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► **To cite this version:**

Yin Ruixue, Luan Fengshi, Luc Doyon. Changes and Consistencies in Bone Technologies as a Sign of Cultural Transition About 4000 Years Ago in Eastern China: Insights from the Yinjiacheng Site, Shandong, China. *Asian Perspectives*, 2023, 61 (1), pp.45-76. <10.1353/asi.2022.0034>. <halshs-03925736>

HAL Id: halshs-03925736

<https://shs.hal.science/halshs-03925736v1>

Submitted on 5 Jan 2023

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Changes and Consistencies in Bone Technologies as a Sign of Cultural Transition About 4000 Years Ago in Eastern China: Insights from the Yinjiacheng Site, Shandong, China

YIN Ruixue, LUAN Fengshi, and Luc DOYON

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Abstract

The study of cultural changes associated with the emergence of complex societies in Ancient China has heavily relied on evidence from ceramics, lithic technologies, changes in settlement pattern, burial practices, and prestige goods. However, it remains unclear whether, and if so to what extent, other aspects of material culture follow

similar evolutionary trajectories. Here, we analyze a large bone tool assemblage found in Longshan ($n = 76$) and Yueshi ($n = 124$) contexts at Yinjiacheng, a key site from the Haidai region. These two cultural entities are of particular interest as they allow to investigate cultural change dynamics in the Haidai region during the transition between the Late Neolithic and early Bronze Age. Our assessment allows us to document changes in bone technology along three lines of evidence: typological diversity, technological know-how, and morphometric standardization. From a typological standpoint, we document an increased diversity in tool types during the Yueshi period compared to Longshan. However, the techniques used to manufacture bone tools during the Longshan and Yueshi periods remain broadly the same. Furthermore, we identify the persistence of specific reduction sequences for the manufacture of some awl and projectile point sub-types shared by the two cultural systems. Morphometrically, Longshan domestic tools are generally more standardized than Yueshi tools, while Yueshi hunting implements show a higher degree of standardization compared to their Longshan counterparts. We argue this pattern reflects the preservation of a common know-how among Longshan and Yueshi settlers at Yinjiacheng. We interpret the typological diversification of Yueshi hunting implements and changes in the standardization of Yueshi bone tools as a proxy for the articulation of this knowledge through applying less rigid rules of production to meet new emerging needs.

Keywords: bone tools, cultural evolution, Holocene, Neolithic, Bronze Age, Longshan, Yueshi

<OP:CR>*Asian Perspectives*, Vol. 62, No. 1 © 2023 by the University of Hawai'i Press.

INTRODUCTION

The Holocene archaeological record in China attests to a rapid succession of regionally circumscribed cultural entities. Changes in pottery, architecture, metal work, prestige goods, and symbolic practices such as burial and divination play a decisive role in defining these entities and elaborating cultural chronologies from the Neolithic to Dynastic periods ([Allard 2014](#); [Cohen 2014](#); [Cohen and Murowchick 2014](#); [Wagner and Tarasov 2014](#)). In recent years, an increasing number of studies have been carried out in China to investigate the underlying causes responsible for these cultural changes ([An et al. 2005](#); [Gao et al. 2007](#); [Han et al. 2007](#); [He et al. 2018](#); [Huang et al. 2011](#); [Pei et al. 2018](#); [Stanley et al. 1999](#); [Staubwasser and Weiss 2006](#); [Wang et al. 2016](#); [Wu and Liu 2004](#); [Wu et al. 2012](#); [Zhang et al. 1997](#)). These studies have mainly been concerned with linking the timing of major cultural transitions with environmental proxies to assess the effect of Holocene climatic fluctuations on trends in cultural evolution (e.g., [Gao et al. 2007](#); [Guo et al. 2013](#); [Jia et al. 2012](#); [Peng et al. 2010](#); [Shi et al. 1993](#)). This approach was recently challenged by [Jaffe and colleagues \(2021\)](#), who aptly pointed out that establishing such causal relationships conceals the complexity of social dynamics and technological adaptations. Specifically, the authors highlight a crucial issue pertaining to the spatial and temporal resolution inherent to this research program, that is, cultural changes identified at a single site that was occupied over a relatively short period may not necessarily reflect environmental changes occurring over long periods of time and affecting large geographic regions ([Jaffe et al. 2021](#)). Of particular interest to our understanding of the emergence of complex societies in East China, the transition from the Longshan (ca. 4500–3900 cal. B.P.) to the Yueshi (ca. 3800–3400 cal. B.P.) period—respectively the final Late Neolithic and initial Early Bronze Age cultures in the Haidai

region of Shandong Province—constitutes a prime example where such cultural change dynamics can be investigated.

The Longshan material culture was first identified in 1928 during an excavation at Chengziya in the town of Longshan, Shandong Province. It is characterized by an abundance of fine black- and grey-polished, eggshell-thin ceramics of various types, which indicates increased reliance on pottery wheel technology and craft specialization ([Druc et al. 2021](#); [Underhill 2002](#)). Stone tools are diverse and predominantly shaped by grinding ([Bennett 2007](#); [Cunnar 2007, 2013](#); [Underhill et al. 2021](#)). Osseous technology from Longshan contexts varies intra-regionally depending on the exploitable resources in the immediate environment. When available, bone, antler, and shell are transformed into a wide variety of tools such as awls, barbed points, projectile points, needles, hairpins, and so on. Some rare bronze items such as small tools (chisels and stick-like objects), ornaments, and small vessels appear during the end of the Longshan period, as evidenced at the Sanlihe, Yangjiaquan, Dianzi, Yaowangcheng, Chengzi, Dafanzhuang, and Luantai sites, while objects made of jade are predominantly found in the eastern part of the Haidai region. The Longshan economy rests on agriculture and husbandry; the Haidai region is generally subdivided into six sub-regional entities based on variations in the material culture and predominant crops ([Luan 2017b](#)).

The Yueshi material culture was first discovered in the 1930s, although this chrono-cultural entity was not recognized as such until the end of the 1970s. In contrast to Longshan, Yueshi pottery is cruder; ceramic types are less diversified, generally thicker, and usually lack decoration ([Luan 2017a](#)). Stone technology is likewise simpler and somewhat more expedient; perforations made by drilling are seldom present on stone implements during this time period. It is commonly assumed that utilitarian bone tools show no obvious differences between Longshan

and Yueshi, although Yueshi contexts often attest to an increased number of skeletal items used in divination activities ([Luan 2017a](#)). The manufacture of bronzeware developed substantially during the Yueshi period. In the Haidai region, the Yueshi is subdivided into seven sub-regional types based on variations in material culture, environmental characteristics, and evidence of cultural influence from groups living outside present-day Shandong Province ([Luan 2017a](#)).

Traditionally, transformations from the Longshan to the Yueshi period are often qualified as representing “cultural decay.” The arguments put forward to support this interpretation often refer to: (1) Yueshi ceramic manufacture, which lacks the refinement and level of expertise observed in Longshan products ([Cohen 2001](#); [Underhill 2002](#)); (2) a less diversified and more expedient Yueshi lithic toolkit primarily composed of harvesting tools ([Wang 2007](#)); (3) a noticeable decrease in the density of sites in the Haidai region from the Longshan to the Yueshi periods ([Peng et al. 2010](#)); and (4) signs of a return to a less hierarchical society, as evidenced by a settlement pattern that is no longer organized into urban centers and tier-ranked satellite sites and burial practices that seldom include features and contents traditionally associated with an elite class ([Feinman et al. 2019](#); [Liu 1996](#); [Liu et al. 2004](#); [Underhill et al. 2008](#)). Taken together, Yueshi cultural contexts appear to signal the fragmentation of the preceding Longshan culture in the Haidai region, although the cause of this change is still debated.

Three contrasting views have been proposed to account for the changes in material culture from the Longshan to the Yueshi period. The first argues that the Yueshi culture originated from within the lower Xiajiadian culture in the Liaodong Peninsula, in present-day Liaoning Province, northeastern China. Tribal warfare and the later conquest of the Jiaodong Peninsula, in present-day Shandong Province, are suggested as causes for the introduction of the Yueshi culture into the Haidai region ([Luan 2017c](#)). The second view suggests that a deterioration in climatic

conditions during the Longshan period had a substantial impact on the economy. For example, increased frequency and amplitude of flooding events and shortfalls in paddy-oriented agricultural production together might have pressured populations to split and relocate, as seemingly attested by a drastic reduction in the number of Yueshi archaeological sites in Haidai ([Gao et al. 2007](#); [Guo et al. 2013](#); [Wagner et al. 2013](#)). In this context, Yueshi Culture would signal a “simplification” of Longshan ceramic production, perhaps owing to the fragmentation of the knowledge transmission networks operating before and during the transition from Longshan to Yueshi. Finally, the recent application of Bayesian modeling techniques to investigate the chronological succession of cultures in the Haidai region using ^{14}C dates has led some to propose a chronological overlap between the second half of the Dawenkou (ca. 6500–4000 cal. years B.P.), the Longshan, and the first half of the Yueshi periods ([Long et al. 2017](#)). This result challenges the assumption of a unilinear chrono-cultural sequence from the Dawenkou to the Yueshi and instead depicts contemporaneous cultural diversity during the end of the Neolithic and beginning of the Early Bronze Age in the Haidai region, but this remains to be documented stratigraphically. To this day, it remains unclear whether and to what extent some aspects of material culture other than the traditionally favored lithics and pottery could help test these contrasting views.

The present article reports the results of our study of a large bone tool assemblage found in Longshan and Yueshi contexts at the Yinjiacheng site, Shandong Province. Our aim is threefold: (1) document for the first time a category of material culture that has been historically neglected in Chinese archaeology; (2) identify elements of continuity, gradual change, and discontinuity in osseous technology between the two periods; and (3) explore how the patterns emerging from this data may contribute to our understanding of cultural change dynamics operating during the

transition from the Late Neolithic to Early Bronze Age in the Haidai region. Three lines of evidence are investigated: typological diversity, technological variability, and morphometric standardization.

THE STUDY OF BONE ARTIFACTS: CONTINUITY AND CHANGE

Traditionally, typological approaches constitute the norm in Chinese archaeology and little focus is given to the technical knowledge associated with the manufacture of bone tools ([Yin et al. 2021](#)). According to published literature and excavation reports, thousands of osseous tools have been unearthed from contexts spanning the Neolithic to the Dynastic periods (e.g., [Cohen 2011](#); [Lu 1998](#); [Shandong 1990](#); [Sun et al. 2014](#); [Wang et al. 2020](#)). Most of the time, the presence of these tools is alluded to in passing or the finds are grouped into broad typological categories that are interpreted as reflecting various aspects of past subsistence strategies. Only on rare occasions are comments provided on the techniques used to manufacture these tools (e.g., [Sun et al. 2014](#)). When present, they usually consist of broad generalizations applicable to the whole osseous tool assemblage rather than providing detailed descriptions of each tool type, let alone each tool. The application of a technological approach based on the concept of *chaîne opératoire* in China remains incipient to this day. Thus far, it has only been applied to the study of artifacts such as bone tools and personal ornaments dating to the early Late Pleistocene and Late Palaeolithic ([Doyon et al. 2019, 2018, 2021](#); [d'Errico et al. 2018, 2021](#); [Pitarch Martí et al. 2017](#); [Wei et al. 2016, 2017](#); [Zhang et al. 2016, 2018](#)).

Given the properties of osseous materials (i.e., antler, bone, horn, ivory, shell, and teeth), past populations could impose shapes on the skeletal remains they selected for manufacturing tools. Such shapes were obtained through a gradual reduction process using techniques (e.g., incising,

sawing, grinding, scraping, gouging) adapted to working hard animal tissues. Technological and morphometric analyses therefore allow us to differentiate between the form and function of prehistoric technology and provide crucial information on how a tool's manufacturing process was undertaken. Consequently, studying bone tool assemblages from a number of complementary perspectives is particularly appropriate for exploring technological organization and investigating changes in cultural and social dynamics ([d'Errico et al. 2018, 2021](#); [Doyon 2019, 2020](#); [Goutas and Tejero 2016](#); [Langley et al. 2020](#); [Zhang et al. 2016, 2018](#)).

Cultural change can be described along two dimensions: pace and scope. "Pace" refers to the speed, from gradual to abrupt, with which changes are introduced into cultural systems. Proper assessment of the pace of change relies on an adequate resolution of the archaeological record itself because seemingly abrupt transformations in the record may in fact be the result of a gradual fixation of novel characteristics in the cultural system over generations. The scope of change, from narrow- to wide-ranging, relates to how many aspects of material culture is affected. Given that cultural adaptations are inherently dynamic systems, changes in one component of the system may have repercussions on concomitant ones. Since both the pace and scope of change may differ between different elements of material culture, even within the same artifact type, it is important to investigate cultural changes from a number of perspectives. With regard to osseous technology, these complementary perspectives include tool typology, technological decisions and actions implemented during manufacture (i.e., the *chaîne opératoire*), and morphometric characteristics of the object.

Investigating cultural changes by studying osseous technology entails interpreting the cultural and environmental processes that could account for the data on the pace and scope of change. When abrupt changes are identified in all sectors of the material culture, it traditionally signals a

disruption in cultural transmission, either owing to significant societal upheavals or to population replacement ([Rigaud et al. 2018](#); [Roux 2013](#); [van der Waals 1985](#)). In osseous technology, such dynamics should result in drastic changes in tool typology, manufacturing process, and morphology in association with marked novelties in other aspects of material culture.

Interpreting changes that occur gradually is more challenging because what we perceive as gradual change may very well conceal complex cultural evolution resulting from multifaceted occurrences of hybridization ([Collard and Tehrani 2005](#); [Greenhill et al. 2009](#)). Generally speaking, the drivers or co-drivers of trends we identify in the archaeological record can be grouped into two categories: environmental and socio-cultural. Changes in the environment may have constrained prehistoric groups to opt for new or improved tools that would meet the new demands of resource acquisition. In this scenario, changes in osseous technology should be correlated with changes in the environment ([Doyon 2019](#)). While new tools could be introduced to satisfy emerging needs, others may remain in the toolkit, albeit with some adjustments to their manufacturing sequence such as the selection of newly available species and skeletal elements.

Among the socio-cultural processes, one must distinguish cultural drift from cultural influence. Cultural drift entails an accumulation of random variation within the parameters essential to meet the tool's functional requirements while perpetuating a cultural tradition over generations ([Binford 1963](#); [Eerkens and Lipo 2005](#); [Koerper and Stickel 1980](#)). Cultural influence is spatially and temporally directional and often affects only parts of a technological system rather than the whole. Given the availability of an adequate spatio-temporal resolution, this process should entail a detectable continuity in tool size and morphology, ideally associated with consistent geographic expansion and a coherent time lag from a particular point of origin; tool typology and technology should not be affected as much by this process, but if so, only marginally ([d'Errico et](#)

[al. 2018](#); [Doyon 2019](#); [Lycett and von Cramon-Taubadel 2015](#); [Schillinger et al. 2014](#)). Another socio-cultural process relates to the division of labor. Increased division of labor may allow for some individuals to gain expertise and develop specialized craftsmanship ([Eerkens 2000](#)). In this context, osseous tool manufacture would ideally follow strict rules of reproduction and the tools' morphometry would show a high degree of standardization; no significant changes would be observed in tool typology.

Finally, changes in material culture can be the result of cultural exaptation or functional diversification. Cultural exaptation refers to the combination of preexisting components of a technological system, either tools or techniques, to solve a new problem or provide a more efficient solution to an already existing one ([d'Errico and Colagè 2018](#)). An example of such a mechanism would be the manufacture of a bone tool that matches the morphometric characteristics of a tool type initially made of stone using techniques adapted to the newly opted raw material. Functional diversification relates to an expansion of the realm of activities for which a tool is used ([d'Errico et al. 2018](#)). In this context, although tool types and their manufacturing processes are expected to remain more or less the same, changes in the tools' morphometry are likely to be introduced to accommodate the newly acquired function. It must be said here that the processes of cultural exaptation and functional diversification are not responsible for the cultural changes *per se* and both these mechanisms can be associated with any of the environmental and socio-cultural processes listed above. In the present study, we document the typological, technological, and morphometric variability of the bone tool assemblage from Yinjiacheng and attempt to interpret the changes in material culture observed at the site between the Late Neolithic and Early Bronze Age.

ARCHAEOLOGICAL CONTEXT

The Yinjiacheng site (35°37'N, 117°11'W) is located on an irregularly shaped terrace about 100 m southwest of Yinjiacheng village, Jinzhuang Township, Sishui County, Jining City, Shandong Province (Fig. 1). The site was discovered in 1962 by the Shandong Team of the Institute of Archaeology, Chinese Academy of Sciences (Luan 2017c). The total original area of the site is estimated to be roughly 160,000 m² and test pits suggest that archaeological structures and remains extend over 4000 m². Six excavation campaigns (in 1973, 1979, 1981, 1985, 1986, and 2000) were organized in the context of an undergraduate field school by the Department of Archaeology, Shandong University, under the successive supervision of Cai Fengshu, Yu Haiguang, and Luan Fengshi.

<FIGURE 1 TO BE INSERTED APPROXIMATELY HERE>

During this project, 2720 m² were excavated at an average depth of 2.8 m, reaching 4 m in some areas (Shandong 1990). The excavation revealed evidence of the occupation of the site over more than four millennia, from the Neolithic (i.e., Dawenkou and Longshan) and Bronze Age (i.e., Yueshi) to the dynastic (i.e., Shang, Zhou, Han, Tang, Song, Yuan) periods. Occupation layers attributed to the Longshan and Yueshi periods provided the bulk of the archaeological and architectural remains at the site. Key findings from the Longshan occupation include 65 burials (60% of which yielded artifacts), 20 houses, 246 pits, 1354 complete or almost complete pottery units, 238 stone tools, 188 modified osseous remains and tools, 106 worked shells, and 3 jade items. In contrast, no burials were found in Yueshi occupation layers, but they yielded 11 building foundations, 195 pits, 352 complete or almost complete pottery units, 601 stone tools, 226 bone tools and by-products, 205 worked shells, 1 jade item, and 14 bronze items.

A stratigraphic gap exists between the last Longshan and first Yueshi layers, which suggests a hiatus between the occupations of the site by the carriers of each cultural entity. Longshan material culture was found in a brown, compact, topsoil with scattered rubefaction spots. Soil formation attributed to the Yueshi period is coarser, with large particles and a loose structure; the gray sediment color is often tainted with green rust spots. Dating attempts on charcoal and charred bones ([Luan and Wagner 2009](#)) and calibration with the IntCal20 curve ([Reimer et al. 2020](#)) in the OxCal v.4.4.4 online software ([Bronk Ramsey 2017](#)) yielded results ranging between 5104 ± 136 to 4388 ± 173 cal. B.P. for the Longshan occupations and between 4273 ± 104 to 3523 ± 68 cal. B.P. for the Yueshi occupations. These ages suggest that the hiatus between the Longshan and Yueshi occupations lasted roughly 100 years. Taken together, the stratigraphic and radiometric data from Yinjiacheng challenge, at least at the local level, the idea that the two cultural entities overlapped chronologically ([Long et al. 2017](#)).

MATERIALS AND METHODS

The material analyzed in the present study is curated at the Shandong University Museum, Jinan, Shandong Province. No permits were required to perform the analysis, which complied with all relevant regulations. The sample considered includes tools and manufacturing by-products excavated from Longshan ($n = 76$) and Yueshi ($n = 124$) contexts. At the time the project was undertaken, 51 of the Longshan bone tools from the Yinjiacheng assemblage were lent to the Institute of Cultural Heritage Museum at Shandong University in Qingdao for its inaugural exhibition in Fall 2020. They consisted of complete objects fit for exhibiting, including projectile points ($n = 19$), awls ($n = 9$), knives or daggers ($n = 6$), hairpins ($n = 6$), needles ($n = 6$), barbed points ($n = 3$), a tube ($n = 1$), and a pendant ($n = 1$). Visual inspection of these items suggests

that their inclusion in our study would not have substantially modified our results and ensuing interpretations. In what follows, they are considered when addressing aspects related to typological diversity, but are left out of the technological and morphometric analyses.

Every item included in the Yinjiacheng osseous tool assemblage was recovered from the context of a pit or residential area; none were found in burial contexts. Anthropogenic surface modifications were distinguished from natural ones following criteria published in the literature ([Behrensmeyer 1978](#); [Behrensmeyer et al. 1986](#); [Fernández-Jalvo and Andrews 2016](#); [Fisher 1995](#); [Lyman 1994](#); [Noe-Nygaard 1987, 1989](#); [Shipman and Rose 1983](#)). The typological assessment of the bone tool assemblage is based on comparison with similar industries from Europe, Caucasus, Levant, North Africa, and North America ([Arai 2020](#); [Camps-Fabrer 1966, 1979, 1982, 1985](#); [David 2007](#); [Garfinkel and Kolska Horwitz 1988](#); [Gates St-Pierre 2007](#); [Grechkina et al. 2020](#); [Moundrea-Agrafioti 2011](#); [Rollefson et al. 1992](#); [Taha et al. 2017](#)). As is the case for most excavations that occurred prior to the 2000s in the region, bone tools were isolated from the rest of the faunal assemblage at the time of recovery. Unfortunately, we could not locate this assemblage for the study, which prevents us from describing the early stages of the manufacturing sequence. This paucity of data on the early stages of manufacture makes it difficult to fully assess if specific species or skeletal elements were targeted for producing the various bone tool types or distinguish whether some, and if so which, tools were introduced as finished products at the site rather than manufactured *in situ*. Therefore, the technological analysis was performed in three steps. First, whenever possible, the species and skeletal elements used to manufacture tools were recorded. Second, the surfaces of tools and manufacturing by-products were closely examined with the help of a magnifying glass and a Leica DVM6 multifocus microscope at magnifications ranging from 10× to 50×. Traces of manufacture were

identified based on similarities with archaeological and experimental specimens ([Averbouh et al. 1999](#); [Averbouh and Provenzano 1998](#); [Buc 2011](#); [David 2004](#); [d'Errico et al. 2018](#); [LeMoine 1994](#); [Li et al. 2020](#); [Provenzano 1999, 2004](#); [Sidéra and Legrand 2006](#); [Zhang et al. 2016, 2018](#)). Third, the traces of manufacture were organized chronologically based on overlapping occurrences in order to establish as precisely as possible the reduction sequence for each specimen.

Morphometric standardization was explored by calculating the coefficient of variation (CV) for selected tool types ([Eerkens 2000](#); [Eerkens and Bettinger 2001](#)). This coefficient, obtained by dividing the standard deviation by the mean value for a given dimension, facilitates the comparison of sub-samples with distinct sample-size. The lower the CV value is for a given tool type, the more standardized it is. Morphometric data was recorded with a digital caliper and included the maximum length, width, thickness, and cortical thickness of each tool. Each specimen was photographed with a Canon EOS 5DS. Photographs were assembled into plates in Adobe Photoshop Creative Cloud 2021. Quantitative analyses and data representation were conducted in R-CRAN ([R Development 2008](#)). The data collected and analyzed in the present study is available online (see [Yin et al. 2022](#) for link to database).

RESULTS

Analysis of the Longshan and Yueshi bone tool assemblages from Yinjiacheng reveals evidence of both cultural change and continuity in osseous technologies at the site. We contrast the two cultural entities along three dimensions: typological diversity, technological variability (i.e., raw material selection and reduction sequence), and morphometric standardization.

Typological Diversity

The Longshan osseous tool assemblage mainly comprises objects used in domestic and hunting activities (Table 1). It includes awls (24%) (Fig. 2), hairpins (18%) (Fig. 3), needles (11%) (Fig. 3), and hunting implements (16% counting only finished objects; 33% including preforms) (Fig. 4, Fig. 5). Both awls and projectile points can be further divided into sub-types. Almost a third of the awls were made from truncated bone shafts (Fig. 2a,b,d); the others are expediently pointed faunal remains. Likewise, we can distinguish three sub-types of projectile implements: simple-based, tanged, and barbed points. More than a third of the objects are either complete or almost complete. Broken pieces are mainly mesial fragments with either the proximal end, distal end, or both ends missing. Except for the fact that they consist exclusively of complete or almost complete tools, most of the objects displayed at the Institute of Cultural Heritage Museum at Shandong University, Qingdao, do not stand out from those we were able to study. However, three tool types displayed at the museum are absent from the studied assemblage: knife/dagger ($n = 6$), tube ($n = 1$), and ornament ($n = 1$).

<TABLE 1 TO BE INSERTED APPROXIMATELY HERE>

<FIGURE 2 TO BE INSERTED APPROXIMATELY HERE>

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The Yueshi osseous tool assemblage is also dominated by tool types used in domestic and hunting activities (Table 1). It includes a majority of awls (27%) (Fig. 2), needles (13%) (Fig. 3),

hairpins (10%) (Fig. 4), and hunting implements (16% finished objects, 30% including preforms) (Fig. 4, Fig. 5). Both awls and projectile points can be further divided into sub-types. Aside from the expediently pointed objects, awls are either bipointed or made on truncated bone shafts. Projectile implements fall into either the bipoint, tanged point, lanceolate, or barbed point sub-types. Other tool types include an ornament, fish hook, and scraper (𠂇), an instrument interpreted as used in food processing activities (Fig. 6). More than half of the objects are either complete or almost complete. Mesial fragments missing the proximal, distal, or both ends are well-represented.

Both the Longshan and Yueshi assemblages include a fair percentage of baguette and rod mesial fragments. Baguette fragments are sub-rectangular in cross-section while rods are sub-circular. Interestingly, the morphometric variability of rod mesial fragments falls within the range of variation documented for needles and hairpins in both the Longshan and Yueshi assemblages (see [Yin et al. 2022](#)). However, the lack of proximal and distal ends prevents a definite typological attribution.

From a typological standpoint, the Longshan and Yueshi assemblages from Yinjiacheng are strikingly similar. In both cases, domestic and hunting tools constitute the bulk of the sample and broad typological categories (i.e., awls, needles, hairpins, projectile points) are well-represented. Differences between the two toolkits become apparent, however, when comparing the sub-types for awls and projectile points. For awls, we notice the introduction of a new sub-type in the Yueshi toolkit, that is, the bipointed awl. For projectile implements, although barbed and tanged points are present in both toolkits, we notice the abandonment of simple-based points in the Yueshi hunting toolkit concomitant with the introduction of bipoints and lanceolate implements.

Finally, notwithstanding the small sample size, it is interesting to note that fish hooks and scrapers are only found in Yueshi contexts at Yinjiacheng, while knives and bone tubes are exclusively associated with the Longshan toolkit.

Technological Variability

Raw Material Selection

The inaccessibility of the whole faunal assemblage from Yinjiacheng makes it difficult to document the early stages of the manufacturing sequences for each tool type and sub-type. It is therefore not possible to fully assess the specific species or elements targeted to produce the various bone tool types. However, in spite of the invasive modifications the skeletal remains underwent in the reduction process, we were able to determine the species and/or element for a quarter of the Longshan and Yueshi tools. Since data on raw material identification is generally missing for needles, hairpins, barbed points, baguettes, and rods, we here focus on awls, projectile points, scrapers, and ornaments.

In the Longshan toolkit, bird tarsometatarsi (71.4%), and rabbit tibiae and radii (28.6%) were preferentially selected for the manufacture of awls made on truncated bone shafts. The remaining Longshan awls were mainly made on rib and long bone fragments. Regardless of the sub-types, cervid antler is the single most-used raw material for making projectile points. One simple-based point, however, suggests mammal ribs were at times selected to be transformed into hunting implements. The single ornament displayed at the Institute of Cultural Heritage Museum, Qingdao, was made from a fragment of a rib split along the antero-posterior aspect.

In the Yueshi toolkit, expedient awls are either made on rib or long bone fragments. In a single instance, a dog ulna was transformed into an awl. With regard to awls made on truncated shafts,

the only specimen for which we have data on the species and element was made from a fox ulna. The dimensions of the other Yueshi awls made on truncated shafts are too large to suggest they come from either birds or rabbits. Yueshi projectile points were predominantly made of thick mammal ribs and long bone and in some instances cervid antler. Whenever identifiable, scrapers were always produced from mammal ribs. The two Yueshi ornaments were respectively made from a fragment of a rib split along the antero-posterior aspect (Fig. 6g) and a badger canine (Fig. 6f).

<FIGURE 6 TO BE INSERTED APPROXIMATELY HERE>

Keeping in mind the difficulty of determining the exploited species and elements from complete or almost complete objects alone, we find that, aside from a single dog ulna transformed into a Yueshi awl (Fig. 2j), most of the Longshan and Yueshi osseous tools were made from wild animals remains. In both toolkits, antler is used solely for the manufacture of projectile points and it appears to be the raw material primarily used to make tanged points (Yin et al. 2022). The composition and structure of antler allow for this raw material to withstand compressive forces more efficiently than long bone diaphyseal fragments (Knecht 1991), a factor that may have influenced the choice of raw material by Longshan and Yueshi settlers at Yinjiacheng. Mammal ribs and long bones were transformed into expedient awls in both the Longshan and Yueshi toolkits. Likewise, rib fragments were sometimes transformed into personal ornaments.

Differences in raw material selection between Longshan and Yueshi osseous tools are mainly discernible for the awls made on truncated shafts and projectile points. Contrary to the preceding Longshan, Yueshi human groups did not target bird and rabbit bones to make this awl sub-type. With regard to hunting implements, and although cervid antler is still used to manufacture tanged

points, it appears that Yueshi artisans increasingly relied on mammal ribs and long bones to produce the other points (i.e., bipoints and lanceolate points) contained in their hunting toolkit.

Reduction Sequence

Owing to the fact that most specimens considered in the present study are completely worked osseous tools, many objects only preserve evidence of the final stages of their production; this is particularly the case for hairpins and needles (see [Yin et al. 2022](#)). Here, we describe briefly the manufacture of each type and sub-type.

The manufacture of hairpins and needles most likely started by delimiting the outlines of the tools on a bone shaft using the groove-and-splinter technique ([Clark and Thompson 1953](#); [Goutas and Christensen 2018](#)). After removing a longitudinal blank, the tools were first shaped by grinding against a coarse-grained surface, then a fine-grained one, and lastly scraped to smooth their surface. In contrast with hairpins, the manufacture of needles entailed three extra steps. First, the apex was sharpened to allow its penetration into cloth. Second, the proximal portion was thinned on both the inner and outer surface to form a bevel ([Fig. 3e,f,l,m](#)). Finally, a drill was used to perforate the two thinned surfaces, resulting in a hole with an opposing-funnel cross-section ([Fig. 3e,f,k,l,m](#)). Bifacial perforation is also the technique used to make perforations in Yueshi personal ornaments ([Fig. 6f,g](#)).

The manufacture of awls varies based on their sub-types. Most specimens were likely made on the waste generated during butchery and carcass processing activities. Indeed, some awls still bear clear percussion notches that are usually produced when fracturing the bone to extract marrow ([Fig. 2i,g,n](#)). The sharpening of these awls is relatively straight-forward. Usually, only the active end and surrounding surfaces are modified. The form of the tip is primarily achieved

by grinding it against a coarse- or fine-grained surface or a combination of both. It is then finished by scraping (when the tip sides are convex) or by gouging and then scraping (to produce concave sides). In the latter case, the awl's tip becomes quite narrow and pointy (Fig. 2e,m,n,o). The manufacture of awls from the truncated bone shaft sub-type is slightly more complex. In the cases where the bone shaft was sectioned from the epiphysis (Fig. 2a,d,l), remnants of sawing traces on the proximal end indicate this technique was used to complete the task. In all cases, the active bevel was first delineated by grooving and the two ends of the bone shaft were then snapped apart; accidental damage resulting from this operation is sometimes apparent (Fig. 2k). The fracture plane of the open truncated shaft was subsequently leveled by gouging or grinding, either against a coarse- or fine-grained surface or both, and then regularized by scraping. Finally, the manufacture of Yueshi bipointed awls relied on the combination of grinding against a fine-grained abrasive surface and scraping to smooth the active ends.

The manufacture of Yueshi scrapers is difficult to assess. In most cases, only traces of scraping are visible, with the exception of some occasional traces of grinding and flaking (see [Yin et al. 2022](#)). Technological studies from other contexts can, however, help us outline the manufacturing process ([Bird and Beeck 1980](#); [Provenzano 1999](#); [Roussot 1966](#); [Tartar 2009](#)).

The first step likely involved scraping the anterior and posterior aspects of the rib to produce a flat surface where a groove could be produced more easily. By inserting wedges in this groove, a series of successive blows would have allowed the rib to split in half, providing two longitudinal, flat halves that would later be ground and scraped into their final shapes. Some segments of these half ribs were perforated, probably to be used as personal ornaments by Longshan and Yueshi people (Fig. 6g). It remains unclear whether the primary intention of the rib splitting and shaping process in these instances was deliberately aimed at producing ornaments or if the settlers at

Yinjiacheng recycled broken scrapers that could no longer be reshaped for their intended primary function.

Unlike the aforementioned broad osseous tool categories, the manufacture of projectile points is better understood thanks to the relatively high frequency of preforms from both the Longshan and Yueshi contexts (Fig. 5). It is difficult to establish how blanks were extracted for Longshan and Yueshi bone and antler implements. In some rare instances, traces of sawing at the proximal end suggest this technique was used to cut the blanks and delimit the maximum length of the preform (Yin et al. 2022). The implement was then shaped by a gradual reduction process combining grinding against a coarse- or fine-grained abrasive surface to ensure the longitudinal alignment of the proximal and distal portions of the tool and roughly define the desired cross-section as either cylindrical, triangular, rectangular, or rhombus-like (Fig. 5a,f). At this step in the reduction sequence, the manufacture of tanged points entailed a further stage, namely the shaping of the proximal end. In the case of Longshan and Yueshi tanged points, a deep incision was made on the proximal circumference to delimit the proximal length of the implement (Fig. 5b). Gouging was then used to gradually remove the osseous tissue and shape the proximal end (Fig. 5c,d). Finally, grinding against a coarse-grained abrasive surface helped regularize the surface of the hafted portion of the implement (Fig. 5e). With regard to Yueshi lanceolate points, the reduction process was slightly simpler. First, the proximal end was roughly shaped by grinding (Fig. 5g). Then, gouging was applied on either side to give the proximal part its final shape (Fig. 5h). In most cases, the final step of the reduction sequence entailed the scraping of the distal end to ensure a smooth surface.

Owing to their limited number, it is not possible to reconstruct the manufacturing process of barbed points and fishhooks. They bear, however, traces of grooving, gouging, sawing, scraping,

and grinding, which suggests the Longshan and Yueshi settlers at Yinjiacheng were able to combine the range of techniques at their disposal to produce osseous tools with complex shapes whenever needed.

When considering the variety of techniques used in the manufacture of bone tools, it appears that Longshan and Yueshi settlers at Yinjiacheng shared a common technological know-how.

Grinding, either against a coarse- or fine-grained abrasive surface, was the predominant technique used for modifying osseous materials in both cultural entities, followed by scraping, gouging, grooving, drilling, incising, and sawing. Flaking was observed on a single Yueshi scraper (no. T227 7:33) ([Yin et al. 2022](#)). Traces of this technique on other Longshan or Yueshi items may have been obliterated during the reduction process that led to the final shaping of the tools. In both cultural contexts, these techniques appear to have been solicited in similar ways to produce similar tool types. This is well-illustrated by the manufacture of awls made from truncated shafts and tanged points. Indeed, the reduction sequence of these two sub-types remains unchanged from the Longshan to the Yueshi period. Interestingly, the production of lanceolate points in the Yueshi toolkit clearly follows a simplified version of the reduction sequence implemented to manufacture tanged points.

Morphometric Standardization

Despite the small sample size for some osseous tool types, an interesting pattern emerges when comparing their size standardization at Yinjiacheng ([Table 2](#), [Fig. 7](#)). In the Longshan assemblage, domestic tools (i.e., awls, hairpins, needles) all show CV values ranging 20–30 percent for their maximum length, width, and thickness. Longshan hunting implements, however, yield contrasting CV values depending on sub-type. Whatever the dimension, tanged points are substantially more standardized than simple-based points.

<TABLE 2 TO BE INSERTED APPROXIMATELY HERE>

<FIGURE 7 TO BE INSERTED APPROXIMATELY HERE>

In the Yueshi toolkit, domestic tools show CV values often exceeding 30 percent, reaching up to approximately 64 percent for the maximum length of needles. These CV values are in striking contrast with those obtained for hunting tools, which are often below 20 percent. Interestingly, for each sub-type of points considered, Yueshi artisans appear to have paid less attention to one dimension over the two others when making a projectile point. In the case of bipoints and lanceolate points, the lower CV values for the maximum length and width suggest these dimensions had to fall within a somewhat more constrained range compared to the maximum thickness. In the case of tanged points, maximum width and thickness are more standardized than maximum length.

Although the CV values recorded for maximum width and thickness substantially overlap in Longshan and Yueshi tools, Yueshi domestic items, particularly awls, are generally wider, thicker, and less standardized than their Longshan counterparts. Hunting implements, however, show the opposite trend. The CV values recorded for Yueshi tanged points are substantially lower than those obtained on the Longshan specimens. This trend appears to be maintained for the dimensions of all other hunting implements, regardless of sub-type, excepting perhaps the thickness of Yueshi lanceolate points (Table 2).

DISCUSSION

Our analysis of the Longshan and Yueshi osseous tool assemblage from Yinjiacheng provides a new outlook on cultural change dynamics during the transition from the Late Neolithic to the Bronze Age in Ancient China. Specifically, our study aims to meet three objectives: (1)

document for the first time Neolithic and Bronze Age bone tool assemblages from three complementary perspectives (i.e., typology, technology, morphometry); (2) compare these assemblages to establish aspects of change and continuity in bone tool manufacture in order to assess whether such comparison supports the common “cultural decay” theory for the Yueshi period; and (3) explore how data from osseous technology can help us identify processes and mechanisms responsible for changes in material culture from the Longshan to the Yueshi period. Our contributions to meeting these objectives are presented below.

When dealing with osseous technology, Chinese archaeologists have traditionally assigned the cultural remains to the broad typological categories of domestic tools (e.g., awls, needles, hairpins, scrapers) and prey procurement implements (e.g., projectile points, fish hooks, harpoons). Our study shows that using such a restrictive approach may give the false impression that no obvious differences exist between the Longshan and Yueshi osseous toolkits ([Luan 2017a](#)). Indeed, the bone tool assemblages from both contexts at Yinjiacheng include more or less the same broad typological categories, with the possible exceptions of Longshan knives/daggers and bone tubes and Yueshi scrapers. Clear differences, however, become apparent between the two cultural entities when sub-types are carefully examined. At Yinjiacheng, simple-based points are restricted to Longshan contexts while bipointed awls and bipointed and lanceolate projectile points are exclusively found in Yueshi contexts. However, our comparison of the Longshan and Yueshi osseous tools extends beyond typology to consider technological and morphometric evidence, which together reveal unsuspected complexity in the development of this aspect of material culture.

A number of observations attest to some continuity in the production of osseous cultural items. From a typological perspective, expedient awls and awls made from truncated shafts,

needles, hairpins, and barbed and tanged points are found in both Longshan and Yueshi toolkits. Likewise, perforated rib fragments appear to have been used as personal ornaments during both periods. From a technological perspective, the range of techniques used to modify osseous remains and transform them into tools remains unchanged from the Longshan to the Yueshi period. Although cultural convergence could explain this pattern, the persistence of specific manufacturing processes, in particular the *chaîne opératoire* implemented when preferentially selecting antler and transforming this raw material into tanged points and the reduction sequence employed for manufacturing awls from truncated shafts, suggest strong affinities between the two cultural traditions and maintenance of some technological expertise over generations.

Despite this continuity pattern, a number of subtle changes appear in the Yueshi osseous tool assemblage. From a typological perspective, awls and projectile points are the most impacted by these changes. During the Yueshi period, the abandonment of simple-based points is synchronous with a diversification of the awls and projectile sub-types. However, one hunting implement sub-type, the Yueshi lanceolate point, presents a very high degree of similarity in the range of shapes and sizes with an analogous Longshan period projectile point sub-type made of stone ([Shandong 1990](#)). This particular case appears to be an example of cultural exaptation ([d'Errico and Colagè 2018](#)), whereby some components associated with two aspects of material culture, that is, the morphology of the stone armature and a simplified version of the manufacturing process implemented to produce Longshan and Yueshi antler tanged points, were combined by Yueshi settlers at Yinjiacheng to make a novel osseous implement from mammalian ribs and long bones.

Other discontinuities between the Longshan and Yueshi toolkits are observed from a technological perspective. Regarding awls made from truncated shafts, the Longshan preference

for selecting bird and rabbit skeletal elements to make this sub-type appears to have been replaced by a reliance on the bones of small carnivores (i.e., fox long bones) during the Yueshi period. As for projectile points, the reduction sequence for the innovations (i.e., bipointed and lanceolate projectile points) is simpler than that used to manufacture tanged points. Moreover, the simplification of the reduction sequence seems to coincide with an increase in the relative proportions of bone versus antler selected as the raw material for manufacturing hunting implements. In other contexts, a similar pattern of reduction sequence simplification and raw material diversification has been interpreted as evidence for the implementation of more flexible rules of production in the manufacture of projectile points ([Doyon 2019](#), [2020](#)).

Finally, with regard to morphometric standardization, our analysis reveals a combination of complex trajectories co-occurring from the Longshan to Yueshi periods. Yueshi domestic tools are generally wider, thicker, and less standardized than the Longshan ones. In contrast, hunting implements seem to be more standardized in the Yueshi toolkit than they were during the Longshan period.

Our collective results do not fit the idea that the transition from Longshan to Yueshi should be interpreted as evidence of “cultural decay” between the final Neolithic and earliest Bronze Age cultural entities in the Haidai region. The notion of cultural decline rests on a number of co-occurring changes: (1) ceramic production appears somewhat cruder during the Yueshi period ([Cohen 2001](#); [Underhill 2002](#)); (2) stone tool manufacture seems more expedient and some techniques (e.g., perforation by drilling) are seldom documented ([Luan 2017a](#); [Wang 2007](#)); (3) site density at the regional level shows a marked decline from the Longshan to the Yueshi period ([Peng et al. 2010](#)); and (4) settlement organization and burials suggest a return to a less hierarchical society at the onset of the Bronze Age following the Longshan period ([Liu](#)

[1996; Liu et al. 2004](#)). In contrast, our analysis of the Yinjiacheng bone tool assemblage highlights the fact that cultural change in the Haidai region over the time period in question did not uniformly affect every aspect of material culture. Indeed, rather than indicating significant cultural loss, Yueshi osseous technologies indicate the clear persistence of a technological tradition that was already in place during the Longshan period. Most importantly, despite the loss of some Longshan cultural items, the emergence of the Yueshi toolkit at Yinjiacheng appears to be accompanied with a diversification of some tool categories. Likewise, the trends identified from morphometric analysis suggest that, even within the osseous toolkit, each tool type responded to the dynamics of change in distinct ways. Our identification of this contrasting pattern highlights two important points. First, cultural change may manifest in multiple ways even within a single sphere of material culture, hence the importance of studying cultural phenomena from a number of complementary perspectives. Second, all types of cultural items should be considered before we form generalizations about cultural change dynamics.

One remaining question concerns why the trajectories observed in bone technology differ so strikingly from other aspects of the cultural system, particularly the evidence from ceramics, stone tools, and settlement patterns that support the hypothesis of Yueshi “cultural decay.” We acknowledge that answering this question requires gaining an understanding of the processes and mechanisms responsible for changes in various aspects of material culture and comparing these trajectories to one another. Ideally, this task would require large-scale syntheses bringing together evidence from multiple sites. Nevertheless, the pattern emerging from the study of the assemblages at Yinjiacheng highlights the pertinence of including bone tools in this research project.

As mentioned previously, cultural change can be described along two dimensions: pace and scope. At Yinjiacheng, the resolution of the archaeological record allows us to contrast cultural change between Longshan and Yueshi osseous technology (i.e., at the chrono-cultural level) rather than documenting the pace of change within each context separately. The hiatus between the Longshan and Yueshi occupation layers indicates that the site was abandoned after the Longshan period for almost a century. This observation suggests that the cultural dynamics documented at Yinjiacheng constitute trends that unfolded over a minimum of three to four generations. Although it is entirely possible that some of the changes documented from the Longshan to Yueshi periods may have emerged abruptly, the data on their scope rule out the hypothesis of a major disruption in cultural transmission owing to significant societal upheavals or population replacement ([Rigaud et al. 2018](#); [Roux 2013](#); [van der Waals 1985](#)).

The evidence we gathered on the scope of the changes reveals that a common cultural package was maintained from the Longshan to Yueshi periods, but it was combined with the “loss” of some cultural traits and gradual introduction of innovations during the latter period. On the one hand, continuity between the two cultural entities is apparent from the maintenance of broad typological categories in both toolkits, the range of techniques used to modify osseous remains and, most importantly, the persistence of specific technical know-how for the manufacture of tanged points and awls made from truncated shafts. Gradual change, on the other hand, is visible in the introduction of new awl and projectile point sub-types and the abandonment of others, as well as in the decreased standardization of domestic tools and the increased standardization of prey procurement implements during the Yueshi period.

Our analysis reveals that the changes documented in the Yueshi toolkit were likely introduced as a result of functional diversification and cultural exaptation. Trends suggestive of

functional diversification are observed at Yinjiacheng in the manufacture of Yueshi needles of various caliber. Large-scale comparisons of bone eyed needles from China ([Wang et al. 2020](#)) and other regions in the northern hemisphere ([d'Errico et al. 2018](#)) suggest that the manufacture of needles of various sizes within a given cultural context may be indicative of their use in a broader range of distinct activities. The production of needles of at least two distinct sizes combined with the introduction of a new awl sub-type appear to signal an expansion in the range of tasks for which piercing and sewing tools were used during the Yueshi period. Functional diversification is also apparent in the manufacture of procurement technologies (i.e., composite tools used in hunting or fishing activities). While simple-based points disappear from the Yueshi toolkit, two new sub-types are introduced: bipointed and lanceolate points. These innovations are concomitant with diversification of the raw materials selected for manufacturing projectile points and increased standardization of the Yueshi hunting toolkit; together these appear to signal increasing reliance on specialized technology perhaps related to broadening the faunal spectrum exploited by the settlers at Yinjiacheng. In addition, the production of lanceolate points constitutes evidence of cultural exaptation where Longshan stone hunting implements and a simplified version of the manufacturing sequence for tanged points (which persists during the Yueshi) are combined to produce a novel hunting device.

Establishing the cause of these concomitant changes in the Yueshi toolkit will require further investigation. However, some preliminary inferences can be outlined. As stated previously, the changes in osseous technology at Yinjiacheng do not appear to be linked with a major population replacement event. Also, given our focus on a single site, it is not possible to evaluate the impact of cultural influence from neighboring groups on the emergence of Yueshi innovations. It is entirely plausible that the introduction of the bone scraper (匕) to the Yueshi

toolkit could be due to this process. Cultural drift may explain some of the transformation we document here. It is likely that changes affecting the typology and morphometry of awls and needles could be attributed to this process although we would require more detailed chronological resolution to reach to a definitive conclusion.

While the morphometric standardization of Yueshi hunting implements hints toward expertise and craft specialization, perhaps owing to transformations in the division of labor, the diversification in hunting implement sub-types suggests this process may have had only a limited role to play in the origin of these changes. If, on the contrary, changes in Yueshi osseous hunting technologies were indeed caused by increased expertise and specialized crafts skills, one would have to explain why this pattern is in stark contrast with the one documented for ceramic production. Finally, although it is difficult to establish whether environmental changes had a major impact on the cultural evolution from Longshan to Yueshi because of the inaccessibility of the faunal assemblage, it is possible that shifts in preferred species and elements selected for the manufacture of awls and projectile points may have been encouraged by fluctuations in locally available animal resources. Irrespective of the multiple and converging processes likely responsible for cultural change, Yueshi settlers at Yinjiacheng appear to have adopted more flexible technological behaviors by recombining knowledge already implemented during the Longshan period so they could manufacture innovative technologies that would meet newly arising needs. Future research will need to be undertaken at other localities and at a regional scale to establish whether the patterns in cultural evolution identified at Yinjiacheng are representative of the overall cultural dynamics that took place during the transition from the Neolithic to Bronze Age in the Haidai region.

CONCLUSION

In contrast to ceramics and prestige goods, it has been proposed that there were no obvious differences in osseous technology during the transition from the Late Neolithic to the early Bronze Age in the Haidai region. We argue that this misconception results from the limited resolution offered by typological approaches when dealing with this aspect of material culture. The present study combines typological, technological, and morphometric analyses of the Longshan and Yueshi osseous tool assemblage from Yinjiacheng to provide a more dynamic and complex view on how cultural change may manifest in different ways within a single cultural sphere. We highlight a continuum in technological know-how between the two cultural entities, combined with gradual changes expressed through typological diversification and contrasting trends in morphometric standardization during the Yueshi period. We propose that cultural changes observed from the Longshan to the Yueshi period are best explained by the maintenance of a core cultural system and gradual introduction of innovations through cultural drift, exaptation, and functional diversification rather than as the consequence of a major population replacement or heavy cultural influence from neighboring groups.

ACKNOWLEDGMENTS

We thank Wang Hua for her help in the archaeozoological identification. We are also grateful to the Editor, Francis Allard, and three anonymous reviewers for their comments and suggestions that allowed us to improve an earlier version of this manuscript. This research was funded by the Chinese National Cultural Heritage Administration and the Seventh Five-Year Plan of the Chinese National Education Commission, the China Postdoctoral Science Foundation through the China/Shandong University International Postdoctoral Exchange Program, the School of

History and Culture, Shandong University, the PHC Xu Guangqi program, the “Talent” Program from the Initiative d’Excellence (IdEx), the French government in the framework of the University of Bordeaux’s IdEx “Investments for the Future” program/GPR Human Past and the Initial Support to Exploratory Project (PEPS – Projet Exploratoire Premier Soutien) “DyNeo: Biological and cultural DYNamics in Shandong during the Chinese NEOLithic” funded by the Institut National Écologie et Environnements of the CNRS (Centre National de la Recherche Scientifique).

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Science 93:82–93, doi:10.1016/j.jas.2018.03.003.

Fig. 1. Location of Yinjiacheng (star) and other sites mentioned in the present study: (1) Chengzi;
(2) Chenziya; (3) Dafanzhuang; (4) Dianzi (Beichangshan Island); (5) Luntai; (6) Sanlihe;
(7) Yangjiaquan; (8) Yaowangcheng (map made by LD using QGIS v. 2.14.3-Essen [Free
Software Foundation, Inc., Boston] and free vector and raster from Natural Earth
[naturalearthdata.com]).

Fig. 2. Selection of awls from Longshan (a–h) and Yueshi (i–p) contexts found at Yinjiacheng
(1 cm scale): repository no. (a) 86SYT322 (8)d:21; (b) T257 H280:2; (c) 86SYT243
H764:4; (d) 86SYT322 (8)d:36; (e) T278 H248:6; (f) 86SYT322 H706:17; (g) 86SYT322
H799:42; (h) 86SYT321 (8)b:23; (i) T278 (7)a:11; (j) T288 (7):24; (k) 81SY T301 (7)a:23;

(l) T223 H430:1; (m) 81SYT228 (7)b:64; (n) T278 (7):15; (o) 81SYT228 (7)b:58; (p) T288 (7):28 (see [Yin et al. 2022](#) for details).

Fig. 3. Selection of hairpins (a–d, g–j) and needles (e–f, k–m) from Longshan (a–f) and Yueshi (g–m) contexts found at Yinjiacheng (1 cm scale): repository no. (a) T342 (8)a:7; (b) 81SYT228 (8):72; (c) T202 H444:1; (d) 86SYT332 H774:12; (e) T257 (8)a:25; (f) 81SYT208 (8):16a; (g) 86SYT231H734:2; (h) 81SYT249 (7)a⁺:33; (i) 81SYT239 (7):3; (j) T266 (7):4; (k) 86SYT322 H765:1; (l) T245 (7)c:26; (m) T287 (7):5 (see [Yin et al. 2022](#) for details).

Fig. 4. Selection of projectile points (a–c, e–k), barbed points (d, l), and fish hooks (m) from Longshan (a–d) and Yueshi (e–m) contexts found at Yinjiacheng (1 cm scale): repository no. (a) 86SYT321 (8)a:27; (b) T255 (8)a:18; (c) T265 H512:10; (d) 86SYT221 H755:4; (e) T249 (7)折:31; (f) 86SYT192 H714:18; (g) T255 (7)e:14; (h) T223 (7)c:23; (i) T195 (7)a:4; (j) T212 (7)c:27; (k) T267 (7):14; (l) T257 (7)a:38; (m) T244 H437:24 (see [Yin et al. 2022](#) for details).

Fig. 5. Selection of specimens illustrating different stages of the reduction sequence for the manufacture of Longshan (a–e) and Yueshi (f–i) projectile points found at Yinjiacheng (1 cm scale): repository no. (a) 81SYT269 H31:22; (b) 86SYT322 (8)c:22; (c) T265 H512:10; (d) T266 H574:4; (e) 86SYT321 (8)a:27; (f) T209 H8:6; (g) T228 H17:2; (h) 86SYT192 H714:18; (i) T212 (7)c:27 (see [Yin et al. 2022](#) for details).

Fig. 6. Selection of scrapers (a–e) and ornaments (f–g) from Yueshi contexts found at Yinjiacheng (1 cm scale): repository no. (a) T244 (7):4; (b) T202 (7)a:7; (c) T255 (7)a:8; (d) T244

H437:20; (e) T268 (7); (f) T222 (7)a:8; (g) 81SYT239 (7):17 (see [Yin et al. 2022](#) for details).

Fig. 7. Distribution of values recorded for maximum length (top), width (middle), and thickness (bottom) for selected types found in Longshan (left) and Yueshi (right) contexts at Yinjiacheng. Note: data presented for maximum length was calculated only on complete and almost complete specimens (see [Yin et al. 2022](#) for details).

Table 1. Typological Variability and State of Completeness of Longshan and Yueshi Bone Tool Assemblage From Yinjiacheng

	Longshan						
Tool type	Total ^a	Complete	Almost complete	Proximal	Mesial-Proximal	Mesial	Mesial-Distal
Awl	15 (+7)	9	4				
Awl – truncated shaft	7 (+2)	5					2
Awl – bipointed							
Hairpin	17 (+6)	8		2			4
Needle	8 (+6)	1			1		5
Needle – preform							

Simple-based point	2 (+8)		2				
Simple-based point – preform	6	3	1		1		
Bipoint							
Bipoint – preform							
Tanged point	4 (+6)	2			2		
Tanged point – preform	7 (+5)	3	1		3		
Lanceolate point							
Lanceolate point – preform							
Barbed point	1 (+3)	1					
Fish hook							
Scraper (匕)							
Knife/dagger	(+6)	5	1				
Tube	(+1)		1				
Ornament	(+1)	1					
Unknown – mesial rod	8					8	

Unknown – mesial baguette	1					1	
Total	76 (+51)	38	10	2	7	9	11

^a Numbers in parentheses represent the number of objects that could not be analyzed in the present study because they had been lent to the Institute of Cultural Heritage Museum, Shandong University, Qingdao, Shandong Province. Empty cells correspond to absence of data.

Table 2. Comparison of the Metric Variability and Coefficient of Variation (CV) for Selected Osseous Tool Types Found in Longshan and Yueshi Contexts at Yinjiacheng

Cultural attribution	Tool type	<i>n</i>	Length				
			Average	SD	Min	Max ^a	CV
Longshan	Awl – truncated shaft	7	71.56	22.43	38.10	99.68	31.34%
	Hairpin	18	120.42	30.97	66.70	151.96	25.72%
	Needle	8	67.46	–	–	–	–
	Simple-based point	2	76.94	21.57	61.69	92.19	28.03%
	Tanged point	3	28.11	–	–	–	–
Yueshi	Awl – truncated shaft	4	86.91	40.96	57.94	115.87	47.14%
	Hairpin	13	145.35	38.44	105.02	199.95	26.45%

	Needle	16	50.60	32.28	3.49	94.65	63.80%
	Bipoint	10	70.17	5.63	64.54	78.37	8.03%
	Tanged point	3	63.95	23.21	47.53	80.36	36.30%
	Lanceolate point	7	68.51	11.96	60.05	76.97	17.46%

^a Maximum length data were calculated only on complete or almost complete specimens

(see [Yin et al. 2022](#) for details).