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Economic embeddedness and small-scale iron production in the capital region of the Han Empire: the perspective from faunal remains

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ABSTRACT

Most studies of the Han iron industry in the previous literature focus on large-scale ironworks, whereas the organization of small-scale iron production and its social, political, and economic connection to the overall Han Empire have not been empirically analyzed. This article offers the first discussion exploring the organization of small-scale iron production at a site called Taicheng associated with a medium-level settlement of Han country in the Guanzhong Basin, Shaanxi. We suggest that, using parameters proposed in the literature, evidence for iron production processes, such as manufacturing waste and techniques of final products, is inadequate to pinpoint clearly the type of organization used at Taicheng ironworks. However, by focusing on the domain of "economic embeddedness", which draws upon multiple lines of evidence including that relating to all craft goods manufactured and food production, as well as the supply system for food, this article argues that it may be possible to more effectively evaluate if the ironworks was operated on the basis of so-called independent household production. This article proposes a theoretical scheme to explain and conceptualize how independent household production differs from other types of organization (i.e., nuclear corvée/convict, nucleated workshop, and retainer workshop) in terms of the degree of economic embeddedness. Through analyzing the faunal remains from Taicheng and comparing the results with those from Zhonghang, which was a large-scale Warring States ironworks in an urban center and therefore most likely relied upon a specialized food production system, this research suggests that the Taicheng evidence reveals a strong degree of economic embeddedness. Our finding challenges the often-repeated assumption, based on ancient textual sources, that small-scale ironworks were usually independent, household-based production units. Instead, the relatively small-scale ironworks at Taicheng was more likely a full-time, factory-like retainer or nucleated workshop. In a broader context, this new piece of information also suggests that the Han iron industry, particularly in the capital region, had a more complicated structure than that described by previous textually derived models.

1. Introduction

Iron production was an important contributor to the state financial system of the Qin (221-206 BCE) and Han (202 BCE- 220 CE) Empires (Lin, 1999:801–813; Ma, 1983:114–127; Nishijima, 1986; Zang, 2012:106–110). Through implementing the monopoly policy[1] beginning in 117 BCE, the government of the Han Empire successfully imposed a high degree of centralized management onto the production domains of iron and some other critical resources (e.g., salt and bronze coin minting). During the Qin-Han period, ironworks in the Central Plains primarily used blast furnaces for making cast iron (the type of iron that was produced in a liquid stage for casting and has a carbon content usually about 4%, see Wagner, 2008: 5, 13). Large-scale cast iron production of standardized tools and vessels can be efficient, but the manufacturing needs to involve the cooperation of a large number of workers with different craft working skills, for example relating to furnace operation to sustain a high temperature, the production of metallurgical ceramics, and the treatments needed to convert cast iron to steel. Studies of cast iron production can thus provide a useful perspective through which Han economies can be explored. However, the value of iron production as a contributor to our understanding of the socio-economic foundations of the Han period has yet to be fully evaluated, since most discussions have focused on a few large-scale ironworks (e.g., Li, 1995, 2003), while medium to small-scale examples

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[1] *Shiji* [Records of Grand Historian by Shima Qian], 1997, 30:1434.

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Table 1
Information of previously published Han ironworks.

Ironworks	Excavated area (m^2)	Estimated area (m^2)	Location	Components	Source
Wafengzhuang (Henan)	4864	> 28000	Within a county walled-town	Melting and casting a wide range of agricultural tools, chariot-fittings, weapons, and vessels	Li, 1995
Tieshenggou (Henan)	2000	> 21600	Within an ore-rich area	Smelting, casting, and fining; a wide range of agricultural tools and craft production tools were found, which might have been made by the ironworks	Henan and Zhongguo, 1962
Guxing (Henan)	1700	> 120000	Adjacent to a county town	Smelting and casting a wide range of agricultural tools and chariot fittings	Zhongguo, 1978
Dongpingling (Shandong)	1213	Ironworks remains covering a large area	Within a county town; adjacent to the city wall	Including kilns and furnaces for casting a wide range of agricultural tools, chariot-fittings, weapons, and daily items	Shandong, et al., 2011
Chang'an Xishi (Shaanxi)	Northern part 112; Southern 140	Unclear	Within the city wall of Chang'an	Including kilns and furnaces for casting a wide range of chariot-fittings	Zhongguo, 1995, 1997
Taicheng (Shaanxi)	600 (most concentrated area of remains)	< 10000	Unclear in terms of the relation with the county town	Melting and casting two major types of agricultural tools, namely hoe-heads and plowshares. The mold remains represent at least 170 sets of complete hoe-head molds and about 100 sets of plowshare molds	Shaanxi, 2018

have remained underexplored.

In this article, a small-scale ironworks named Taicheng (邰城), which only covers an area of less than 10,000 square meters (Table 1) and is located in the political core region also known the Guanzhong Basin (Fig. 1), is analyzed as a case study. Even though the site dates to the early Western Han period (ca. 202-140 BCE) and lasted a short time, this Han ironworks was the first well-investigated site of its type in the capital region (Shaanxi, 2018:18–19), therefore providing critical information contributing to a better understanding of the iron industry. The authors propose that faunal remains, which provide one important line of evidence concerning food consumption and supply at the ironworks, can be combined with other lines of evidence related to craft production to assist in our attempts to differentiate between "individual/community, "nuclear corvée /convict", and "nucleated production/retainer workshop" types of craft organization (Table 2), although we acknowledge that the parameters for identifying these types of organization suggested in the literature remain controversial (e.g., Costin, 1991, 2005, 2007; and for different views see Flad and Hurby, 2007). We begin by introducing the concept of "*economic embeddedness*", or the degree of economic connection that production units were able to generate with customers and adjacent communities through the exchange of manufactured products and the procurement of daily necessities. The presence of remains relating to craft goods manufacture and food production, together with the degree of reliance on an external supply of food are the key dimensions illustrating the connection. We then explain how the study of faunal remains can be employed within this framework. By comparing the Taicheng data with those from another ironworks named Zhonghang (中行), which dates roughly to the earlier, Warring States period (453-221 BCE) and was located within a large capital center, this article attempts to demonstrate the value of "economic embeddedness" as a means of understanding the relations between iron producers, local communities, and the overall managerial system. This paper argues that, in contrast to the conventional idea that small-scale ironworks were probably household production units, Taicheng was more likely to be an ironworks employing full-time specialized labor either in an independent nucleated or attached retainer workshop manner. This study therefore not only addresses a previously underexplored aspect of the iron industry, but also provides a framework through which market integration, administrative involvement, and the labor system used in such "small-scale" production centers in the Han period can be investigated in a broader context.

2. Taicheng ironworks and the organization of the Han iron industry

2.1. Taicheng ironworks and previous studies of the Han iron industry

The Taicheng ironworks is located in Yangling, Shaanxi Province, and it was a small foundry in a county-level site complex producing only a limited range of agricultural tools (Fig. 2). According to textual records, the ironworks was affiliated with Tai (邰) county (Fig. 1), and archaeological survey indicated that the Tai county town, which is located about 200 meters to the south of the ironworks, covered an area of about 1.2 km^2 (Shaanxi, 2018:5–7). This falls within the range of medium-sized walled centers in the Qin-Han period in the Middle-Lower Yellow River Valley (Xu, 2013:106, 108). According to ceramic typology and datable materials, the ironworks dates to the early Western Han period, probably before the implementation of the iron monopoly (Shaanxi, 2018:72–77; Zhao, et al., 2012). Based on survey and augering results, it was estimated that the ironworks encompassed less than 10,000 square meters, which is much smaller than most previously excavated ironworks (e.g., Li, 1995; Zhongguo, 1978; for detailed information about ironworks, see Table 1), but some uncertainty exists over the original size as the ironworks was partially damaged by flooding in later periods (Shaanxi, 2018:3).

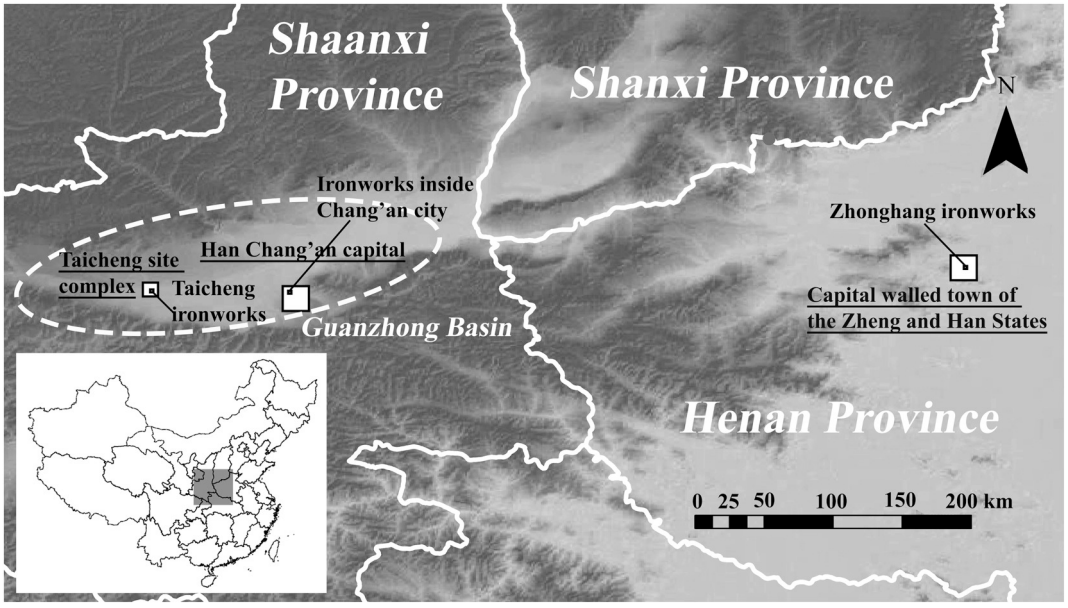

Fig. 1. Location of major ironworks and sites mentioned in the text. Drawn by authors in ArcGIS using a data set from Harvard's China Historical GIS (https://sites.fas.harvard.edu/~chgis/data/chgis/v6)

In 2011, based on the findings of the auger survey, excavations (Fig. 3) were conducted in zones with rich and deep depositional sequences within the ironworks (Shaanxi, 2018:10–11, 21), but the archaeological fieldwork could not identify any residential houses, roads, wells, or facilitates related to production. The unearthed remains comprised mostly of casting molds, indicating that this workshop specialized in the casting of two types of agricultural implements; namely, hoe-heads and plowshares (Fig. 2). The assemblage of manufactured iron products at Taicheng was therefore different from those of other known large ironworks, which usually included a wide range of agricultural tools, chariot-fittings, and vessels (Table 1). Through metallurgical analyses of manufacturing remains from the ironworks and iron objects from a nearby cemetery, our previous research showed that some raw materials used in production were externally sourced, and most final products recovered from burials could not have been manufactured by the local ironworks (Lam et al., 2015, 2018).

In previous discussions (Kageyama, 1984:285–290; Wagner, 2008:156–159, 186–188; Yamada, 1998), the organization of iron production with the Qin-Han period occurred in three main forms: large-scale non-kin based ironworks that were usually controlled by the state through adjacent administrative centers, large iron estates controlled by rich merchants in regions with iron ore deposits, and small-scale independent household production units. After the Qin Empire, the development of bureaucratic and legal systems allowed the state to force convict and corvée labor, or *zutu* (卒徒) as mentioned in historical texts[2], into various types of construction and low-skilled production work (Barbieri-Low, 2007:108–109; Yu, 2012). Most previously excavated large ironworks sites (Table 1) and ironworks inside the capital city of Chang'an (Zhongguo, 1995, 1997) were considered, because of their size or location, to be of this type (e.g., Bai, 2011; Li, 1995). The second type of ironworks, which according to ancient textual records[3] occurred primarily in ore-rich areas, was controlled by private merchants and employed bound servants or slaves in addition to waged labor. Unfortunately, no archaeological sites have thus far been confirmed as examples of this type. In contrast, the third type of ironworks was small-scale and widespread in areas lacking major iron ore deposits, and manufactured implements through the recycling of scrap iron. These ironworks were considered to be privately owned and took the form of household production units[4] operated by workers who were mostly members of the same family (Kageyama, 1984:287; Wagner, 2008:156–159, 186–188; Yamada, 1998). In other words, the textual perspective suggests that, especially during the early Western Han period, the size or scale of ironworks as well as their distribution should somehow be indicative of their affiliation with the state and the social relations of their workforce.

Having said that, a key issue in the study of small-scale ironworks organization still remains under-addressed; namely, whether the size of archaeologically-excavated examples can unambiguously be used to pinpoint the various types of organization mentioned above. Since most previous literature considers size to be a comparative parameter (Kageyama, 1984:287; Wagner, 2008:156–159, 186–188; Yamada, 1998), no objective standard for the categorization of archaeological cases nor means of attributing them to specific types of organization have been proposed, not to mention the lack of study of other archaeological attributes, such as distribution patterns of specialists and their social relationships, for more comprehensive analyses. Furthermore, within the excavation area at Taicheng, sizable waste disposal features containing large volumes of manufacturing waste, including slag, tuyères, furnace walls, and casting molds were discovered (Shaanxi, 2018:46–54). It is therefore unclear whether Taicheng should be placed within the category of independent household production units employing kin-based members or nucleated ironworks employing full-time waged labor (or even some convict labor). The clarification of Taicheng's organization is not only important for the study of the iron industry itself, but also is beneficial for the discussion of craft production in anthropological discourses.

The following section synthesizes the evidence for the Han period ironworking in terms of the broader literature addressing craft specialization. This theoretical component provides explanations of terminologies used and, therefore, allows the identification of archaeological attributes that may be used to highlight the social and political relationships within ironworks.

[2] *Yantielun jiaozu* [Annotation of "Discourses on Salt and Iron" by Huan Kuan"], 1992 36:430.

[3] *Yantielun jiaozu* [Annotation of "Discourses on Salt and Iron" by Huan Kuan], 1992, 9:120.

[4] *Yantielun jiaozu* [Annotation of "Discourses on Salt and Iron" by Huan Kuan], 1992, 36:430.

Table 2
Definitions of the four parameters and eight types of specialization in Cathy Costin's framework. (Based on Costin, 1991:11, 13, 15, 16; Costin, 2007:152).

Context: affiliation of producers and the sociopolitical components of the demand for their wares. Attached specialization makes and distributes goods under some ruling elites or state. Independent specialization makes and exchanges goods without overt elite or state involvement		***Concentration***: the distribution pattern of specialists across the landscape. Nucleated and disperse at the two extremes of this parameter	***Scale***: contingent on the size of workforce and principles of labor recruitment. Small, individual kin-based units and wage-labor forces that were employed based on skill are the two extremes	***Intensity***: the amount of time producers spent in craft production. Part-time and full-time are the two extremes of this parameter
Types of"context"	**Types of specialization**	**Types of concentration**	**Types of scale**	**Types of intensity**
Attached specialization	Dispersed corvée	Dispersed	Possibly kin-based	Part-time
	Individual retainer	Dispersed	Possibly kin-based	Full-time
	Nuclear corvée	Nucleated	Labor	Part-time
	Retainer workshop	Nucleated	Labor	Full-time
Independent specialization	Individual	Dispersed	Kin-based	Part-time?
	Dispersed workshop	Dispersed	Labor	Full-time
	Community	Nucleated	Kin-based	Part-time?
	Nucleated workshop	Nucleated	Labor	Full-time

2.2. Parameters for identifying independent household production in the Han period

In archaeology, various models have been proposed to conceptualize the various forms that craft specialization can take (e.g., Clark and Parry, 1990; Peacock, 1982; van der Leeuw, 1977), by focusing on attributes such as the scale of production units, the intensity of production, or the participation of elites. Of these conceptual frameworks, Cathy Costin (1991) proposed a comprehensive four-parameter framework with a broad applicability to the classification of types of production. In this framework, context, intensity, scale, and concentration are the four related dimensions that can articulate degrees of specialization and classify production sites into eight types (Table 2). This conceptual framework was demonstrated to be a useful heuristic tool for clarifying organization and management in studies of craft production in Bronze Age China (e.g., Flad, 2011; Sun, 2008), and it is therefore worthwhile here to first describe and explain how these types of organization could be interpreted from archaeological evidence.

In the framework (Table 7), "context" refers to the physical environment and "the social, political, and economic, and ideological milieus that structure relations among producers and between producers and consumers" (Costin, 2007:150). "Attached" and "independent" specialization were used to distinguish two types of production system "context", corresponding respectively with those under the aegis of political institutions or elites and those without obvious governmental or elite involvement (ibid., 152). "Intensity" is a scalar parameter with full-time and part-time at the two ends of the continuum, depending on the proportion of time devoted to a particular productive activity within a worker's overall time spent on production (Flad, 2011:17), either in one day or another period of time. Although "scale" is literally contingent on size, in Costin's framework (1991) this parameter is also determined by types of social relations involved in production, such as kin-based or using hired laborers. Because we already indicated that Taicheng was a small-scale ironworks during the Han period, in the organization framework below, we further considered "scale" to describe how producers involved in production were associated with one another (e.g., kin-based and hired labor) (Flad, 2011:23), rather than simply in terms of the physical size. "Concentration" refers to the distribution pattern of specialists. However, given that only one ironworks was found at Taicheng, it is impossible to determine whether the identified production site was a nucleated workshop or not. By using the three parameters (context, intensity, and scale), it can be seen that the type of independent household production that was suggested in Han period texts is probably equivalent to an individual or community workshop (Costin, 1991:8) that employed kin-based part-time labor, either within a nucleated or dispersed layout.

Ethnographic and archaeological studies of household craft production in prehispanic and modern Mesoamerica (e.g., Arnold, 2014; Feinman, 1999; Hirth, 2009) provide further explanations for characterizing independent household production units. Based on these comparative examples, the management of production as a means of balancing various risks is always a key feature of kin-based, independent production units in household settings. For instance, independent potters may need to reduce the impact of pottery market fluctuations if the workers are entirely responsible for their own survival. Diversified economic strategies, such as farming or providing another service to the community, were often adopted to supplement income lost due to change in the pottery market. In comparison with full-time nucleated workshops, independent household production units, or individual/community specialization in Costin's (1991) framework, cannot rely fully on an embedded relationship within a specialized supply network that only interacted with certain or limited groups of customers and conducted production continuously throughout the year. Archaeologically, evidence indicating self-supporting systems for daily necessities, producing multiple types of craft

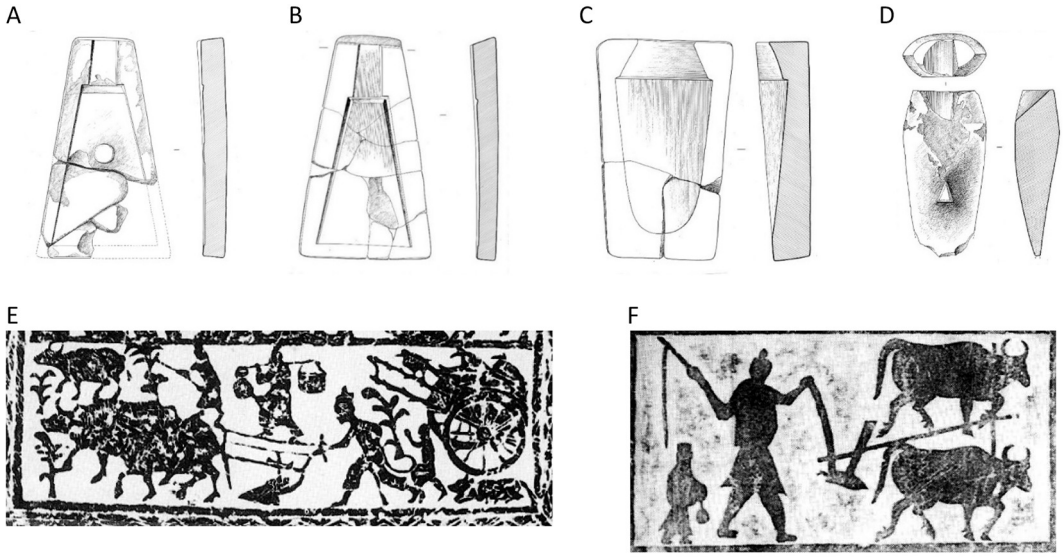

Fig. 2. Casting molds from Taicheng and pictorial bricks showing how the plowshares manufactured by Taicheng could have been used (A&B hoe-head molds; C&D, plowshare mold and plowshare core; E&F, pictorial bricks depicting agricultural production scene in the Han period using iron plows, After Zhongguo, 1996: A5, A11. The length of a Han iron plowshare that was drawn by oxen is usually about 40–50 cm).

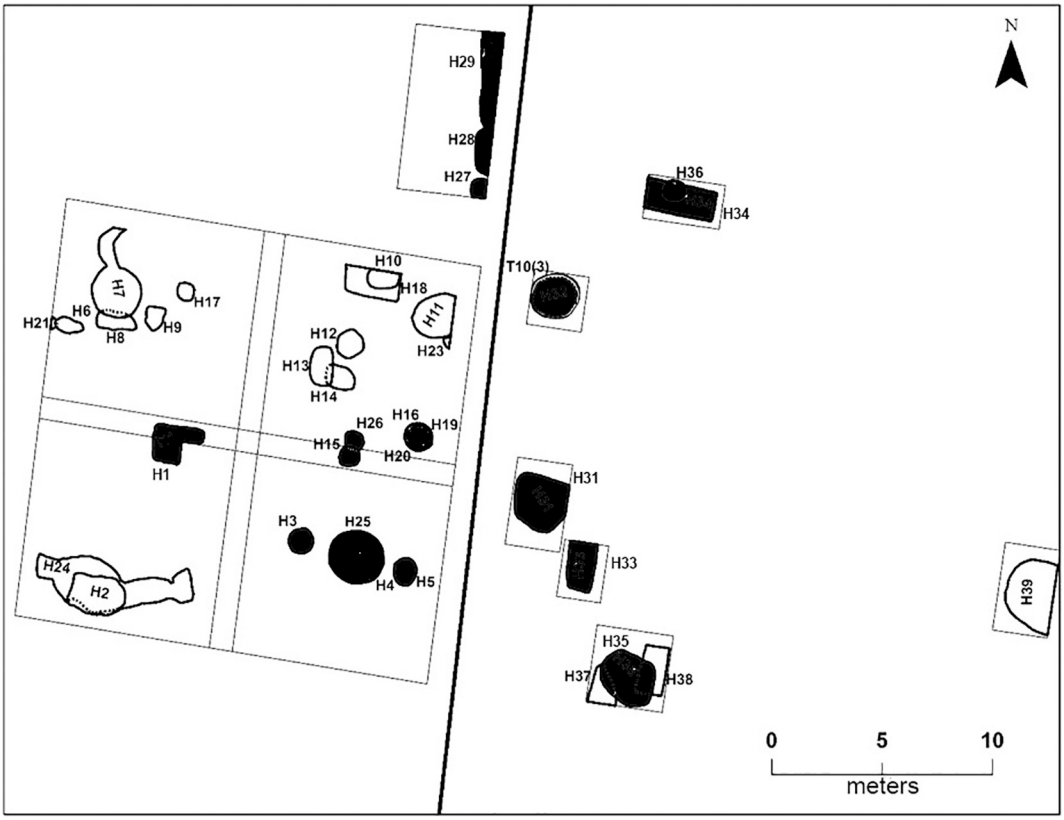

Fig. 3. Layout of Taicheng ironworks (filled features representing pits dating to the Early Western Han period; unfilled features representing pits pre-dating or post-dating the Early Western Han period) (After Shaanxi, 2018: 11, Fig. 5.).

products, and intermittent production will be associated with workshops belonging to independent household-level production (e.g., Feinman, 1999; Hirth, 2009).

It is important to note that significant differences exist between the Han Empire and prehispanic Mesoamerica, not to mention modern Mesoamerica, in terms of their geographical conditions and social contexts. Therefore, independent household production units in the Han period might not have operated in the same way as ceramic workshops in Mesoamerica. However, indicators of independent household production that were derived through the use of analogies in ethnographic and archaeological reasoning can provide a conceptual tool for identifying Han small-scale iron production that was only recorded sparsely in historical texts. Drawing these strands from comparative examples and anthropological frameworks together, an independent household production unit can be potentially distinguished from workshops of the nucleated retainer or nucleated corvée/convict

type depending on whether kin-based labor was primarily employed in part-time specialization seasonally or non-seasonally. Also, the site should not present evidence indicating that elites or political institutions had authority or the means to directly control some or all components of the manufacturing process (e.g., access to production tools and the supply of raw materials) and the distribution of products (Costin, 2007:153). Meanwhile, household production might be expected to involve multiple types of economic activities as well as food production and have associated evidence for residential occupation on site.

Even though these parameters derived from theoretical frameworks and ethnographic and archaeological records for identifying independent household production appear to be comprehensive and self-evident, the employment of these concepts as a means of differentiating independent household production units from other types of organization through the analysis of evidence for final products, manufacturing remains, and associated features in a Western Han archaeological setting is hindered by a number of challenges. First, like Taicheng, other small-scale iron production sites in settlements outside the Han capital core (e.g., Nangucheng in present-day Fengxiang, see Qin, 1980) did not yield clear evidence and such background information showing methods of governmental control. Nonetheless, evidence for distinguishing attached and independent specialization is essential for the identification of independent household production units. In archaeological context, evidence in this regard includes political symbols (e.g., seals or high-status architecture) suggesting the official involvement in manufacturing, an archaeological context showing if the raw materials were accessed by limited members, and signs indicating who (elites or workers) controlled the process of distribution (Costin, 2005: 1072; Flad, 2011:27); none of them were identified through the excavations at Taicheng. Moreover, no other residential sites have been excavated within the Taicheng site complex or nearby. The distribution of final products would not be helpful in addressing the issue under consideration here. Given the constraints of the archaeological evidence at hand and the absence of other textual records, it is difficult to identify to what extent the Taicheng ironworks was affiliated with the state.

Second, the clarification of the other two parameters (scale and intensity) through excavated features or remains related to manufacturing is no less complicated in the context of the Han Empire. In theory, as a nucleated or retainer workshop would employ mostly full-time non-kin based workers, evidence for long-term dwelling and daily residential remains should rarely be found near the production area of this type (Santley and Kneebone, 1993), similar to what one might expect near a modern industry site. The Taicheng ironworks did not yield tools or assemblages indicative of multiple types of craft production, such as spindle whorls, tools related to bone manufacturing, or complete farming tools; there was thus no obvious evidence for other craft manufacturing or crop production on site. As explained above, the excavation and survey of the entire Taicheng complex also confirmed that no household structures were found within the surviving part of the ironworks (Shaanxi, 2018:10). However, it is worthwhile to consider whether this apparent absence of evidence might be contingent upon preservation, since part of the site was destroyed. Meanwhile, the Taicheng ironworks yielded an assemblage including both a high density of iron manufacturing waste and remains associated with food consumption (i.e., faunal remains) (Shaanxi, 2018:60–61). The concentrations of manufacturing waste, the absence of clear evidence related to residential houses, artifact assemblages, and excavated features are collectively ambiguous when attempting to determine if the Taicheng ironworks operated as an independent household production center, or a nucleated retainer, or even a nuclear corvée workshop. The suggestion derived from textual sources that Taicheng was a household independent unit needs to be subjected to a more fine-grained analysis. In this regard, we propose the concept "economic embeddedness" to synthesize various lines of evidence potentially related to "risk balancing" and a "diversified economic strategy" in order to shed light on the connection between producers, adjacent communities, and customers (or patrons) in craft production.

3. Framework of economic embeddedness and evaluation of the reliability of an external food supply system

3.1. Economic embeddedness and independent household production

In fact, similar difficulties have been encountered when applying Costin's parameters to the characterization of production in other complex societies, such as Carla Sinopoli's study of textile production during the Vijayanagar Empire (see Sinopoli, 2003:32, 302). For this challenge, Sinopoli (2003:36) suggested to not only look at products *per se* but also further consider how products were moved between various economic spheres as a means of evaluating the relationships between craft production and state economies. In this vein, we would add the movement of necessities for both the manufacturing of goods and workers' survival to the list of variables under consideration, with the aim of better understanding how the organization was embedded within broader social, economic, and political contexts. This article argues that by studying the following lines of evidence, namely craft goods manufacture and food production, alongside the supply system for daily necessities beyond raw materials, can better explain how specialists depended upon patrons or customers, while also revealing the degree of interaction taking place within communities. We propose that these two aspects can be usefully synthesized within the concept of "economic embeddedness". In this paper, we define *economic embeddedness* as a scalar variable, reflecting an ironworks' degree of economic connection with customers and adjacent communities established through the exchange of all types of manufactured products and the procurement of daily necessities. As we explained earlier, no other types of craft manufacturing remains were found in features associated with the Taicheng ironworks. But within the "economic embeddedness" framework, the absence of multiple types of craft production is insufficient to draw a solid conclusion about the organization of a workforce. We should also examine the line of evidence indicating the degree of reliability of the food from an external supply for workers in order to comprehensively illustrate the interaction taking place within communities, or the type of economic embeddedness.

It must be noted that our framework employs "economic embeddedness" in a way different from the widely-known term "embeddedness" used in Karl Polanyi's work (Polanyi, 2001 [1944]), which refers to the type of economic activities that were contingent upon social relations rather than "rational calculation". As Feinman and Garraty (2010) argued, Polanyi's definition underestimated an important fact, that embedded "social relations" often play an important role even in modern economies. In this article we consider that embeddedness was shaped by both market exchange, a manufacturing site's capacity to be self-sustaining, and its relations with other members of the community. Although it is not easy to employ "economic embeddedness" to characterize each site type mentioned in the aforementioned framework (Costin, 1991), the major distinctive domains that characterized household production: self-sufficiency in daily necessities and the crafting of multiple product types (e.g., Feinman, 1999; Hirth, 2009) in fact reflect a type of economic embeddedness quite distinct from other forms of organization discussed above and, therefore, are essential for the discussion here.

In contrast to full-time nucleated or retainer workshops, household production units cannot fully rely on an embedded relationship within a specialized supply network and only interact with certain or limited groups of customers throughout the year. As a result, independent household production units usually have to diversify their economic strategy using various sources of income and food in order to support themselves (Hirth, 2009), as we mentioned above. On the contrary, a full-time and non-kin based workshop (nucleated convict workshop or

nucleated/retainer workshop), whether it was an independent or a state-controlled one employing retainers, might not need to diversify its economic strategy. In addition, as full-time laborers, the workforce is more reliant on its neighboring communities for support than part-time workers within independent household production units, who should have more time to spend on farming or husbandry as a means of procuring food resources to sustain themselves (Flad, 2011:19). Regardless of whether they are of the independent or attached specialization type, full-time production units based on waged labor, retainers, or convict labor must be deeply embedded in a specialized exchange network and rely on their patrons or other local specialists to procure raw materials and food. As a consequence, workers in such situations appear to be less self-sufficient and less flexible, thereby creating a distinctive type of "economic embeddedness". Of course, each type of organization sometimes employs more than one type of labor. For instance, a kin-based household production unit could employ some waged labor for low-skilled work. Moreover, household production units could rely on food markets to a certain extent. Nonetheless, as we will explain later, food, especially meat, was relatively expensive in the Han period. In such a social setting, we assume a strong degree of reliance on an external food market for an independent production unit could not be feasible. Thus, the dominant species in the archaeobotanical and faunal assemblages would be different between major types of Han iron industry mentioned in ancient texts.

For heuristic purposes, we can consider that the types of organization relating to the study of the Han iron industry were actually embedded in two main ways (Table 3). The first of these can be labelled "simplistic economic embeddedness", which is the type occurring within local communities and is characterized by a self-sustaining mechanism that diversifies the supply and buffers risk. This case is more-or-less equivalent to "individual" or "community" specialization in Costin's framework (1991), in which a self-sustaining food system and the crafting of multiple products were the major strategies for survival. As a result, no indicators should appear showing a deep reliance on an external food supply system. For the second type, termed here "deep economic embeddedness", full-time workers in a retainer workshop or nucleated workshop (Table 2) produce limited types of goods and might be heavily reliant upon relationships with limited ranges of customers or suppliers. Although evidence of multiple types of craft production might have been identified, these types of production identified usually share fuel or similar kinds of raw materials (for the purpose of sharing resources in multiple types of craft production, see Shimada, 2007). Because of their full-time manner of specialized production, the communities within nucleated or retainer workshops would be reliant upon a specialized food supply network, have a more concentrated demand for final products, and would be associated with mechanisms that could efficiently draw customers to a location to access to their products (Flad, 2011:20) as well as to distribute food to the workshop.

It must also be noted that workers in some types of organization, for example a nuclear corvée/convict workshop, could receive minimal amounts of food provided directly from the government or via a centralized supply system. Since workers of these types would engage in production only during certain periods of time throughout a year, and usually provided goods or services directly to the government, rather than to specific groups of customers in adjacent communities, we consider that the degree of economic embeddedness of this kind of workshop probably falls somewhere between that of independent households and nucleated/retainer workshops. In addition, some types of organization discussed in relation to previous conceptual frameworks, such as "individual retainers", "dispersed corvée" and "dispersed workshop", might not be distinguished when applying the concept of "economic embeddedness". Instead, their identification must be contingent upon evidence explicitly suggesting official management, spatial relations with other local residents, and materials that can indicate the identity and rank of workers.

Table 3
Types of economic embeddedness and corresponding types of Han workshop organization.

Types of organization	Evidence of multiple types of craft production	Subsistence patterns	Archaeological evidence of faunal remains	Types of economic embeddedness
Individual/community workshop, or independent household production (independent household-level production involved non-kin based members in a part-time manner)	Might engage in multiple types of craft production or have seasonal alternation; multiple types of craft production might involve goods that do not share similar types of resources such as farming or textile	Primarily based on a self-sustaining mechanism	Associated with husbandry	Simplistic
Nuclear corvée /convict[a] (attached production involved non-kin based part-time labor)	Evidence for multiple types of craft production is very rare or indicates the sharing of fuel or raw materials	Evidence related to self-sustaining mechanism is very rare	Very few faunal remains would be found because of the low social status	Medium
Retainer workshop/Nucleated workshop (full-time non-kin based specialization that is with or without state involvement)	Evidence for multiple types of craft production is very rare or indicates the sharing of fuel or raw materials	Evidence related to self-sustaining mechanism is very rare	The taxa, assemblage of body parts, and age profile of faunal remains are likely to indicate the meat consumption heavily relies on an external source.	Deep

[a] In Costin's framework (1991), the attached production involved non-kin based part time labor refers to "Nuclear corvée". But in the Han context, corvée and convict labor were often used at the same time, especially for large-scale projects with low-technical requirement. Even though convict labor usually served the state much longer than the duration of corvée (Zang, 2012), laborers of these two types were general low-status and received very limited subsidies from the state. Therefore, we add convict labor to this category.

3.2. Faunal remains and the reliability of an external food supply system in the Han period

In our framework, we propose to look at various lines of evidence relating to the food production and food supply in addition to multiple craft production in order to understand the degree of economic embeddedness. In this case study, we selected faunal remains as a key proxy for evaluating food consumption patterns and organization of the workforce. One critical reason is that, when compared with palaeobotanical remains, animal bone assemblages are more often published in the Chinese archaeological literature of the Qin and Han periods; more examples are therefore available for comparative study. For using the consumption patterns reflected by animal bones to evaluate the reliance on an external food supply system, we assume that workers in a full-time specialized workshop working throughout the year were reliant upon the supply from the state or received intensive support from neighboring communities, probably through the meat market (Flad, 2011:19). Thus, the bone assemblage in a retainer or nucleated workshop is expected to be different from an independent household ironworks, in that the latter would try to retain its flexibility and employ self-sustaining economic strategies such as raising livestock in the environs of the workplace. Using the procurement and exchange of meat as an analytical unit, this paper evaluates the extent to which ironworks' communities were linked to or had relationships with other communities in order to procure food or other daily necessities.

The Han period's rich textual records and related discussions in the literature (e.g., Hayashi, 1975; Sterckx, 2011) also offer an important, complementary line of evidence when interpreting the implications of faunal remains for studying the food supply and the social connectivity underlying craft production. Previous textual studies of Han period cuisine showed that chickens usually were the major source of meat for commoners during that period (Yu, 1977) because of the relatively high price of meat in relation to the low wages of laborers. For instance, according to excavated written sources from the Hexi corridor, in northwest China, livestock such as pig and sheep/goats ranged in price from 200 to 1000 *qian* (钱), and their meat was usually sold for about 2.5~7 *qian* per *jin* (斤, one *jin* is equivalent to about 245g, see Loewe, 1986: xxxviii) (for the textual evidence and summary, see Ding and Wei, 2016:166–168). In places where animal husbandry was less well developed than in the Hexi corridor, the price of meat would have been even higher. Nonetheless, whether working as hired waged labor or convict labor, laborers could usually make about 8~12 *qian* per day during the Qin and early Western Han periods (for the textual evidence and summary, see Ding and Wei, 2016:279–282). For labor-intensive works, staple food would be provided for each laborer, but the subsidies only included 1.5~2 *shi* (石, equivalent to 19.968 liters, see Loewe, 1986:xxxviii) of grain per month, and no other types of food were included (Yu, 2012:167–186). Given that meat was relatively expensive in the Han period, even common waged labor and farmers, not to mention convict labor, might have found it impossible to regularly afford meat (beef, pork, or mutton) (Yu, 1977), beyond consuming the occasional household chicken or pig in order to supplement their diets.

Archaeologically, for contexts associated with independent household production, we might expect to see excavated faunal assemblages consist primarily of chicken bones with a smaller component from domesticated livestock such as pig which could be raised in a courtyard. An independent household unit would rely primarily upon a self-sufficient food provisioning system rather than procuring meat from the market (Table 3). In contrast, in a nuclear corvée workshop, the consumption of meat should be low as a result of the low status of workers and the minimal amount of staple food provided, even though the workforce was economically embedded in and reliant upon local communities for its food. Animal bones should therefore be rare within any midden deposits present, and probably would not include those of valuable livestock, such as cattle. In contrast, retainer workshops, in which the majority of workers were state-supported artisans, and nucleated workshops employing mostly waged labor, should both show the strongest degree of economic embeddedness among the category of workshops under consideration here. In the latter case, most workers rely upon a specialized meat provisioning system, and faunal remains beyond poultry should be found. In addition, the body-parts represented and kill-off patterns for major taxa should be indicative of meat that was primarily provided by specialists who raised animals to maximize meat production for the market. In the following section, we will use the case study of Taicheng to illustrate how this framework can facilitate the discussion about the small-scale iron production in the Han period.

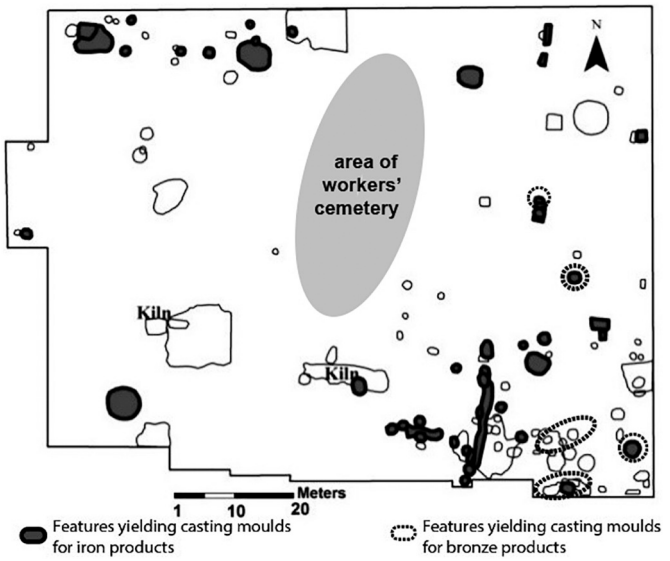

Fig. 4. Layout of features excavated at the Zhonghang ironworks (After Henan, 2006: 727, Fig. 491).

4. Comparative example and data processing

As we explained earlier, economic embeddedness is a scalar, relative parameter. In order to strengthen our arguments about Taicheng, in this article we adopt a comparative framework to discuss the social embeddedness reflected in the Han food system. The Zhonghang ironworks, which is located in a capital setting dating to the Warring States period, was therefore selected for this study in order to comparatively assess the degree of specialization and social connections of the Taicheng ironworks. The background of the site will now be explained below.

Zhonghang ironworks (Henan, 2006) was situated in the capital walled town of the Zheng and Han states in present-day Xinzheng city, Henan Province, and was one of three ironworks inside the capital (Fig. 1) (Ma, 1999). Like Taicheng, Zhonghang is located in the Central Plains and has a similar geological environment. Even though Zhonghang predates Taicheng, and this comparative example was different in terms of its large scale, Zhonghang is the only available case related to craft production for comparison within the Qin-Han period. Besides casting iron farming tools, the site also manufactured bronze ornaments and coins, which reflects the fact that both types of manufacturing required the same fuel supplies and used similar techniques for making casting molds. No other types of craft production (e.g., ceramic vessel making, textile making, and bone production) were identified. This ironworks was intensively excavated within an area totalling about 8000 m^2 (Fig. 4), and all zooarchaeological results were systematically published both in the full site report (Luo et al., 2006) and an online database[5].

[5] The database can be downloaded from http://www.archaeology.net.cn/html/cn/xueshuziliao/kaogushujuku/dongwukaoguziliaoku/2013/1025/31728.html

Given the large numbers of casting molds identified at Taicheng and Zhonghang, both ironworks were clearly engaged in the manufacture of agricultural tools. Nonetheless, beyond their relative size, these two sites differ from one another in several other ways. First, tombs and kilns or furnaces were identified in the center of the Warring States period Zhonghang ironworks. One contemporary cemetery situated inside the ironworks included at least 80 tombs (Fig. 4) of individuals who might have been workers or people dwelling near the site. Second, the Zhonghang site cast a wide range of goods including agricultural tools, iron bars (a kind of semi-product), and even bronze ornaments and coins were all produced. Third, the Zhonghang site is adjacent to high-status palaces within the capital. Its location and proximity to buildings that are indicative of governmental control suggest that they were most likely to be attached to the state (c.f., Fargher, 2009). In contrast, Taicheng was a small production center located in a lower-ranked administrative town. Neither evidence of coin minting nor other types of craft production has been found there. Also, no cemeteries or other production facility were identified through augering. In spite of these differences, these two broadly contemporary ironworks both concentrated on manufacturing similar types of products using iron casting technology, and thus provide comparable datasets that can enhance our understanding of the daily lives and social connections of iron manufacturing communities.

Before explaining the faunal records in detail, the data collection method used in the field and post-excavation analytical methodology will first be introduced. The fill from each pit was screened using a 1.5 × 1.5 cm mesh in order to systematically collect remains during the excavation. Only specimens seen with the naked eye were collected. In addition, soil samples were taken for flotation as a means of understanding the extent to which small bones and bone fragments were underestimated by other methods. In the analysis below we convert the data from NISP (number of individual specimens) to MNE (minimum number of skeletal elements) format and use the recovery rate to study the percentage of different body parts represented. In this study, MNE refers to the minimum number of skeletal elements necessary to account for an assemblage of specimens of a particular skeletal element or part thereof (for definition see Landon, 1996; Legge and Rowley-Conwy, 1991; Lyman, 2008), and was calculated based on the NISP of each anatomical unit. Based on the MNE, the recovery rate was calculated to show the relative abundance of different anatomical units. Here we define the recovery rate as "the percentage of the expected elements actually recovered, given the minimum number of animals (elements) represented in the assemblage" (Landon, 1996:47). For the Taicheng samples, animal bones were collected during the excavation using screening. In addition, bulk soil samples from features were also collected for flotation to test whether other small mammal or fish bones had been missed during the excavation (Shaanxi, 2018:70).

One major challenge in this study is that the total number of bones discovered at Taicheng is quite small. As Robert Drennan has noted (Drennan, 2009:142), working with a small sample is often problematic as "whatever proportion we find in it may be quite different from the proportion in the population from which it was selected." However, since all major features identified through systematic survey were fully excavated during the fieldwork, the small number of bones recovered might actually reflect the fact that meat was relatively expensive during the Han period, and the number of bones preserved in the surviving part of the ironworks was therefore originally quite small. Despite the fact that very few contemporary zooarchaeology datasets from adjacent urban centers have been published and are available for comparison (e.g., Hu et al., 2006 from Chang'an), we would nevertheless argue that the conclusions derived from our Taicheng data are still meaningful and enhance our understanding of the urban food supply system in ancient China, although the statistical significance (see definition in Drennan, 2009:152) must be reinforced through further data collection in the future.

Table 4
Taxonomic representation at the Taicheng ironworks

		NISP		Weight
Classification	Common Name	Count	%	G
Bos taurus	Cattle	97	18.8	7803.1
Sus scrofa	Pig	49	9.5	872.4
Ovis aries/Capra hicus	Sheep/goat	37	7.2	686.8
Canis sp.	Dog	73	14.2	769.0
Equus caballus	Horse	19	3.7	1717.1
Odocoileus virginianus	Deer	3	0.6	141.3
Rodentia	Rodent[a]	14	2.7	< 1
Unidentified fish		3	0.6	< 1
Gallus gallus	Chicken	3	0.6	5.1
Anas sp.	Duck	1	0.2	2.5
Unidentified birds		7	1.4	1.7
Large mammals		59	11.5	727.4
Medium mammals		120	23.3	430
Large-medium mammals		12	2.3	21.1
Small mammals		18	3.5	< 1
Total		515	100	13177.5

[a] Rodent that was found in the assemblage may be intrusive.

5. Taxonomy and types of animals consumed

The bulk of faunal remains from Taicheng used in this study came from sixteen features, all of them garbage pits, and the number of identified specimens was 515 (Table 4). In contrast with the textual records, which suggest that household units might have relied on poultry for their meat, cattle and dog were clearly the two most important species in the diet of the workforce. Pig and sheep/goat made only a minor contribution to the workers' diet. According to the meat volume calculation methods proposed in previous studies (e.g., Yang, 2007), the recovered faunal assemblage might reflect a maximal meat consumption of just 7.8 kg annually[6], which is not very much for a labor-intensive community. Other species identified include horse, chicken, deer, and fish. It is noteworthy that horses and cattle in the Han period were the most valuable species of livestock. Bamboo slips mention that when a horse or cow belonging to the government died, the local official had to immediately sell every part of the carcass (e.g., meat, hide, and horn) and collect the cash from its sale[7]. It is possible, therefore, that horse and cattle bones found on site, rather than reflecting the animals' rearing primarily for meat, might originally have been government-owned livestock sold to the meat market when they were old or had died. Fish and deer bones account for less than 4% of identifiable specimens, and resources obtained through hunting or fishing appear to have played only a limited role in subsistence.

Even though small bone remains (e.g., bird and fish) were collected primarily through flotation, their number is very low (Table 4). As is typical of many zooarchaeological studies, the majoity of small bone fragments, whether hand collected or from flotation, were unidentifiable to either species or element. Overall, about 90% of identifiable faunal remains associated with the ironworks belong to the major species of domestic mammals mentioned above. Bone fragments unidentifiable to species were classified according to size categories, but

[6] The MNI of cattle, pig, and dog from Taicheng, which are 4, 6, and 4 respectively (Shaanxi, 2018), represent maximally 702 kg of meat could be provided (assuming the whole body of each individual was brought to the site). Since the ironworks might have been used maximumlly for around 80~90 years, even assuming one MNI means the whole body this assemblage indicates that only about 7.8 kg of meat could be consumed by workers annually.

[7] *Shuihudi*, "Statutes on Stables and Parks" (Shuihudi, 1990: 24, trans. Hulsewe, 1985:28–29, A9); *Zhangjiashan,* "Statutes on Food Relations at Conveyance Stations" (Zhangjiashan, 2006:164-165, trans. Barbieri-Low and Yates, 2015: 682-685); *Zhangjiashan,* "Statutes on Finances" (Zhangjiashan 2006:191, trans. Barbieri-Low and Yates, 2015: 925).

Table 5
Taxonomic representation at the Zhonghang ironworks (data from Luo et al., 2006).

		NISP	
Classification	Common Name	Count	%
Bos taurus	Cattle	562	28.4
Sus scrofa	Pig	398	20.1
Ovis aries/Capra hicus	Sheep/goat	78	4.0
Canis sp.	Dog	75	3.8
Equus caballus	Horse	117	5.9
Odocoileus virginianus	Deer	90	4.6
Unidentified clam		3	0.2
Unidentified birds		7	0.4
Large mammals		324	16.3
Mammals		319	16.2
Unidentified carnivores		4	0.2
Total		1977	100

mammal bones of this type from the site only represented a very small proportion of the total assemblage.

In terms of taxa, the NISP values of all identified species at Zhonghang are shown in Table 5. The taxonomic assemblage at Zhonghang also consists of cattle, pigs, sheep/goats, dogs, and horses, and is very similar to Taicheng. But the major difference between the taxonomic assemblages from the two sites lies in the fact that pigs seem to have played a more significant role in the workers' diet at Zhonghang, where the percentage of pigs (20.1%) is significantly higher than all other species except cattle (28.4%). In addition, deer and horse bones at Zhonghang account for 5.9% and 4.6% of the total NISP respectively, and these values are even higher than those of sheep/goats (4%) and dogs (3.8%). At Zhonghang, dog bones represent only 3.8% of the total NISP in the assemblage, whereas workers at Taicheng relied heavily on dog meat as their bones account for about 24% of the total NISP. In the Zhonghang assemblage, there are only two specimens identified as bird bones, which may be related to the recovery and collection method. In spite of these variations, these two studies show that cattle was the dominant taxon at both sites, while pigs and dogs were also important at Zhonghang and Taicheng respectively. If the range of domesticated mammal species at Zhonghang supports the idea that the ironworks was not involved in animal husbandry, then the similar taxonomic assemblage at Taicheng similarly suggests that it is unlikely to have been an independent household production unit.

6. Assemblages of body parts and cuts of meat

In order to better depict the acquisition pattern of different cuts of meat at Taicheng, we first converted the MNE of the three major species: cattle, pig, and dog, into recovery rates for their different skeletal elements as listed in Table 6. Although the sample size is small, the assemblages of body parts seem to reveal several patterns. For cattle (Fig. 5), the proximal radii, proximal metacarpals, and distal metatarsals all appear to be well represented in the body-part assemblage as their recovery rates are higher than 50%. Skulls and mandibles are also well-represented elements in the assemblage, but the examples of these cranial parts discovered from the site are very fragmentary. Studies of the differential survival of body parts (Binford, 1980, 1981; Lyman, 1984) show that mandibles and maxillae are usually two of the most common surviving elements. The atlas and axis also survive destructive forces well and have a higher percentage survival rates than any of the other vertebrae. These two elements in the Taicheng assemblage, however, are poorly represented (Fig. 5). Also, cattle vertebrae and ribs are not surprisingly underrepresented because these fragments are difficult to identify down to species level. In general, the recovery rates of axial elements and cranial bones are relatively low, and this is unlikely to have resulted solely from poor preservation.

Another remarkable pattern in the assemblage is that the bones of forelimb and hindlimb extremities (e.g., phalanges, carpals, and tarsals) also had very low recovery rates, while other less meaty lower parts of limb bones (e.g., metatarsus and metacarpus) are generally better represented. In order to evaluate potential biases caused by post-depositional processes, we also examined the recovery rates of other robust elements that can survive destructive forces well (e.g., scapula, pelvis, distal humerus and tibia, and proximal radius) (Binford, 1981:281–237). This revealed that in the body-part assemblage, with the exception of the proximal radius, all other robust elements that might be expected to survive were not well represented. Based on the taphonomic evidence identified, butchering, cooking and carnivore gnawing might all have impacted preservation rates. For instance, butchery or chopping marks were common on cattle bones, while quite a number of dog bones had been burnt. In addition, carnivore gnawing marks were identified on some cattle bones (Table 7). Given the underrepresentation of robust elements in the bone assemblage, the high recovery rates of some elements from Taicheng were clearly not completely the result of biases in preservation; instead, market preferences and transportation factors may both have contributed significantly to assemblage composition.

At Taicheng, dog bones have the second largest NISP value in the assemblage (Table 4). But unlike cattle, the most common elements in the assemblage of dog bones are the skull (calculated based on maxillae) and mandibles (Table 6). The high recovery rates of these elements are not surprising because they are robust and diagnostic. Beyond the cranial elements, femurs are also well represented with a recovery rate of over 50%. The figures for the forelimbs are slightly lower, and the recovery rate for distal humeri and proximal radii are both only 33%. The small bones of the forelimb and hindlimb extremities and post-cranial axial bones are also particularly lacking in the assemblage, indicating that dog carcasses might have been arrived on site as butchered cuts of meat.

In the pig bone assemblage, significant differences exist in the proportions of elements present when compared with cattle and dog (Table 6; Fig. 6). Pig post-cranial bones are remarkably underrepresented in comparison with cranial elements. Limb and axial bones were similarly scare in the pig assemblage. Among all limb bones, the proximal ulna has the highest recovery rate, but its figure is just 25%. This pattern is quite different from that of cattle and dog bones. For these two taxa, the recovery rates of limbs bones are much higher in the body-part assemblages. The overwhelmingly head-dominant pattern in pig assemblages may not actually mean that other portions of carcasses were not brought to or consumed at the site. As we will discuss in the next section, this pattern may, in fact, be partially attributable to the killing age of animals, as evidenced by teeth eruption data.

The patterning in body-part assemblages suggests that the consumption preferences for different species varied to a certain extent. For cattle, and pig as well, one dominant feature of the recovery pattern was the over-representation of skulls and the less meaty parts of limbs versus rich meaty parts of animals. This patterning indicates that workers might rarely have consumed meaty portions like loin associated with the axial skeleton. Such main meat-bearing elements might have been intensively processed before deposition or were traded elsewhere, never entering this archaeological assemblage. Also, the underrepresentation of the small bones of the distal forelimb and hindlimb in the urban assemblage indicates that processed carcasses brought to the site were likely to have been in the form of small-sized cuts of meat.

The body-part assemblages at Zhonghang reveal similarities in preference between the two communities, even though some differences can also be observed. Figs. 5 and 6 show comparisons of body-part recovery rates between the two sites. In Fig. 5, the cattle bone assemblage is dominated by cranial elements, followed by humeri, scapulae, and tibiae. Like Taicheng, lower limb bones such as metapodials were not well represented at Zhonghang. The cranial elements,

Table 6
Minimum numbers of elements and recovery rates for cattle, dogs and pigs at the Taicheng ironworks.

	Cattle			Dog			Pigs	
	%Recovery rate	MNE		%Recovery rate	MNE		%Recovery rate	MNE
Skull (Frontal)	44.44	2	Skull (Maxilla)	100.00	6	Skull (Maxilla)	75.00	3
Mandible	33.33	3	Mandible	58.33	7	Mandible	100.00	8
Axial	22.22	1	Axial	16.67	1	Axial	0.00	0
Atlas	0.00	0	Atlas	0.00	0	Atlas	0.00	0
Cervical	3.17	1	Cervical	4.76	2	Cervical	0.00	0
Thoracic	0.00	0	Thoracic	1.28	1	Thoracic	0.00	0
Lumbar	0.00	0	Lumbar	2.78	1	Lumbar	0.00	0
Sacrum	44.44	2	Sacrum	16.67	1	Sacrum	25.00	1
Scapula	22.22	2	Scapula	8.33	1	Scapula	12.50	1
Proximal humerus	0.00	0	Proximal humerus	16.67	2	Proximal humerus	0.00	0
Distal humerus	33.33	3	Distal humerus	33.33	4	Distal humerus	12.50	1
Proximal radius	100.00	9	Proximal radius	33.33	4	Proximal radius	0.00	0
Distal radius	44.44	4	Distal radius	33.33	4	Distal radius	0.00	0
Proximal ulna	33.33	3	Proximal Ulna	33.33	4	Proximal Ulna	25.00	2
Distal ulna	22.22	2	Distal Ulna	25.00	3	Distal Ulna	0.00	0
Carpal	9.26	5	Carpal	16.67	0	Carpal	0.00	0
Pelvis	33.33	3	Pelvis	41.67	5	Pelvis	37.50	3
Proximal femur	11.11	1	Proximal femur	50.00	6	Proximal femur	0.00	0
Distal femur	11.11	1	Distal Femur	58.33	7	Distal Femur	0.00	0
Proximal tibia	0.00	0	Proximal tibia	16.67	2	Proximal tibia	0.00	0
Distal tibia	22.22	2	Distal tibia	33.33	4	Distal tibia	0.00	0
Calcaneus	22.22	2	Calcaneus	0.00	0	Calcaneus	0.00	0
Astragalus	0.00	0	Astragalus	16.67	0	Astragalus	0.00	0
Tarsal	11.11	1	Tarsal	0.00	2	Tarsal	0.00	0
Proximal metatarsus	44.44	4	Metatarsus	3.33	5	Metatarsus	0.00	0
Distal metatarsus	55.56	5	Metacarpus	8.33	1	Metacarpus	0.00	0
Proximal metacarpus	66.67	6	Metapodials	1.67	2	Metapodials	1.25	1
Distal metacarpus	33.33	3	1st phalange	0.00	0	1st phalange	0.00	0
Metapodials	11.11	2	2nd phalange	0.00	0	2nd phalange	0.42	1
1st phalange	11.11	4	3rd phalange	0.83	1	3rd phalange	0.00	0
2nd phalange	5.56	2						
3rd phalange	5.56	2						

even omitting loose teeth from the calculation, appear to be more dominant in the assemblage at Zhonghang than at Taicheng. Distal limb bones such as the calcaneus, talus and phalanges, bones of the axial skeleton such as axis and atlas, and humeri and femurs are all better represented in the Zhonghang assemblage when compared with Taicheng.

In the body-part assemblage of pigs (Fig. 6), it is also of interest to note that, like cattle, the skull and mandible are similarly the most dominant elements. In addition, appendicular bones, including limb bones, are significantly underrepresented at both sites. Although meaty elements, such as humeri and femurs, were more frequently identified in the Zhonghang assemblage with recovery rate of about 20%, the lower limb bones, such as metapodials and phalanges, are significantly underrepresented. Both cases demonstrate a prominent discrepancy between cranial and post-cranial elements, which indicates that neither Taicheng nor Zhonghang were places where butchering or food processing took place.

7. Age profiles and kill-off pattern

The estimation of slaughtering ages of animals can help reveal associated livestock exploitation strategies and meat production systems. Age profiles can also help evaluate the skewing effects of post-depositional destructive forces on faunal assemblages, as the bones of young animals generally do not survive as well as those of adult of the same species (Landon, 1997). The age profile data and possible taphonomic effects must therefore be considered together in order to build stronger arguments regarding the animal husbandry at Taicheng.

Slaughtering ages are calculated based on epiphyseal fusion and the degree of tooth wear (e.g., Grant, 1982; Silver, 1969; Zeder et al., 2015). However, the tooth-wear data available for cattle in this case study are insufficient to draw any reliable conclusions. We therefore only examine the epiphyseal fusion data in order to reconstruct the age-at-death of cattle. In contrast, the slaughtering ages of pigs were estimated based on the degree of tooth wear and eruption because too few limb bones survived. In Table 8 and Fig. 7, we list the epiphyseal fusion

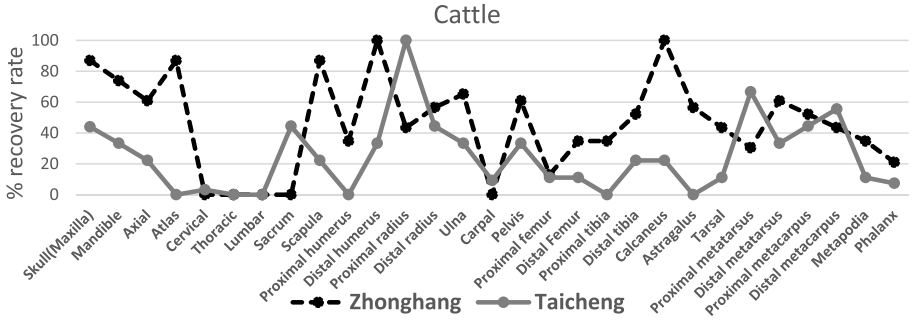

Fig. 5. Recovery rates of cattle elements from Zhonghang and Taicheng.

Table 7
Frequency of taphonomic features and butchery marks for major taxa at the Taicheng ironworks.

	Cattle		Pig		Dog		Caprine		Horse	
Taphonomy/modification	NISP		NISP		NISP		NISP		NISP	
	Count	%	Count	%	Count	%	Count	%	Count	%
Weathering[a]	11	11.3	4	8.2	1	1.2	3	8.1	2	10.5
Burning[b]	7	7.2	4	8.2	26	35.6	3	8.1	1	5.3
Carnivore gnawed	18	18.6	3	6.1	1	1.2	1	2.7	2	10.5
Rodent gnawed	1	1.0	0	0.0	0	0.0	0	0.0	1	5.3
Butchered[c]	23	23.7	4	8.2	8	10.1	1	2.7	3	15.7

Note:
[a] For criteria see (Behrensmeyer, 1978).
[b] For criteria see (Buikstra and Swegle, 1989).
[c] For criteria see (Lyman, 2005; Shipman and Rose, 1983).

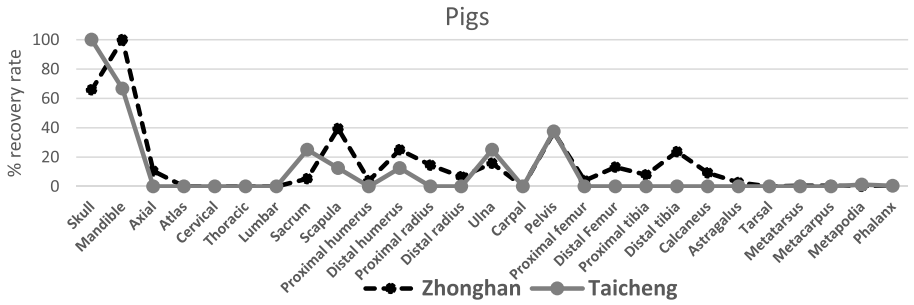

Fig. 6. Recovery rates of pig elements from Zhonghang and Taicheng.

data for different elements in order to calculate the "survivorship score"[8], or "the proportion of specimens that survived beyond the age at which an element fused" (Zeder et al., 2015), for cattle and dogs at Taicheng. We also list the counts of teeth by mandible reflecting different stages of tooth eruption and degree of wear in Fig. 8. According to the epiphyseal fusion and survivorship score, most cattle consumed at Taicheng were relatively old animals, such that 60% of animals in the assemblage had survived beyond the age class E (estimated epiphyseal fusion at between 42 and 48 months) when killed (Fig. 7). Also, at least 8 cases of pathology were found on cattle bones in the Taicheng assemblage (Shaanxi, 2018). These cases were all related to arthropathy, probably resulting from long-term traction work such as plowing and pulling. The majority of beef consumed by workers at Taicheng seems to have been from old or worn-out animals, whose meat was tough and considered undesirable (Bowen, 1998). These animals might have been raised primarily for traction (plowing) or as draft animals, rather than for specialized meat production. One source of such aged cattle was probably this type of government-owned livestock mentioned in excavated texts, as we introduced above, which at the end of their lives were disposed of through the market system.

When compared with cattle, the slaughtering ages of pigs and dogs present a distinctively different pattern at Taicheng. In Fig. 7, the counterintuitive increased survival rate of dogs from a younger (age class A) group (75%) to an older (age class B) group (about 90%) is most likely a result caused by stochastic variation due to low sample numbers. However, the survivorship score of age class C, which is much lower than either classes A or B at about 40%, suggest that most dogs consumed were juveniles or young adults. Similarly, in Fig. 8A, about 70% of pigs fall within the slaughtering age range of 12 and 24 months old based on tooth eruption data. In particular, the pig data witness a peak at stage III, corresponding to 9–14 months old. No data indicate that any pig was killed older than 3 years of age. To maximize meat production, the best slaughtering age for pigs not raised by modern industrial husbandry would fall within the range of 1.5 and 2 years old (Li, 2011). It seems very likely that these pigs and dogs were raised primarily for the production of meat. Overall, the slaughtering ages indicate that these livestock might have come from two different production systems: cattle perhaps being raised as traction or draft animals, whereas pigs and dogs were probably raised to maximize meat production and were primarily killed before becoming adults.

Even though the Zhonghang site yielded insufficient dog bones to calculate the kill-off profile of that species, the age profiles of cattle and pigs parallel those at Taicheng (Table 9). The Zhonghang cattle bone data show that a remarkably high proportion of cattle were killed at a relatively old age. According to the epiphyseal fusion data from limb bones, the survivorship rate of age class E is close to 80%. As the majority of animals represented by the assemblage survived beyond the age of 42~48 months when killed, cattle husbandry was evidently not aimed at specialized meat production. The majority of cattle consumed at both Zhonghang and Taicheng was probably raised as draft or traction animals and killed when old or they died of natural causes.

Comparison of the tooth wear and epiphyseal fusion data generates a somewhat confusing image of the slaughtering ages of pigs at Zhonghang (Table 9; Fig. 8B). According to the degree of tooth wear and eruption, the prime slaughtering age of pigs at Zhonghang was between 18 and 24 months, and there is no evidence to suggest that any of the pigs slaughtered had reached 3 years old. But the epiphyseal fusion data seems to present a contrasting picture for the slaughtering age of pigs. The survivorship scores of age classes H and I are 20% and 31% respectively, while the minor increase can be attributable to the small sample number in class H. Although there seems to be a big drop from class F to class H and I, the survivorship scores of class I suggest that about 30% of pigs survived beyond 48 months when slaughtered. This discrepancy might be the result of destructive taphonomic processes, which resulted in the underrepresentation of juvenile pigs. Another possibility is that the age estimation formula based on the degree of tooth wear does not correspond well with the actual data. Perhaps given differences in food or living environment, the wear rate of pig

[8] This formula proposed by Zeder et al., 2015 is computed by ((g * 0.5) + f)/(g + f + u)) * 100. (g = fusing, f = early and late fused; u = unfused).

Table 8
Epiphyseal fusion of cattle and dogs from the Taicheng ironworks.

	Cattle (count)					Dogs (count)			
Age of fusion	Body part	u	e	f	Age of fusion	Body part	u	e	f
0–12 months	Scapula			2	6 months	Pelvis			3
	Acetabulum			3	6–7 months	Scapula	1		
12–18 months	Humerus (distal)	1		2	7 months	Phalanx (proximal second)			
	Radius (proximal)			6	8 months	Metacarpal (distal)			3
18–24 months	Phalanx (distal first)			4	8–9 months	Humerus (distal)			3
	Phalanx (distal second)			2	9–10 months	Ulna olecranon	2		2
24–42 months	Metacarpal (distal)	1		4	10 months	Metatarsal (distal)			1
	Tibia (distal)			2	11–12 months	Ulna (distal)			3
	Metatarsal (distal)			5		Radius (proximal)			3
	Calcaneum			2		Radius (distal)			4
42–48 months	Femur (proximal)				13–16 months	Tibia (distal)	2		2
	Humerus (proximal)					Calcaneus			
	Radius (distal)			3	15 months	Humerus (proximal)		2	
	Ulna	1				Fibula (distal)			1
	Femur (distal)	1			15–18 months	Fibula (proximal)			
	Tibia (proximal)				1.5 years	Femur (proximal)	3		1
						Femur (distal)	4		1
						Tibia (proximal)	1		2
	Total	4	0	35		**Total**	13	2	29

Note:
u: unfused; e: epiphyseal lines; f: fused. The age of fusion is following Silver, 1969.

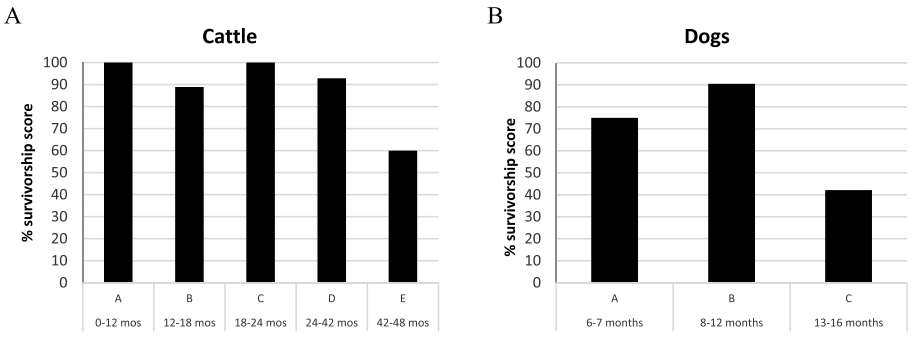

Fig. 7. Kill-off patterns of cattle (A) and dogs (B) based on epiphyseal fusion at Taicheng (mos = months) (Age stages and grouping of cattle bones fusing are following Brunson et al., 2016; Silver, 1969; age stages and fusing of dog bones are following Silver, 1969).

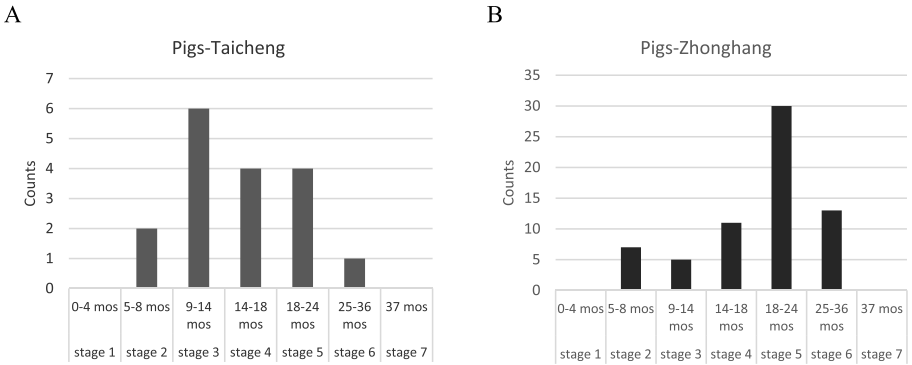

Fig. 8. Eruption and wear stage of teeth in pig tooth-rows and loose teeth (mandible) at Taicheng (A) and Zhonghang (B). Mos = months. The estimated age of each stage is based on Grant, 1982 and adjusted based on the Bronze Age pig assemblages at Yinxu by Li, 2011.

teeth during Warring States China was slightly lower than that predicted by the standards we adopted here (Li, 2011; Ma, 2008), which could lead to an underestimation of slaughtering ages of archaeological specimens. The existence of animals slaughtered relatively late in life indicates that, while the majority of pigs were killed to maximize meat production, a self-sustaining system that usually resulted in a pig being killed only when there was a need, might also have partially contributed to the subsistence system.

In general, the kill-off profiles of pigs and cattle reflected by the assemblages suggest that these two sites relied to a certain extent on a specialized meat supply system. Based on the kill-off profiles, the systems that provided pigs for Zhonghang and Taicheng both butchered the livestock before they reached adulthood. In addition, those in charge of meat supplies at these two sites appear to have procured only certain parts of carcasses. Meanwhile, the workforce at both sites consumed beef from old cattle that could have first been used for other

Table 9
Zhonghang epiphyseal fusion age score by age class (data from Luo et al., 2006).

	Class	Age range	Unfused	Fusing	Fused	Total	Survivorship score%
Cattle	A	0–12 mos			21	21	100.0
	B	12–18 mos	1		32	33	97.0
	C	18–24 mos			24	24	100.0
	D	24–42 mos	3	2	37	42	90.0
	E	42–48 mos	8	4	36	48	78.3
Total			**12**	**6**	**150**	**168**	
Dogs	A	6–7 mos			3	3	100.0
	B	8–12 mos		1	21	22	97.3
	C	13–18 mos	10		10	20	50.0
Total			**10**	**1**	**34**	**45**	
Pigs	D	7–8 mos	1		20	21	95.2
	E	8–18 mos	4		15	19	79.0
	F	18–24 mos	5	1	12	18	68.9
	H	36–48 mos	4		1	5	20.0
	I	48–60 mos	40	2	18	60	31.3
Total			**54**	**3**	**66**	**123**	

Note:
Cattle: class A: Scapula, Acetabulum; class B: Humerus-D, Radius-P; class C: 1st phalanx, 2nd phalanx; class D: MC-D, Tibia-D, MT-D, Calceneum; class E: Femur-P, Humerus-P, Radius-D, Ulna-P, Femur-D, Tibia-P (Age stages and grouping of bones fusing are following Brunson et al., 2016; Silver, 1969).
Dogs: class A: Pelvis, Scapula, 2nd phalanx; class B: MC-D, Humerus-D, Ulna-P, MT-D, Ulna-D, Radius-P&D; class C: Tibia-P&D, Calcaneus, Humerus-P, Fibula-P &D, Femur-P&D (Age stages and bones fusing are following Silver, 1969).
Pigs: class C: Axis, Atlas; class D: Pelivs, Scapula, Radius-P; class E: 2nd Phalanx, Humerus-D; class F: 1sts Phalanx, Tibia-D; class G: MC-D, MT-D, Fibula-D; class H: Calcaneum-D, Femur-P; class I: Radius-D, Ulna-P, Femur-D, Tibia-P, Ulna-D, Fibula-P, Humerus-P; class K: Radius&Ulna (Age stages and grouping of bones fusing are following Zeder et al., 2015).

purposes, e.g., wagon pulling, before they eventually became the workers' supper. The only difference between the two examples lies in the fact that more pigs at Zhonghang might have survived to a greater age when killed. Therefore, the kill-off patterns and the body-part assemblages at both sites indicate that the majority of livestock consumed, including cattle, pigs and perhaps even dogs, were probably processed or butchered by other specialists. These patterns also suggest that the livestock consumed were unlikely to have been raised in the backyard of domestic dwellings by the iron workers themselves. However, at this stage it is not possible to determine whether the workers procured their meat through the market, directly from other specialists, or via the state supply network.

8. Discussion

In this article, we have argued that the study of faunal data could serve as an important line of evidence for the discussions concerning the "economic embeddedness" of the workforce in iron production during the Qin-Han period. One of the key text-based ideas we aimed to test was that small-scale ironworks such as Taicheng were probably independent household production units and would have provided their own supplies of meat—most likely from poultry and pigs—that could be raised in the yards behind workers' dwellings. In theory, the large-scale capital center ironworks at Zhonghang should have produced a contrasting picture of government-controlled meat supply via external specialists and the market.

Given the above expectation, it was somewhat surprising to find that the sites had a similar range of domesticated animal taxa, including in both cases significant components of cattle, pig, dog, horse, and sheep/goat bones, albeit in different proportions (see Tables 4 and 5). Interestingly, poultry was relatively rare in the assemblage of faunal remains at both Zhonghang and Taicheng. The taxonomic assemblage at Taicheng also shows that workers relied heavily on domestic animals for their meat, while wild resources (e.g., deer) were barely exploited. The limited exploitation of poultry and pigs at Taicheng appears to contradict the text-based conventional wisdom that sees such sites as self-sufficient household production units.

Beyond the taxonomic assemblage data suggesting that neither site was supported by a self-sustaining system, the comparison of elements and age profiles also indicates that both ironworks relied heavily upon an external supply system. The animal bone assemblages show that butchery activities were almost absent on site, and the range of elements present suggest that meat was procured through external specialists. The age profiles illustrate that the majority of livestock were raised to a specific age range for killing in order to optimize the utilization of the animals, either primarily for meat production, or following a life of traction or draft work. All these lines of evidence strongly support the idea that the meat resources identified were probably supplied via a specialized system of animal husbandry and well-managed meat production.

The clarification of the degree of economic embeddedness enjoyed by ironworks helps to elucidate the connections and interactions of workers with their social settings. It is perhaps unsurprising to find that the Zhonghang faunal remains match the pattern expected of an urban food supply chain. But it is more significant and interesting to find that the patterning of faunal records from Taicheng—which at best was a medium-ranked county center—are similar to Zhonghang in terms of the dominance of beef, body-part representation, and kill-off patterns for major taxa. When all these lines of evidence are viewed together, a strong degree of economic embeddedness and integration within a specialized meat supply system is indicated. If we view Zhonghang as a potentially state-controlled ironworks situated in an urban center and specialized in production—i.e., a workshop that relied mostly upon the state for its provisioning or the market to obtain meat produced by others, then, according to the evidence from faunal remains, Taicheng should be categorized as a workshop employing full-time specialized labor either in an independent nucleated or attached retainer workshop manner. Although family household workshops could also rely on the market-oriented food chain to a certain extent, the high degree of reliance on a specialized food provisioning system at Taicheng, added to the lack of other evidence for craftworking or self-sufficient meat prodcution, suggests that Taicheng was unlikely to be operated by part-time specialists in household production units.

The deep reliance on an external meat supply system at Taicheng appears to challenge the over-simplistic text-based model that equates "small-scale" ironworks with a household-level of production center, thus indicating that the iron industry in the capital region had a more complicated organization. Having said that, within the constraints of the current evidence, it is difficult to determine the extent to which the state played a managerial role in Taicheng's operation and, by extension, the type of deep economic embeddedness the site represents. Nevertheless, our comparative study encourages us to reflect upon and consider the broader social setting within which full-time specialized ironworking communities like Taicheng were able to operate, procure raw materials, manufacture to meet the intensive demand for their small range of final products, distribute them efficiently in order to satisfy the needs of their customers, and receive regular supplies of meat and other foodstuffs in return. In future research into Taicheng, and similar sites, more fine-grained analyses will be needed to address some unresolved questions concerning craft specialization (Costin, 2005:1064–1065); such as how workers were compensated and by whom, and who controlled the production and distribution processes.

As mentioned in the introduction, ironworks relied on workers specialized in different craftworking procedures, and the labor system therefore had to allow sufficient mobility of skilled labor, while also coordinating the flow of information regarding the supply and demand, even in small or medium ranked settlements. Given the dietary similarities at Taicheng and Zhonghang, one cannot rule out the possibility that some highly-skilled workers there might have been retainers who

were partially supported by the state. If this was the case, then Taicheng's operation might have involved some degree of centralized administrative control and, by extension, some convict/corvée labor, since labor of these types were also used in state-controled production. Whether the Taicheng ironworks was independently run or state-owned, its full-time manner of intensified production of limited types of goods and its deep reliance on a specialized food supply system together provide new information concerning the rise of the iron industry during the Han period.

9. Conclusion

This article employed the concept of economic embeddedness and examined faunal remains together with other lines of evidence as a novel means of evaluating the potential social connections between Taichang ironworks and its neighboring communities. We have highlighted several evidential lines of evidence, including the heavy reliance on other specialists for food supplies and the lack of multiple type of craft production on site, which together lead us to propose that Taicheng, like Zhonghang, was a production center employing externally provisioned, full-time specialists or artisans. Due to the inherent limitations of the available evidence, the Taicheng ironworks cannot unequivocally be identified as either an independent, nucleated workshop or an attached retainer workshop; but, given the economic embeddedness demonstrated, this seemingly small-scale workshop was unlikely to be an independent household production unit suggested by previous text-based models. As Taicheng ironworks must have been interconnected within the overall economic system of the political core region, this study provides reasonable foundations for further speculation regarding the nature of the market integration, transportation, and channels of exchange that allowed the movement of food and craft products of the kinds excavated at the medium county-level settlements such as Taicheng.

If these small-scale sites represent an example of deep economic embeddedness, then future archaeological research on the Han period has to work on economic connections in a broader context. For instance, we need to consider how the market system operating in the political core region enabled workers involved in the craft manufacturing of such a limited range of items to become so deeply embedded within the external food supply system. Moreover, it is important to investigate whether other, non-ironworking, communities also participated in the same specialized meat market network. These questions needed to be addressed through more comprehensive studies of faunal remains from various site types, including small-scale ironworks, other types of craft production centers, and non-industrial residential areas in urban centers within the Guanzhong Basin. Although further comparative studies will be required in future, we hope this case study has demonstrated that zooarchaeological evidence for past meat consumption offers a fruitful means of providing fuller and better depictions of industrial workers' social relations in China's Qin-Han, and other, periods. Finally, we hope that this research will encourage further studies aimed at elucidating the economic foundations of the Han Empire from the perspective of craft specialization.

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References

Arnold, D.E., 2014. The Evolution of Ceramic Production Organization in a Maya Community. University Press of Colorado, Boulder, CO.
Bai, Y., 2011. Han Chang'an cheng shougongye yicun de kaoguxue yanjiu (Archaeological research on craft production remains in Han Chang'an city). In: Yanjiusuo, Zhongguo Shehui Kexue Kaogu, Yanjiusuo, Shaanxisheng Kaogu, Kaogusuo, Xi'anshi Wenwu Baohu (Eds.), Han Chang'an Cheng Kaogu yu Hanwenhua [Archaeology of Han Chang'an City and Han Culture]. Kexue Chubanshe, Beijing, pp. 97–161.
Barbieri-Low, A.J., 2007. Artisans in Early Imperial China. University of Washington Press, Seattle and London.
Barbieri-Low, A.J., Yates, R.D.S., 2015. Law, State, and Society in Early Imperial China: A Study with Critical Edition and Translation of the Legal Texts from Zhangjiashan Tomb No. 247. Brill, Leiden.
Behrensmeyer, A.K., 1978. Taphonomic and Ecologic Information from Bone Weathering. Paleobiology 4, 150–162.
Binford, L.R., 1980. Willow Smoke and Dogs' Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation. Am. Antiq. 45, 4–20.
Binford, L.R., 1981. Bones: Ancient Men and Modern Myths. Academic Press, New York.
Bowen, J., 1998. To Market, to Market: Animal Husbandry in New England. Hist. Archaeol. 32, 137–152.
Brunson, K., He, N., Dai, X., 2016. Sheep, Cattle, and Specialization: New Zooarchaeological Perspectives on the Taosi Longshan. Int. J. Osteoarchaeol. 26, 460–475.
Buikstra, J.E., Swegle, M., 1989. Bone modification due to burnings: experimental evidence. In: Bonnichsen, R., Sorg, M.H. (Eds.), Bone Modification. Center for the Study of the First Americans, Institute for Quaternary Studies. University of Maine, Orono, ME, pp. 247–258.
Clark, J.E., Parry, W.J., 1990. Craft specialization and cultural complexity. Res. Econ. Anthropol. 12, 289–346.
Costin, C.L., 1991. Craft specialization: issues in defining, documenting, and explaining the organization of production. In: Schiffer, M. (Ed.), Archaeological Method and Theory Volume 3. University of Arizona Press, Tuscon, AZ, pp. 1–56.
Costin, C.L., 2005. Craft production. In: Maschner, H., Chippindale, C. (Eds.), Handbook of Archaeological Methods. AltaMira Press, Lanham, MD, pp. 1032–1105.
Costin, C.L., 2007. Thinking about production: phenomenological classification and lexical semantics. In: Hurby, Z.X., Flad, R.K. (Eds.), Rethinking Craft Specialization in Complex Societies: Archeological Analyses of the Social Meaning of Production. American Anthropological Association and the University of California Press, Arlington, VA, pp. 143–162.
van der Leeuw, S.E., van Beek, B.L., 1977. Towards a study of the economics of pottery making. In: Brandt, R.W., Groenman-van Watteringe, W. (Eds.), Ex Horreo. University of Amsterdam, Amsterdam, pp. 68–76.
Ding, B., Wei, X., 2016. Qinhan Wujia Shiliao Huishi [Collection of Textual Records About Prices During the Qin and Han Periods]. Zhongguo Shehui Kexue Chubanshe, Beijing.
Drennan, R.D., 2009. Statistics for Archaeologists: A Common Sense Approach, Second Edition. Springer, New York.
Fargher, L.F., 2009. A comparison of the spatial distribution of agriculture and craft specialization in five state-level societies. J. Anthropol. Res. 65, 353–387.
Feinman, G.M., 1999. Rethinking our assumptions: economic specialization at the household scale in ancient Ejutla, Oaxaca, Mexico. In: Skibo, J.M., Feinman, G.M. (Eds.), Pottery and People: A Dynamic Interaction. The University of Utan Press, Salt Lake City.
Feinman, G.M., Garraty, C.P., 2010. Preindustrial markets and marketing: archaeological perspectives. Annu. Rev. Anthropol. 39, 167–191.
Flad, R.K., 2011. Salt Production and Social Hierarchy in Ancient China. Cambridge University Press, Cambridge.
Flad, R.K., Hurby, Z.X., 2007. "Specialized" production in archaeological context: rethinking specialization, the social value of products, and the practice of production. In: Hurby, Z.X., Flad, R.K. (Eds.), Rethinking Craft Specialization in Complex Societies: Archeological Analyses of the Social Meaning of Production. American Anthropological Association, Arlington, VA, pp. 1–19.
Grant, A., 1982. The use of tooth wear as a guide to the age of domestic animals. In: Wilson, B., Grigson, C., Payne, S. (Eds.), Ageing and Sexing Animal Bones from Archaeological Sites. BAR, Oxford, pp. 91–108.
Hayashi, M., 1975. Kandai no inshoku (Food and Drink in Han Times). Tōhō gakuhō 48, 1–98.
Henan, [Henansheng Wenwu Kaogu Yanjiusuo], 2006. Xinzheng Zhengguo Jisi Yiizhi [The Sacrificial Site of the Zheng State in Xinzheng]. Daxiang Chubanshe, Zhengzhou.
Henan and Zhongguo, [Henanxing Wenhuaju Wenwu Gongzuodui, Zhongguo Kexueyuan Kaogu Yanjiusuo], 1962. Gongxiang Tieshengguo [Tieshengguo in Gongxian]. Wenwu Chubanshe, Beijing.
Hirth, K.G., 2009. Housework and domestic craft production: an introduction. In: Hirth, K.G. (Ed.), Housework: Craft Production and Domestic Economy in Ancient Mesoamerica. Archaeological Publications No 19, American Anthropological Association, Washington D.C., pp. 1–12.
Hu, S., Liu, Z., Zhang, J., 2006. Xi'an Han Changancheng chengxiang xinanjiao yizhi chutu dongwu guge yanjiu baogao (Report on faunal remains from the North-Western corner of the enclosing walls of Han Chang'an). Wenbo 2006 (5), 59–60.
Hulsewe, A.F.P., 1985. Remants of Ch'in Law. Brill, Leiden, Netherlands.
Kageyama, T., 1984. Chūgoku kodai no seitetsu shukougyou to senbaisei (Iron handicraft and monopoly in ancient China). In: Kageyama T., (Ed.),. In: Kageyama, T. (Ed.), Chūgoku kodai no shōkōgyō to senbaisei [Industry, Business, and Monopoly in Ancient China]. Tōkyō daigaku shuppankai, Tokyo, pp. 271–309.

Lam, W., Chen, J., Chong, J., Lei, X., Zhao, Y., Chen, G., 2015. Shilun Handai Guanzhong diqu tieqi shengchan yuanliao de laiyuan yu liutong-Taicheng zhutie zuofang chutu tieyiwu de yejin fenshi (On the provenience and circulation of raw materials for iron production in the Guanzhou area of the Han period: a case study of iron remains identified from the Taicheng foundry). Kaogu yu Wenwu 2015 (6), 95–109 124.
Lam, W., Chen, J., Chong, J., Lei, X., Tam, W., 2018. An iron production and exchange system at the center of the Western Han Empire: scientific study of iron products and manufacturing remains from the Taicheng site complex. J. Archaeol. Sci. 100, 88–101.
Landon, D.B., 1996. Feeding colonial boston: a zooarchaeological study. Hist. Archaeol. 30, 1–153.
Landon, D.B., 1997. Interpreting urban food supply and distribution systems from faunal assemblages: an example from Colonial Massachusetts. Int. J. Osteoarchaeol. 7, 51–64.
Legge, A.J., Rowley-Conwy, P.A., 1991. "... Art made strong with bones": a review of some approaches to osteoarchaeology. Int. J. Osteoarchaeol. 1, 3–15.
Li, J., 1995. Nanyang Handai Yetie [Iron Production During the Han Period in Nanyang]. Zhongzhou Guji Chubanshe, Zhengzhou.
Li, J., 2003. Zhongyuan Gudai Yejin Jishu Yanjiu [A Study of Ancient Central Plains Metallurgical Technology]. Zhongzhou Guji Chubanshe, Zhengzhou.
Li, Z., 2011. Yinxu Xiaomintu yizhi chutu jiazhu de siwang nianling yu xiangguan wengti yanjiu (A study on death age of domestic pigs excavated from Xiaomintun site of Yin Dynasty ruins and relatedissues). Jianghan Kaogu 2011 (4), 89–96.
Lin, G., 1999. Zhongguo Jingji Tongshi. Qin Han Jingjijuan [The History of Chinese Economies. Volume of the Qin and Han]. Jingji Ribao Chubanshe, Beijing.
Loewe, M., 1986. The Cambridge History of China, Vol. 1: The Chin and Han Empires, 221 B.C.-A.D. 220 Cambridge University Press, Cambridge.
Luo, Y., Yang, M., Yuan, J., 2006. Zhengguo Jisi Yizhi Dongwu Guge Yanjiu Baogao (Report of faunal reamins from the Xinzheng sacrificial site). In: Henansheng Wenwu Kaogu Yanjiusuo (Ed.), Xinzheng Zhengguo Jisi Yizhi [The Sacrificial site of Zheng State in Xinzheng]. Daxiang Chubanshe, Zhengzhou, pp. 1063–1152.
Lyman, L.R., 1984. Bone density and differential survivorship of fossil classes. J. Anthropol. Archaeol. 3, 259–299.
Lyman, L.R., 2005. Analyzing cut marks: lessons from artiodactly remains in the northwestern United States. J. Archaeol. Sci. 32, 1732–1777.
Lyman, L.R., 2008. Quantitative Paleozoology. Cambridge University Press, Cambridge.
Ma, D., 1983. Handai Caizhengshi [The Financial History of the Han Dynasty]. Zhongguo Caizheng Jingji Chubanshe, Beijing.
Ma, J., 1999. Zheng-Han liangdu pingmian buju chulun (A preliminary analysis on the spatial layout of capital of the Zheng and Han states). Zhongguo Lishi Dili Luncong 1999 (2), 115–129.
Ma, X., 2008. Pig husbandry strategies in an emergent complex society in Central China. J. Indo-Pacific Archaeol. 24, 91–102.
Nishijima, S., 1986. The economic and social history of Former Han. In: Loewe, M. (Ed.), The Cambridge History of China, Vol.1: The Chin and Han Empires, 221 B.C-A.D.220. Cambridge University Press, Cambridge, pp. 545–607.
Peacock, D.P.S., 1982. Pottery in the Roman World: an Ethnoarchaeological Approach. Longman, London and New York.
Polanyi, K., 2001 [1944]. The Great Transformation: The Political and Economic Origins of Our Time. Beacon Press, Boston.
Qin, J., 1980. Fengxiang Nangucheng yizhi de zuantan he shijue (Augering and preliminary excavation of the Nangucheng site in Fengxiang). Kaogu yu Wenwu 1980 (1), 48–54.
Santley, R.S., Kneebone, R.R., 1993. Craft specialization, refuse disposal, and the creation of spatial archaeological records in prehispanic Mesoamerica. In: Santley, R.S., Hirth, K.G. (Eds.), Prehispanic Domestic Units in Western Mesoamericas: Studies of the Household, Compound, and Residence. CRC Press, Boca Raton, FL, pp. 37–63.
Shaanxi, [Shaanxi Provincial Institute of Archaeology], 2018. Taicheng Zhutie: Shaanxi Yangling Handai Zhutie Yizhi Fajue yu Yanjiu [Taicheng Ironworks: Report on the Excavation and Resarch of a Cast Iron Foundry of the Han Period in Yangling, Shaanxi]. Shanghai Guji Chubanshe, Shanghai.
Shandong, Beijing, and Jinanshi, [Shandongsheng Wenwu Kaogu Yanjiusuo, Beijing Daxue Kaogu Wenbo Xueyuan, Jinanshi Kaogu Yanjiusuo], 2011. Shandong Zhangqiu Dongpingling gucheng (Dongpingling walled-town in Zhangqiu, Shandong). In: Zhongguo Wenwu Baoshe (Ed.), Zhongguo Kaogu Xingfaxing Niandu Jilu 2010 [Annual Report on New Archaeological Discoveries in China 2010]. Zhongguo Wenhua Yichan, Beijing, pp. 250–253.
Shiji [Records of Grand Historian by Shima Qian], 1997. Annotated by S. Zhang, Z. Shima, and Y. Pei. Zhonghua Shuju, Beijing.
Shimada, I., 2007. Introduction. In: Shimada, I. (Ed.), Craft Production in Complex Societies: Multicraft and Producer Perspective. University of Utah Press, Salty Lake City, pp. 1–21.
Shipman, P., Rose, J., 1983. Early hominid hunting, butchering, and carcass-processing behaviors: approaches to the fossil record. J. Anthropol. Archaeol. 2, 57–98.
Shuihudi, [Shuihudi Qinmu Zhujian Zhengli Xiaozu], 1990. Shuihudi Qinmu zhujian [Bamboo Slips from the Qin Tomb at Shuihudi]. Wenwu Chubanshe, Beijing.
Silver, A., 1969. The Ageing of Domestic Animals. In: Brothwell, D., Higgs, E. (Eds.), Science in Archaeology: A Survey of Progress and Research. Thames and Hudson, London, pp. 283–302.
Sinopoli, C.M., 2003. The Political Economy of Craft Production: Crafting Empire in South India. C. 1350–1650. Cambridge University Press, New York.
Sterckx, R., 2011. Food, Sacrifice, and Sagehood in Early China. Cambridge University Press, Cambridge.
Sun, Z., 2008. Craft Production in the Western Zhou Dynasty (1046–771BC): a Case Study of a Jue-earrings Workshop at the Predynastic Capital Site, Zhouyuan, China. Archaeopress, Oxford.
Wagner, D.B., 2008. Ferrous Metallurgy, Volume 5, Part 11 of Joseph Needham's Science and Civilization in China. Cambridge University Press, Cambridge.
Xu, L., 2013. Qin-Han Chengyi Kaoguxue Yanjiu [Archaeological Study of Qin-Han Walled Towns]. Zhongguo Shehui Kexue Chubanshe, Beijing.
Yamada, K., 1998. Qinhandai syukougyou no tenkai: Qinhandai gongguang no hensen kara kangaeru (The development of manual industries and the vicissitudes of government workshops (Gong Guan) in the Qin and Han Dynasties). Toyoshi kenkyu 56, 701–732.
Yang, J., 2007. Gudai juming roushi jiegou de fuyuan (Reconstruction of the structure of meat consumption in ancient societies). Kaogu yu Wenwu. 2007 (6), 103–105.
Yantielun jiaozhu [Annotation of "Discourses on Salt and Iron" by Huan Kuan], 1992. In: Compiled and annotated by L. Wang. Zhonghua Shuju, Beijing.
Yu, Y.-S., 1977. Han. In: Chang, K.C. (Ed.), Food in Chinese Culture: Anthropological and Historical Pespectives. Yale University Press, New Heaven, pp. 23–53.
Yu, Z., 2012. Jiandu yu Qinhan shehui [Bamboo slips and Qin-Han society]. Hunan Daxue Chubanshe, Changsha.
Zang, Z., 2012. Qinhan Fuyi yu Shehui Kongzhi [The Tax and Corvée System in the Qin-Han Period and Social Management]. Sanqin Chubanshe, Xi'an.
Zeder, M.A., Lemoine, X., Payne, S., 2015. A new system for computing long-bone fusion age profiles in Sus scrofa. J. Archaeol. Sci. 55, 135–150.
Zhangjiashan, [Zhangjiashan 246 hao Hanmu Zhujian Zhengli Xiaozu], 2006. Zhangjiashan Hanmu Zhujian (247 hao Mu): (Shiwen Xiudingben) [Bamboo Slips from the Tomb No. 247 at Zhangjiashan (with Transcription and Annotation)]. Wenwu Chubanshe, Beijing.
Zhao, Y., Chong, J., Chen, G., 2012. Shaanxi Yangling Taicheng Handai zhutie zuofang yizhi (The Han Iron Foundry at Taicheng in Yangling, Shaanxi). Zhongguo wenwubao, 2012/3/16. pp. 8.
Zhongguo, [Zhongguo Longye Bowuguan], 1996. Handai Nongye Huaxiang Zhuanshi [Collection of Pictorial Bricks Depicting Agricultural Production in the Han Period]. Zhongguo Nongye Chubanshe, Beijing.
Zhongguo, [Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo], 1995. 1992 nian han-changan yezhu yizhi fajue jianbao (Excavation of an iron foundry site at Han Chang'an city, 1992). Kaogu 1995 (9), 792–798.
Zhongguo, [Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo], 1997. 1996 nian han-changan yezhu yizhi fajue jianbao (Excavation of an iron foundry site at Han Chang'an city, 1996). Kaogu 1997 (7), 5–12.
Zhongguo, [Zhongguo Yejinshi Bianxiezu], 1978. Cong Guxing yizhi kan handai shengtie yelian jishu (Ancient cast iron technology during the Han period based upon evidence from Guxing). Wenwu. 1978 (2), 44–47.

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Erratum regarding missing Declaration of Competing Interest statements in previously published articles – Part 2

Declaration of Competing Interest statements were not included in the published version of the following articles that appeared in previous issues of Archaeological Research in Asia.

For the below articles, the authors were contacted after publication to request a Declaration of Interest statement.

1. "Lithics in the steppe landscape: An off-site spatial analysis of stone artefacts in the Khanuy Valley, Mongolia" [Archaeological Research in Asia, 2018; 16: 1–13] https://doi.org/10.1016/j.ara.2018.01.003

Declaration of competing interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

2. "Bridging the time gap in the Bronze Age of Southeast Asia and Southwest China" [Archaeological Research in Asia, 2020; 22: 100189] https://doi.org/10.1016/j.ara.2020.100189

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3. "Bloomery iron smelting in the Daye County (Hubei): Technological traditions in Qing China" [Archaeological Research in Asia, 2018; 16: 148–165] https://doi.org/10.1016/j.ara.2018.10.001

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4. "Tolbaga revisited: Scrutinizing occupation duration and its relationship with the faunal landscape during MIS 3 and MIS 2" [Archaeological Research in Asia, 2018 17: 9–23] https://doi.org/10.1016/j.ara.2018.09.003

Declaration of competing interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

5. "Symbolic bead exchange and polity interaction in Mahan civilization (c. 100 BCEâ€"300 CE), South Korea" [Archaeological Research in Asia, 2020; 23: 100205] https://doi.org/10.1016/j.ara.2020.100205

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6. "A non-ordinary goods complex of the paleometal period in the southern Russian Far East" [Archaeological Research in Asia, 2018; 16: 34–45] https://doi.org/10.1016/j.ara.2018.02.001

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7. "Ordering the material world of the Western Zhou" [Archaeological Research in Asia, 2018; 19: 100096] https://doi.org/10.1016/j.ara.2018.01.002

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8. "The first laminar Mousterian obsidian industry in the north-central Caucasus, Russia (preliminary results of a multi-disciplinary research at Saradj-Chuko Grotto)" [Archaeological Research in Asia, 2019; 18: 82–99] https://doi.org/10.1016/j.ara.2019.03.001

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9. "Specialised lithic technology of terminal Pleistocene maritime peoples of Wallacea" [Archaeological Research in Asia, 2018; 16: 78–87] https://doi.org/10.1016/j.ara.2018.05.003

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10. "Understanding the pattern and distribution of sculptural and architectural remains in the archaeological site of Kamakhya" [Archaeological Research in Asia, 2020; 22: 100193] https://doi.org/10.1016/j.ara.2020.100193

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11. "Economic embeddedness and small-scale iron production in the capital region of the Han Empire: the perspective from faunal remains" [Archaeological Research in Asia, 2018; 17: 117–132] https://doi.org/10.1016/j.ara.2018.11.002

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12. "Faunal remains and environments from the Bronze age of Kalehkoob, Lut Desert, eastern Iran" [Archaeological Research in Asia, 2018; 16: 139–147] https://doi.org/10.1016/j.ara.2018.09.002

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13. "Early Upper Paleolithic blade technology in the Japanese Archipelago" [Archaeological Research in Asia, 2018; 17: 79–97] https://doi.org/10.1016/j.ara.2018.03.001

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14. "The earliest Neolithic lithic industries of the Central Zagros: New evidence from East Chia Sabz, Western Iran" [Archaeological Research in Asia, 2018; 16: 46–57] https://doi.org/10.1016/j.ara.2018.02.002

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15. "Detecting patterns of local raw material utilization among informal lithic assemblages at the late Paleolithic site of Shuidonggou Locality 2 (China)" [Archaeological Research in Asia, 2018; 17: 137–148] https://doi.org/10.1016/j.ara.2018.11.003

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