: BAR Publishing.

Sanders, William, Henry T. Wright, and Robert McCormick Adams. 1984. *On the Evolution of Complex Societies; Essays in Honor of Harry Hoiger 1982*. Malibu: Published for the UCLA Dept. of Anthropology by Undena Publications.

Scheel, Bernd. 1989. *Egyptian Metalworking and Tools*. Aylesbury: Shire Publishers.

Shalev, Sariel. 1994. "The Change in Metal Production from the Chalcolithic Period to the Early Bronze Age in Israel and Jordan." *Antiquity* 68: 630–637.

Shephard, R. 1980. *Prehistoric Mining and Allied Industries*. London: Academic Press.

Shipman, Pat. 1981. "Application of Scanning Electron Microscopy to Taphonomic Problems." *Annals of the New York Academy of Sciences* 375: 357–385.

Shipman, Pat, and Jennie Rose. 1988. "Bone Tools: An Experimental Approach." In Sandra J. Olsen (ed.), *Scanning Electron Microscopy in Archaeology*, British Archaeological Reports, International Series 452, 303–336. Oxford: BAR.

Shugar, Aaron N., and Christopher J. Gohm. 2011. "Developmental Trends in Chalcolithic Copper Metallurgy: A Radiometric Perspective Changed the World." In Jaimie Lovell and Yorke M. Rowan (eds.), *Culture, Chronology and the Chalcolithic: Theory and Transition*. Levant Supplementary vol. 9. Oxford: Council for British Research in the Levant and Oxbow Books.

Steiner, Margreet L., and Ann E. Killebrew, eds. 2014. *The Oxford Handbook of the Archaeology of the Levant c. 8000–332 BCE*. Oxford Handbooks in Archaeology. Oxford: Oxford University Press.

Straub, Evan T. 2009. "Understanding Technology Adoption: Theory and Future Directions for Informal Learning." *Review of Educational Research* 79(2): 625–649.

Tadmor, M., D. Kedem, F. Begemann, A. Hauptmann, E. Pernicka, and S. Schmitt-Strecker. 1995. "The Naḥal Mishmar Hoard from the Judean Desert:

Technology, Composition, Provenance." *'Atiqot* 27: 93–146.

Tallet, Pierre. 2010. "Le roi Den et les Iountiou. Les Égyptiens au Sud-Sinaï sous la 1re dynastie." *Archéo-Nil* 20: 97–105.

Taylor, Robin J. 1993. *Hoards of the Bronze Age in Southern Britain: Analysis and Interpretation*. Oxford: BAR.

Tillmann, Andreas. 1999. "Dynastic Stone Tools." In Kathryn A. Bard (ed.), *Encyclopedia of the Archaeology of Ancient Egypt*, 310–314. London: Routledge.

Tylecote, R. F. 1986. *The Prehistory of Metallurgy in the British Isles*. London: The Institute of Metals.

———. 1987. *The Early History of Metallurgy in Europe*. London: Longman.

———. 1992. *A History of Metallurgy*. 2nd ed. London: The Institute of Metals.

Verly, Georges, Frederik W. Rademakers, Claire Somaglino, Pierre Tallet, Luc Delvaux, and Patrick Degryse. 2021. "The Chaîne Opératoire of Middle Kingdom Smelting Batteries and the Problem of Fuel: Excavation, Experimental and Analytical Studies on Ancient Egyptian Metallurgy." *Journal of Archaeological Science: Reports 37*: 102708. DOI: https://doi.org/10.1016/j.jasrep.2020.102708.

Walker, Phillip L. 1978. "Butchering and Stone Tool Function." *American Antiquity* 43(4): 710–715.

Walker, Phillip L., and Jeffrey C. Long. 1977. "An Experimental Study of the Morphological Characteristics of Tool Marks." *American Antiquity* 42(4): 605–616.

Wengrow, David. 2005. *The Archaeology of Early Egypt. Social Transformations in North East-Africa 10000 to 2650 BC.* Cambridge: Cambridge University Press.

Wenke, Robert J. 1989. "Egypt: Origins of Complex Societies." *Annual Review of Anthropology* 18: 129–155.

Wright, Henry T. 1986. "The Evolution of Civilizations." In David. J. Meltzer, Don D. Fowler, Jeremy A. Sabloff and Society for American Archaeology (eds.), *American Archaeology Past and Future: A Celebration of the Society for American Archaeology 1935–1985*, edited by, 323–365. Washington, D.C.: Smithsonian Institution Press.

Wright, Henry T., James A. Neely, and Gregory A. Johnson. 1975. "Early Fourth Millennium Developments in Southwestern Iran." *Iran* 13: 129–147.

Notes

1 Recent reanalysis of the IB Jericho material is now pointing to the absence of metal butchering marks in the faunal assemblage, and lower frequencies in the MB IIA material than previously reported elsewhere (Greenfield 2005). Hence, for now, the Jericho material must be discounted.