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SHELL-TEMPERED POTTERY: OPPORTUNISM OR/AND TECHNICAL CHOICE? ON THE USE OF A COMMON RESOURCE BY NORTHEAST CHINA HUNTER-GATHERERS

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Abstract

This article investigates the origins, contexts, and extent of use shell-tempered pottery in Neolithic Northeastern China. Using available site inventories, thin-section petrography, spatial mapping, and extensive environmental and subsistence data, this research demonstrates that far from being a uniform phenomenon, shell temper's use varied according to a variety of social and environmental factors. Shell temper's use in environments where shell was abundantly available, and shellfish were an important component of the diet, show that ancient hunter-gatherers were making efficient use of their locally available resources. Thin-sectioning demonstrates unique recipes for manufacturing shell-tempered vessels that also vary through space and time, strongly suggesting local, household-level production of pottery vessels. Especially given the absence of many other common tempering materials in this region, shell-tempered pottery had a particular advantage in terms of functional performance. Multiple types of data are employed to create a multidimensional picture of the use of shell-tempering in Neolithic China, shedding light on the close relationships inherent in human-environmental-technological interactions.

Keywords

Petrography Ceramic technology GIS Settlement archaeology Subsistence Northeast China

1. Introduction

The presence of crushed shells in the pottery from Northeast China is often noted by local specialists and considered a normal, unquestioned regional characteristic. However, it may also be possible to understand the motivation beneath such a choice, whether cultural, stylistic, aesthetic, or functional. This study aims to investigate this motivation by asking several specific questions: why crushed shell was present in the fabric; where this type of pottery emerged; whether this pottery was produced in one center and then exchanged; and if so, what was transmitted—the objects, the techniques, or a tradition.

We will present data on shell-tempered pottery (STP) and the sites where it is found, outside archaeological cultures' strict divisions. We employ a multidisciplinary approach to come to a new understanding of these artifacts, including spatial analysis, petrography, and paleoenvironment (climatic, faunal, and palaeobotanical) data. Such a large data spectrum allows us to interrogate the use of a specific resource and its links with subsistence strategies. We will thereby demonstrate that shell tempering was used mainly in environmental zones

where aquatic resources were available and exploited, revealing a close relationship between humans, environments, and technologies.

1.1 Geographic background of Northeast China

Located at the heart of Northeast Asia, Northeast China is the northernmost region of China, located between Mongolia, Russia, and the Korean Peninsula (Fig. 1). It is bordered by the Da Xing'an Mountains and the Inner Mongolia plateau to the west, the Xiao Xing'an Mountains and the Amur River to the north, and the Changbai Mountains to the southeast, creating a vast plain with rivers flowing into the Bohai Bay. This vast plain is linked to the surrounding regions by many waterways, rivers that act as roads crisscrossing the landscape and sometimes end in topographical conditions so flat that they have nowhere to drain, creating lacustrine and marshy landscapes. The Northeast China Plain is one of the earliest places in the world where pottery emerged, with ceramic production dating to before 10,000 BC, which makes it a particularly interesting area to raise technological questions about pottery production. Its harsh winter climate also makes it a challenging area for ancient populations, who developed original subsistence strategies in order to thrive there.

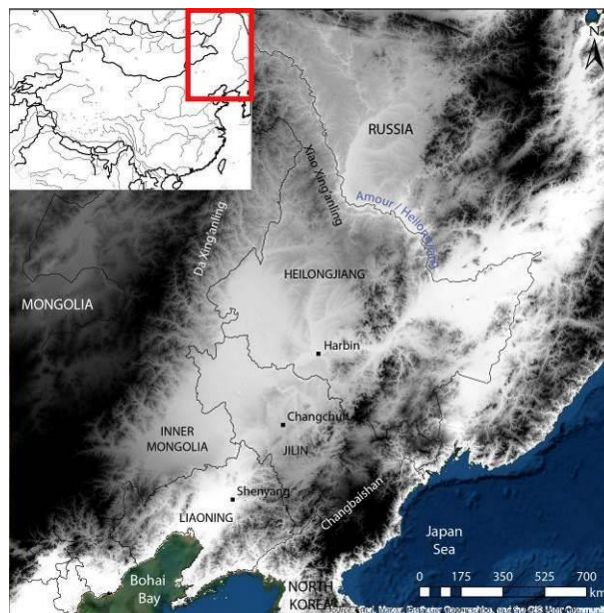


Fig. 1 Topographical map of Northeast China

1.2 History of archaeological research on shell-tempered pottery

STP constitutes a special pottery category in the scientific literature: this name designates a manufacturing technique, and generally refers to a type of ceramic whose spatio-temporal distribution is known and where the paste and more precisely the inclusions are the major criteria for identification (Miksic and Teck 1992; Dung et al. 2011). Much research focuses on production centers and diffusion (Deru and Paicheler 2001; Dumpe et al. 2008; Blackmore and Pearce 2010). In these cases, the pottery is identified with the naked eye, by presence or absence of shell fragments visible in the cross sections. The production technique or the specific nature of the inclusions are rarely detailed (good counter-examples include Rieger and Möller [2012] and Sorresso and Quinn [2020]). Similarly, the functional or socio-cultural significance of the use of shell temper is not always thoroughly explored (but see Gijanto [2011], Spataro et al. [2021], and Vybornov et al. [2021] for such analysis). Previous research has thus established the essential criteria to recognize STP and their properties, but mainly constitutes case-studies about specific sites or cultures and does not offer a methodology suited to studying large ensembles of sites over a vast region.

United States are an exception: in addition to studies on the emergence and spread of shell temper in pottery (Feathers 2006; Herbert 2008), many papers and experimental studies show how and why crushed shells were used as a temper (Stimmel et al 1982; Steponaitis 1984; Skibo 2013). These ceramics have been extensively analyzed on multiple aspects (chronological, technical, functional, socio-cultural, etc.), and this research provides an essential methodological framework in order to understand, by comparison, STP from Northeast China.

Studies on shell temper pottery in China are of the former, typochronological variety. A few articles, often parts of excavation reports, mention this specific tempering material (Zuo et al. 1997; Nanjing and Yixing 2009; Li 2021; Beijing et al. 2022), but none are specifically dedicated to exploring this choice of temper or the properties of such ceramics. The STP discovered at Neolithic sites in Northeast China, therefore, have previously only been studied for relative dating purposes (e.g. Zhao and Yu 2016), and only complete (refitted) specimens have been published. The morphological traits used in typological analysis in Chinese archaeology are never considered in a technical analysis. Therefore, although in Chinese reports, the type of temper in pottery is systematically noted in the reports, this article is the first to gather this scattered information for a comprehensive analysis.

Petrographic analyses in Northeast China especially remain rare (Nishida 1987; Duan 2013; Liu et al. 2017; Duan et al. 2018; Li 2020). The previous research all relates to datasets from a single site, using a very small sample of thin-sections, and are limited to the production technique and/or the provenance of the objects on a very local scale. By contrast, the present article focuses on the use of crushed shell in ceramic production across a large region and over a very long period. Here, we use petrographic analysis to arrive at a better understanding of shell temper's significance for subsistence and lifestyle.

1.3 Research questions

This paper aims to go beyond what typochronological analysis has already accomplished, that is, using a morphological and chronological approach to develop a robust cultural sequence for the different subregions of Northeast China. We integrate bibliographical, petrographic, spatial, environmental, and subsistence data to look at shell as a resource that was present both in the landscape and in the lifeways of the human groups who produced STP, and to understand the significance of this choice of material.

Here, we primarily employ spatial analysis and petrography to clarify the following questions:

- 1) emergence and distribution of shell temper pottery (When and where does shell temper appear on Northeast China? Is the fabric homogeneous in the whole region during one period, or continuously homogeneous over several periods? Were the shell-tempered objects common or rare?); and
- 2) origin and ecological significance of shells used as temper (Where do the shells come from? Were the shells widely available or scarce? Were they used in other practices? What role did this resource play aside pottery making?).

2. Materials and methods

2.1 Research Methods

2.1.1 Materials

This research is based on previously published examples of STP found at Neolithic, Bronze Age, and Iron Age sites in Northeast China, as well as a large sample of directly observed artifacts, sherds, and thin-sections.

Chinese archaeology generates a bibliographical ocean of book reports and preliminary reports (*jianbao*) on excavated sites, articles on basic surveys, systematic regional surveys

(Sebillaud et al. 2021), local cultural gazetteers, and provincial atlases reporting the National Inventory (Guojia 1993, 2003, 2009, 2015), with varying degrees of detail. Most of the information about sites in this study comes from the National Inventory data, but the dataset also contains about 20 each of excavated sites with detailed published information, sites recently discovered through the Yueliang regional systematic survey, and sites described in non-systematic survey reports (Table 1, Fig. 2).

Table 1 STP sites bibliographical sources

Bibliographical data type	Excavated sites (excavation reports)	Yueliang systematic regional survey	Non-systematic surveys	National inventory surveys	Total
Number of sites	19	21	21	132	193

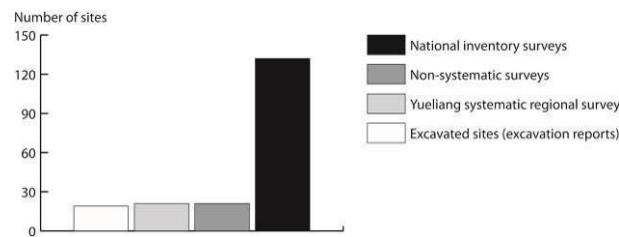


Fig. 2 Bibliographical provenance of the data pertaining to the STP sites

This published material contains reports of pottery sherds containing shell temper, which were identified with the naked eye by local archaeologists, who are used to recognizing such unusual material in the fabric of ceramics (the material most commonly expected being sand). These sherds contain obvious chunks of crushed shells in large quantities in their paste, resembling no other tempering material available in this region. Information about tempering material is systematically reported in the publications. These identification results can be trusted and represent a minimum: only the sherds containing quite a large quantity of crushed shell have been noticed, so pottery containing very small quantities or very finely ground shell might have not been recorded, but none of the obvious examples have been missed. The methodology, identification criteria, and quality of the national inventory data is homogeneous in the four provinces of Northeast China. In addition, the authors personally examined sherds from most of the excavated sites and all the Yueliang survey sites with the naked eye, and confirmed the presence of shell fragments.

Thus, 193 sites have been identified as containing STP. These are often multi-layered settlements, as most of the Neolithic sites' locations were inhabited during the multiple phases of the Bronze Age, Iron Ages, and Medieval period (Sebillaud et al. 2021). The present article only refers to phases of occupation for which STP sherds have been reported, all of which belong to the Neolithic, Bronze Age, or Iron Age periods. The pottery discovered at these sites are mostly cooking jars, with some storage jars and serving cups.

In Chinese archaeology, chronology is mainly based on typological analysis. Radiocarbon dates – when available - are published at the end of site reports and in a special article in the archaeological journal *Kaogu* once a year. Until recently, radiocarbon dating was inconsistently used, with calibrated dates reported alongside uncalibrated ones. More often than not, only one date is available for an excavated site, and the sites which have only been surveyed do not have C14 dates.

2.1.2 Methods

2.1.2.1 Bibliographical data: Shell-tempered pottery in the published materials

Once all the sites where STP was found were identified, information regarding the site locations (coordinates) and excavated materials such as pottery, lithic tools, fauna, botanical data, etc., were gathered into a database (using FileMaker Pro 12). These data, along with sedimentology, lithology, and hydrographic information were mapped using ArcGIS.

Information related to paleoenvironment and subsistence, such as paleoclimate, pollen, carpology, and faunal data were gathered from published materials, mostly site excavation reports. These data are highly local by nature and cannot be easily generalized, so their interpretation should not be extended to large regions (Jaffe et al. 2020; Berger et al. 2021). That is why they will be presented in their site context below.

Because the available C14 dates were sometimes not calibrated or, more often, calibrated using different and outdated curves, the radiocarbon dates related to STP sites gathered in the bibliographical materials for which the original uncalibrated C14 BP data was available have been systematically recalibrated here, using the IntCal20 calibration curve (95.4% probability) and online program OxCal v4.4.4 (Bronk Ramsey 2009; Reimer et al. 2020) (Supplementary Materials Table 1).

2.1.2.2 Direct observation: complete artifacts, sherds, and thin-section samples

In addition to the previously published data, one complete set of sherds has been studied for technical analysis (Duval et al. in prep.), and 86 sherds from five sites have been selected to manufacture 30 μm thin-sections to be examined under a petrographic microscope (x4 to x40, with polarizing light), to carry out a compositional analysis, that is, to characterize the nature of the raw materials and how they were processed (Table 2, Supplementary Information Table 3).

In ceramology, “temper” refers to all the non-plastic materials deliberately added to the clay (Rye 1976). Though they are difficult to determine with certainty, the criteria used to describe temper are the amount of the non-plastic inclusions, the coherence between matrix and non-plastic inclusions, and the grain size distribution of the non-plastic inclusions (Eramo 2020).

During the petrographic compositional analysis, the sherds’ thin-sections have been classified by petrofabrics, according to the nature of the matrix and its degree of porosity, the composition, the shape, the orientation of the main inclusions, and their quantity. Their abundance has been estimated using an abundance comparison chart and described according to frequency labels: predominant (>70%), dominant (70-50%), frequent (50-30%), common (30-15%), few (15-5%), rare (<5%), and absent (0%) (Quinn 2022: 98-113) (Supplementary Materials Table 3).

Distributed broadly in time and space, the chosen sample has a good representativeness (Fig. 3). The chosen sherds all come from artifacts with clear typo-chronological information, most of them from the same type of cylindrical jar (called *tongxingguan* in Chinese archaeological literature). These sites have all been excavated and have clear stratigraphic and chronological data (Supplementary Materials Table 1), belong to different parts of the region where STP was found, and yielded remains belonging to different periods covering over eight millennia.

Table 2 Thin-section STP samples

Site	Abbreviation	Num. thin-sections
Houtaomuga	DH	22
Changtuozi	TC	6
Shuangta	TS	7
Wutaishan	NW	23

Honghe	QH	31
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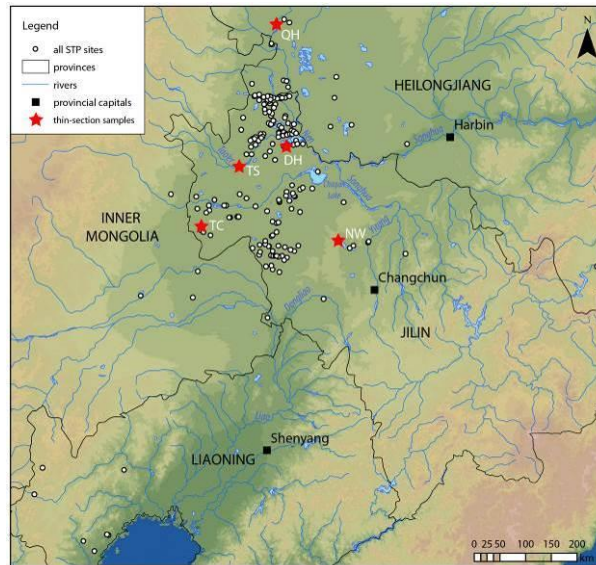


Fig. 3 Map of the STP sites and distribution of thin-section samples

2.2 Analysis of materials

2.2.1 Where and when?

2.2.1.1 Where?

STP has mainly been discovered at sites located in the northwestern part of Jilin Province (Table 3). To put these numbers into perspective, about 5000 archaeological sites of all periods have been inventoried in Jilin Province alone, 242 of them containing Neolithic remains, and only 167 sites of all periods contained STP.

Table 3 STP sites by provinces

Province	Jilin	Heilongjiang	Liaoning	Inner Mongolia
Number of sites	167	16	7	4

These sites mostly date to the Neolithic, but not exclusively, and have been dated with different degrees of precision, depending on the type of documentation available. STP has also been identified in levels dating from the Bronze Age and the Iron Age, though from fewer sites (Table 4, Fig. 4).

Table 4 STP sites by periods across all four provinces examined

Period	Neolithic (without precision)	Early Neolithic 11 000-7000 BC	Middle Neolithic 7000-3500 BC	Late Neolithic 3500-2000 BC	Bronze Age 2000-500 BC	Iron Age 500 BC-0	Total
Number of sites	55	9	56	17	48	8	193
	137				56		

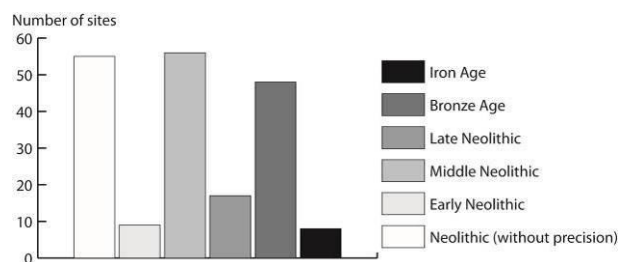


Fig. 4 Temporal distribution of sites containing STP

2.2.1.2 When?

A total of 125 radiocarbon dates are available for only 20 of the sites mentioned in this research (Supplementary Materials Table 1). They are not evenly distributed in time, as half of the dates (58) belong to the 6 phases of the Houtaomuga site, and the remaining 19 sites each have between one and 13 dated samples. The Bronze Age and Iron Age remains are less often subjected to C14 dating than Neolithic sites: for example, at Houtaomuga, 53 dates belong to the early and middle Neolithic phases and only 5 samples have been dated for the late Neolithic, Bronze Age, and Iron Age. Nevertheless, the new calibration of all the available dates provides a robust chronological frame for our diachronic analysis.

According to these data, all the earliest sites yielding STP are located in the Lower Nen River Valley. The Houtaomuga phase I remains, after which the archaeological culture of Houtaomuga phase I is named, can be dated to between 10,900 and 9100 BC (Supplementary Materials Graph 1). The dates of the samples belonging to the first occupation phase of the Shuangta site, eponym of the culture of Shuangta phase I, can be dated to between 9200 and 6000 BC, but they are in fact divided into two groups: 2 samples around 8900-8600 BC and 5 samples around 6600-6000 BC. So, they should be divided into two distinct cultural phases, even though previous publications, including thermoluminescence dates (Supplementary Materials Table 2), lean toward dating the entire culture of Shuangta phase I “earlier than 8000 BC” (Jilin and Jilin 2013). The Changtuosi site has not been excavated, but the pottery from surface collection is attributed through typo-chronological analysis to 9100-8200 BC (Wang L. 2018). All these remains, which date to before 6000 BC, are grouped into an “Early Neolithic” period for the sake of our analysis.

In the Lower Nen River Valley, the samples from phase II of the Houtaomuga site, belonging to the Huangjiaweizi culture fall between 6000 and 5300 BC (Supplementary Materials Graph 2). The occupation of the Huangjiaweizi site is traditionally dated to between 6000 and 5000 BC (Jilin 1988). The Tengjiagang site has been attributed to the Houtaomuga phase III culture by typological comparison of pottery (Wang L. 2018), but two radiocarbon samples from this site date to between 6400 and 5800 BC, bringing the earlier phase its occupation closer to the chronological frame of the Huangjiaweizi culture, and one date from a later tomb (around 3500 BC) shows the presence of a second level of occupation. The Elasu C site, with three dates around 5500 BC, is also considered to belong to the Huangjiaweizi culture (Wang L. 2018). The samples from Houtaomuga phase III, also eponymous with an archaeological culture, all date from 4300-3500 BC, and the samples from the Dongmingha site (3800-3500 BC), attributed to the Houtaomuga phase III culture, date from the last three centuries of this culture. In the Yitong River Valley and the Ke'erqin Basin, the Zuojiashan phase I remains are dated to around 5000-4800 BC, the Yaojingzi site remains are typologically dated to around 5000-4500 BC, and the Yuanbaogou C14 sample is dated to ca. 4300-4100 BC. These are all attributed to the culture of the Lower Level of Zuojiashan (ca. 5500-4000 BC) (Jilin 1989; Jilin et al. 2018), as is the Wutaishan site, for which the dates (4300-3800 BC) point to a late or slightly posterior phase of this culture. In the Liaoxi region, the Xinglongwa site samples are dated to between 6000 and 4400 BC, divided into two groups: 8 samples from between 6000 and 5500 BC, fitting well into the eponymous archaeological culture's chronological frame of 6200-5000 BC (Du and Han 2019). Three later samples from between 4700 and 4400 BC represent a later phase of occupation of this site. The Baiyinchanghan site, with dates between 5900 and 5000 BC, is also attributed to the Xinglongwa culture. The samples from the Zhaobaogou site are dated to between 5100 and 4800 BC, consistent with the culture of the same name, which is typically dated to between

5000-4500 BC (Du 2014). These sites are considered here as belonging to a “Middle Neolithic” period.

In the Xiliao region, the Haminmangha site is also a type site, with samples dated to between 3400 and 3100 BC, and the archaeological culture typically dated to 3500-3000 BC (Zheng et al. 2014) (Supplementary Materials Graph 3). In the Nen River Valley, the samples of phase IV of the Houtaomuga site are dated to around 3000 BC; this phase is more broadly dated as spanning 3500 to 3000 BC by other authors (Wang et al. 2017), and these remains are attributed to the Haminmangha culture. The samples from the Honghe site are dated ca. 2400 BC, and this site is attributed to the Angangxi culture (2500-2000 BC). The Xiaolaha I-B phase sample is dated to around 2100 BC and attributed to the Angangxi culture. In the Yitong River Valley, the sample from the third phase of the Zuojiashan site is dated ca. 3000-2800 BC, and these remains are attributed to the culture of the Upper Level of Zuojiashan (4000-2500 BC) (Jilin et al. 2018). In the Liao River Valley, the Xinle site (5500-4700 BC) and the Longshanlu site (5100-4900 BC) belong to the culture of the Lower Level of Xinle (5500-4500 BC) (Shengyang and Xinle 2018). These sites are traditionally considered as belonging to a “Late Neolithic” period.

The sample from the fifth phase of Houtaomuga is dated to around 600 BC, and these remains are attributed to the Bronze Age culture of Baijinbao (1000-500 BC) (Wang et al. 2017). The two samples from the sixth phase of Houtaomuga are dated to around 380 BC, and are attributed to the Iron Age culture of Hanshu phase II (500-0 BC) (Wang et al. 2017), as are the samples from the third phase of the Xiaolaha site, with a sample dated to 150 BC.

2.2.1.3 Temper or not temper?

All these archaeological cultures have been defined through typological analysis on complete objects. In publications, alongside shell fragments, other tempering materials are mentioned, such as vegetable fibers for the sites attributed to the Houtaomuga I culture (Wang and Sebillaud 2019) and sand, which is described as tempering material in over half of the sites and present in various proportions (Supplementary Materials Table 4).

Overall, petrographic analysis shows that most of the thin-section samples present very elongated, angular shaped and poorly sorted inclusions, which are brown under polarized light, and mostly orientated parallel to the rim of the artifacts, with an average size of less than 1 mm, and only very rare inclusions measuring over 2 mm. Some retain their layered structures, but also developed long transverse fractures, which are characteristic of freshwater mussels (Sorresso and Quinn 2020).

Twenty-six of the 86 samples contain a high abundance of shell inclusions (predominant or dominant); 22 had less (frequent to common); 17 had rare shell inclusions; and 21 had none (Supplementary Information Table 3).

When the shell inclusions are predominant to common, the large volume of inclusions means that they most probably had an impact on the physical properties of the fabric (Eramo 2020). Their addition was therefore almost certainly deliberate. The very angular, long, rod-like shape of the inclusions indicates a stage of preparation where the mussels were possibly burned in order to make them more brittle, and then crushed before being then added to the clay, as these are not features of naturally present inclusions (Feathers 1989). Moreover, the shell fragments observed here are not completely decomposed, so the firing temperature of STP samples must have been lower than 850C° (Maritan et al. 2007). In the samples with rare shell inclusions, they might have been an involuntary addition or were naturally present in the clay.

Petrographic analysis reveals the existence of 19 distinct petrofabrics in our sample (three to five per site), 11 of which show clear evidence of crushed shell used as temper.

2.2.2 Diachronic analysis

2.2.2.1 Early Neolithic 11,000-7000 BC

2.2.2.1.1 Spatial distribution of the STP sites

There are only nine STP sites from the Early Neolithic. They are located in the Lower Nen River Valley, concentrated around the lacustrine and marshy region where the Tao'er River flows into the Nen River, an area with vast available space and resources (Fig. 5).

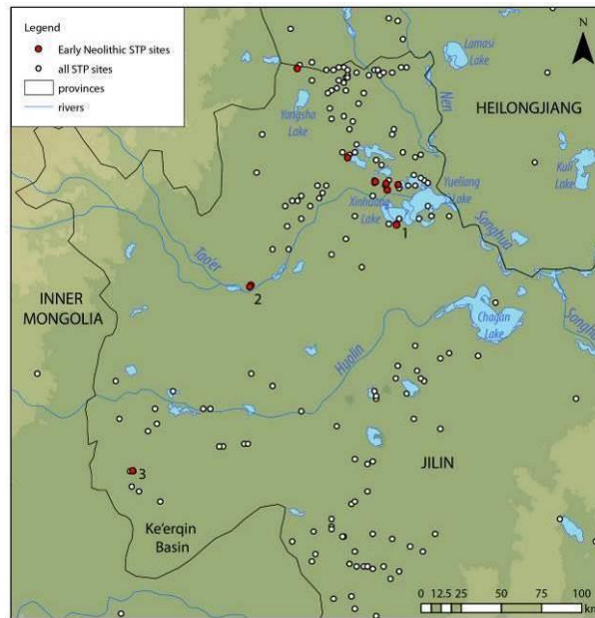


Fig. 5 Spatial distribution of the Early Neolithic STP sites

1. Houtaomuga, 2. Shuangta, 3. Changtuozi

2.2.2.1.2 Environmental conditions and subsistence

Some paleoenvironmental data are available from excavated sites of this time period.

At the Houtaomuga site, during phase I (10,900-9100 BC), pollen assemblages show a large number of fungi, which are characteristic of a Tertiary vegetation. During this period, their proportion gradually decreases, while that of herbaceous plants increases (Tang et al. 2017a). By then, the *Pteridophyte* family (ferns and lichens) constitute the majority of the plants, while trees are almost absent. The landscape is composed of meadows and steppes with a cold and relatively humid climate. *Polygonaceae* pollens indicate the presence of wetlands near the site. Faunal remains are composed of freshwater shells present in large deposits and as funerary offerings, and also of fish, shrimp, birds, and their eggs, which were relatively easy to acquire. Rare mammal bones belong to small game, such as hares, dogs (the only domestic animal), and badgers (Zhang 2015). However, the remains of aquatic animals are much more numerous than those of mammals, indicating that the food supply mainly relied on aquatic resources provided by the immediate environment. In addition, paleopathological analysis reveals severe dentition wear, which can be linked to the consumption of shellfish containing too much sand (Xiao 2014: 9-21). These very early strata also yielded 25 harpoons.

At the Shuangta site, during phase I (9200-6000 BC), the climate was relatively dry and cold, with vegetation cover corresponding to a meadow-dominated landscape (Tang et al. 2017b). Animal remains are mainly shells, especially large freshwater mussels (*Unio douglasiae*), which are present in virtually all the features, elongated freshwater mussels (*Lanceolaria gladiola*), and big cockscomb pearl mussels (*Cristaria plicata*), as well as fish and small mammals (hare and pheasants). The site yielded many fishing tools. No domestic

animals, except for dogs, and no lithic tools associated with agriculture were found (Zhang 2011).

The abundance of microlithic tools and the relative rarity and uniformity in shape and facture of this early pottery points to a mobile foraging lifeway (Bar-Yosef and Belfer-Cohen 1989). All these elements suggest a seasonal occupation of the sites by nomadic or semi-nomadic groups (Sebillaud et al. 2021) mainly relying on shell collection, fishing, and small game hunting.

2.2.2.1.3 Petrographic analysis

The Houtaomuga phase I pottery is the earliest in Northern China (Wang and Sebillaud 2019). The vessels are large in size and thick-walled (0.8 to 1.5 cm), with impressed decoration, made out of a fabric tempered with freshwater reed fibers and fashioned into large coils (Fig. 6-a).

Only one petrofabric has been identified in the Houtaomuga phase I samples (Supplementary Materials Table 3). It is characterized by the presence of a very abundant multifoil porosity (approx. 0.6 mm), which is the imprints left by the vegetable fibers used as temper. The non-plastic inclusions are small (less than 0.2 mm), except for a few shell inclusions which naturally occurred in the raw material (Fig. 6-b).



Fig. 6 Houtaomuga phase I: a. pottery sherds; b. thin-section, sample num. DH01 x2, PPL (plane-polarized light). (Sh: Shell).

At Shuangta, two types of petrofabric coexist: thick- and thin-walled ceramics (Fig. 7-a and b).

Thick pottery sherds have a very abundant porosity, like that of the Houtaomuga phase I fabric, but the voids are ovoid and measure on average 0.1 mm (Fig. 7-c). They are also imprints of organic fibers (reeds). There are few, if any, shell inclusions in these samples.

The second petrofabric is characterized by a predominance of shell inclusions and few non-plastic inclusions greater than 0.2 mm, meaning crushed shells were added (Fig. 7-d).

However, sample TS05, a thin-walled pottery sample, presents both a high concentration of crushed shells and the specific ovoid porosity similar to that of the first petrofabric, but in a larger size (0.2 mm on average) (Fig. 7-e).

These two types of ceramic could correspond to two functions such as cooking and serving, two groups of potters, a difference between local and exogenous productions, or two social levels of consumers. Alternatively, they could have been produced during the two chronological sub-phases brought to light by the analysis of the Shuangta phase I C14 dates, in which case, sample TS05 could represent a transitional phase.

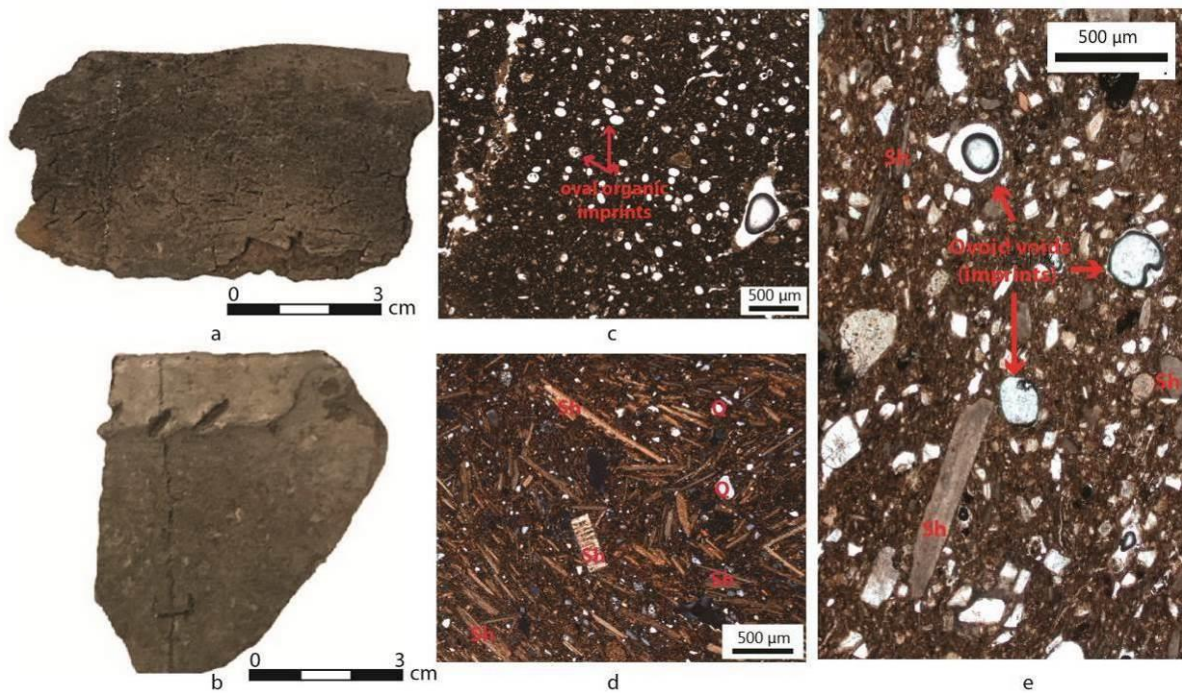


Fig. 7 Shuangta phase I: a. thick-walled pottery sherd, sample TS01; b. thin-walled pottery sherd, sample TS08; c. thick-walled pottery thin-section, sample num. TS02 x4 PPL; d. thin-walled pottery thin-section, sample num. TS09, x4 XP (crossed polarized light); e. organics and shells inclusions, sample num. TS05, x4 PPL. (Sh: Shell, Q: Quartz)

2.2.2.2 Middle Neolithic 7000-3500 BC

2.2.2.2.1 Spatial distribution of the STP sites

During the Middle Neolithic, STP is found at many more sites (56), most of them still concentrated in the northwestern portion of Jilin Province, along the Nen and the Tao'er Rivers. These artifacts also newly appear in the Ke'erqin Basin and along the tributaries of the Songhua River (Fig. 8).

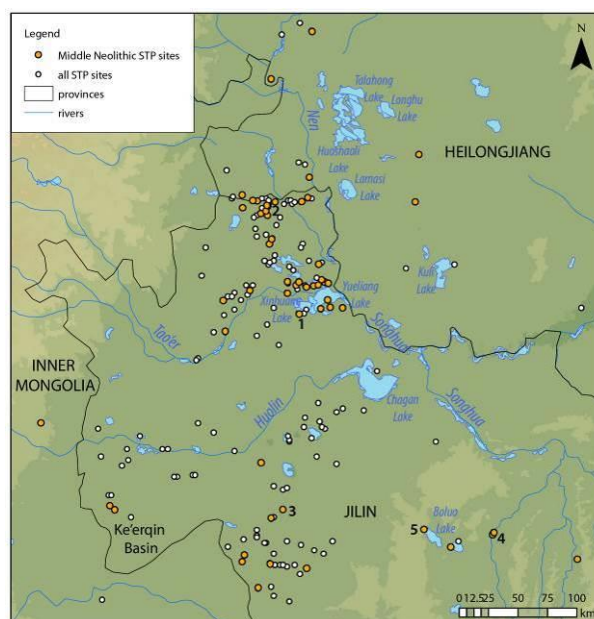


Fig. 8 Spatial distribution of the Middle Neolithic STP sites
1. Houtaomuga, 2. Huangjiaweizi, 3. Yaojingzi, 4. Zuojiashan, 5. Wutaishan

2.2.2.2.2 Environmental conditions and subsistence

Little paleoenvironmental information is available from the excavated sites (Houtaomuga and Huangjiaweizi in the Lower Nen region, Yaojingzi in the Ke'erqin Basin, and Zuojiashan in the Yitong River Valley).

At the Houtaomuga site, during phase II (6000-5300 BC), recovered seeds all come from wild plants, and only two millet seeds suggest the possible use of wild cereals or the beginnings of their domestication (Tang et al. 2020). The remains of fauna are mainly aquatic, dominated by shells and fish, but birds and wild mammals are more abundant (hare, wild boar, fox, tanuki, and Asian deer) (Zhang 2015). Birds are mostly mallards (MNI 62% of bird remains) and pheasants (Liang et al. 2020a). Birds, shells, and mammal bones were used to make objects, such as fishing tools. The Houtaomuga site might have been occupied only periodically.

At the same site, during phase III (4300-3500 BC), plant remains are rare and all wild. Pollens show that the environment was rather humid and slightly warmer than before, and tree cover was developing (Tang et al. 2017a). All the semi-subterranean houses yielded large quantities of shells (mainly *Unio douglasiae*), fishbones, birds, and smaller quantities of mammal remains, as well as objects made out of shells, mammal bones, and bird bones, such as fishing tools and arrowheads, along with microlithic blades. Bird remains are dominated by pheasants (MNI 62% of bird remains) and ducks, mostly mallards (*Anas platyrhynchos*). Adult male birds were hunted during summer and spring. These specialized hunting practices were followed by storage strategies, as shown by pits full of animal bones, such as pit n.12DHAIH165, containing at least 42 pheasants (Liang et al. 2020a). Shells seem to have been mainly collected during the spring. This site can be interpreted as a temporary shell collecting and fishing spot reused year after year (a “long-term temporary occupation”) (Peng 2015).

At the Huangjiaweizi site (6000-5000 BC) (Jilin 1988), likewise, a large number of shells have been found, as well as one pit dedicated to fish storage, and fishing tools such as harpoons and hooks, the lithic assemblage being dominated by microlithic tools.

In the Ke'erqin Basin, at the Yaojingzi site (5000-4500 BC), bone and shell artifacts, stone axes and chisels, and jade ornaments have been discovered, and houses yielded tools associated with fishing and hunting, as well as accumulations of fishbones (Jilin et al. 1992). In the Yitong River Valley, during the first phase of the Zuojiashan site (5000-4800 BC), the faunal assemblage corresponds to a transition phase with a mixed economy, with as many wild boar (*Sus scorfia*) as domesticated pigs, as well as chickens, many deer (elks, water deer), a few aurochs and horses, large quantities of shells (Chinese pound mussels *Sinanondonta woodiana*, large freshwater mussels of the *Unionidae* family, and *Unio douglasiae*), fish (catfish *Siluriformes*), softshell turtles, and furry mammals (otter, grey fox, tiger, tanuki, wolverine), discovered with fishnet weights and microliths. This evidence points to a settlement mode combining sedentarism and mobility (Peng 2015).

2.2.2.2.3 Petrographic analysis

Houtaomuga phase II (6000-5300 BC) pottery (Fig. 9-a, b) shows two recipes: one very rich in shell fragments (Fig. 9-c) and one characterized by a mix of inclusions of round marl fragments and shells (Fig. 9-d). Both are shell-tempered but the processing of the materials is different.

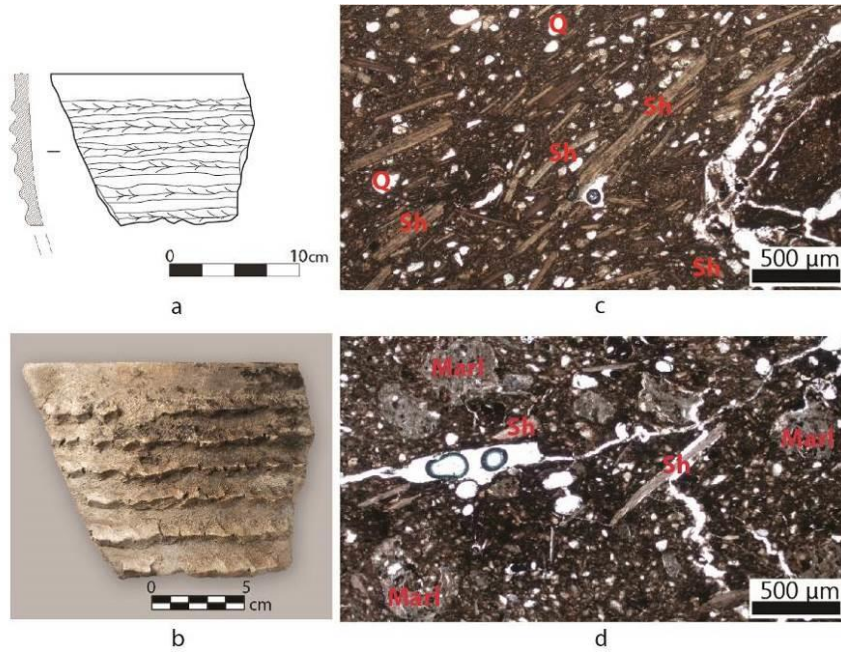


Fig. 9 Houtaomuga phase II: a. pottery sherd drawing; b. pottery sherd photo; c. shell fragments rich fabric thin-section, sample num. DH07 x4 PPL; d. calcareous fabric with marl fragments thin-section, sample num. DH09 x4 PPL. (Sh: Shell, Q: Quartz)

Sherds belonging to the posterior periods of Houtaomuga phases III (4300-3500 BC) (Fig. 10-a, b, c) and IV (3500-3000 BC) (Fig. 10-d) show the same petrofabric, tempered with a mix of shell fragments and sand (monocrystalline quartz, plagioclase and chert). The concentration of shell fragments does not vary much (frequent to few). The clay matrix and the fine fraction are close to that of previous periods, which suggests a continuity in the use of very local resources, such as lakeshore soil as matrix raw material.

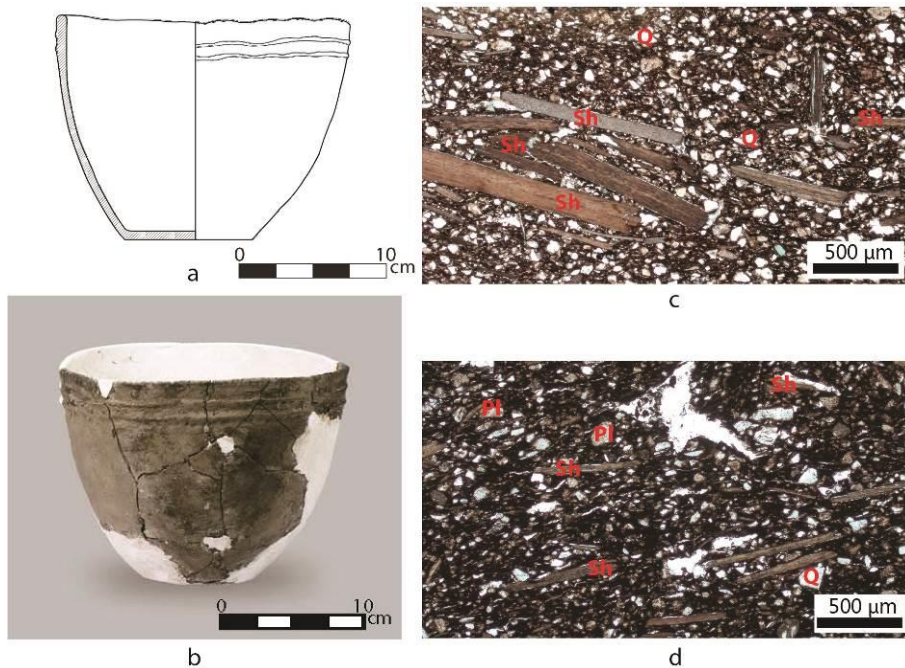


Fig. 10 Houtaomuga phase III and IV: a. pottery drawing phase III (AIIIIG1:42); b. pottery photo phase III (AIIIIG1:42); c. phase III thin-section, sample num. DH16 x4 PPL; d. phase IV thin-section, sample num. DH18 x4 PPL. (Sh : Shell, Q: Quartz, Pl: Plagioclase)

In the Yitong River Valley, the Wutaishan site (4300-3800 BC) presents an interesting case with three types of pottery production and four distinct fabrics, clearly corresponding to one local production and at least two or three imported ones. One of them is characterized by a very high abundance of crushed shells. These inclusions are angular and very poorly sorted. Some sub-rounded inclusions of quartz and plagioclase are also present in the fine fraction. At Wutaishan, there is a clear correlation between this shell-tempered petrofabric and the morphostylistic typology of this pottery, and it is clear that these artifacts, or their contents, were imported from the Lower Nen River Valley (Duval et al. in prep.).

2.2.2.3 Late Neolithic 3500-2000 BC

2.2.2.3.1 Spatial distribution of the STP sites

STP is found at fewer sites during the Late Neolithic (17), but their spatial distribution remains quite stable, with a lower density during this shorter period (Fig. 11) (Sebillaud et al. 2021).

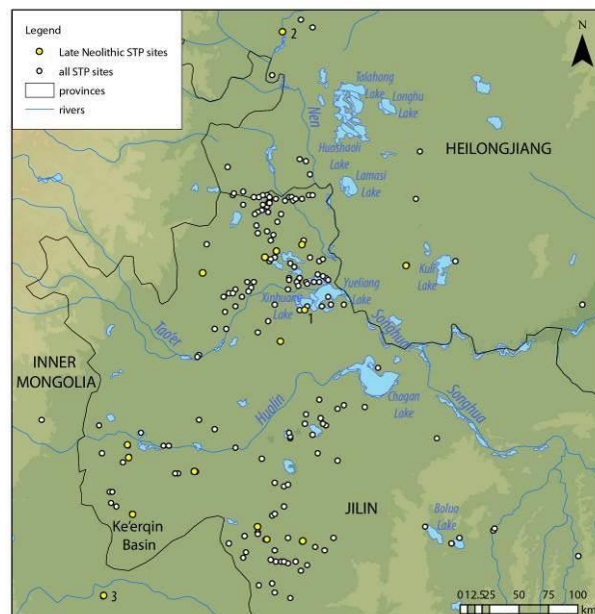


Fig. 11 Spatial distribution of the Late Neolithic STP sites
1. Houtaomuga, 2. Honghe, 3. Haminmangha

2.2.2.3.2 Environmental conditions and subsistence

For this period, paleoenvironmental data are available from the Houtaomuga and the Honghe sites in the Lower Nen River Valley, as well as for the Haminmangha site in the very northeastern part of the Liaoxi region.

At Houtaomuga, during phase IV (3500-3000 BC), preliminary carpology observations show that some rare millet seeds are present; the increase in the number of grinding stones and the appearance of knives indicate a rise in plant use, and may represent the beginnings of some cultivation practices. Animal remains are extremely numerous, and all the houses yielded large quantities of shells (mainly *Unio douglasiae*, accounting for over 90% of the shells, at least 10 times more numerous than *Lanceolaria gladiola*) and fish bones (over 50% being yellowhead catfish *Tachysurus fulvidraco*), which were also used to make a variety of tools and ornaments. Mammal bones are more numerous than before, especially wild bovines (aurochs), and to a lesser extent pheasant (*Phasianus colchicus*), dog, hare, boar, horse, and furry carnivores (tanuki) (Zhang 2015; Wang X. 2018; Wang Y. 2018). Bird remains are still very abundant and dominated by pheasants (72% of bird remains) and mallards, mostly adult males (Liang et al. 2020). Some pits are exclusively filled with fish and shells, suggesting

deliberate storage. Nevertheless, at this point at Houtaomuga, aurochs dominate the diet. Animal remains made up the majority of the fill of the enclosure ditch, and 90% (weight) of these are aurochs' bones, some of which bore traces of fire cooking. The hunt apparently targeted rather young individuals. Overall, meat at the site evidently came from wild cattle and secondarily from boars and horses, as well as from fishing.

At Haminmangha (3400-3100 BC), in the Liaoxi region, faunal remains, mostly unearthened from the semi-subterranean buildings, are 70% small-sized wild mammal remains, mollusks (15% of the identified remains, second most abundant in MNI), birds (12% of the identified remains, third most abundant in MNI), reptiles (2%), and fish (1%). The estimates of meat proportions are: 60% boar, 13% hare, 9% aurochs, 7% roe deer, 5% horse, 2% red deer, 2% pheasant, and 2% small deer (Chen 2014). No trace of agriculture or animal domestication was found. Subsistence was based on hunting, collecting, and fishing. The unearthened grinding stones are used to process wild plants (cereals, nuts). Analysis of the collecting season for shells and deer antlers demonstrates that the site was occupied all year long. This shows a very different subsistence pattern, but still leaves an important place for shells in the economy, with a large quantity of worked shell artifacts. The 1477 mollusk fragments are mainly composed of *Unio douglasiae* (NMI 171), over 10 times more numerous than *Lanceolaria gladiola* (MNI 12), with some fragments of *Margaritiferidae* (middle-size freshwater mussels of the *Unionidae* family). The 91 shell artifacts (knives, spatulas, and ornaments) unearthened at this site exhibit various manufacture techniques, with a clear sorting of raw materials according to the type of object and a tendency towards standardization of the shapes and dimensions (Chen et al. 2015). The discovery of 70 pieces of prepared raw material point to on-site production.

At the Honghe site (around 2400 BC), the fauna was composed of large quantities of shells, fish, and birds, as well as wild mammals (aurochs, horse, red deer, roe deer, boar, wolf, dog, fox, tanuki, badger, and hare—all hunted wild game, except for the dog). Artifacts made out of bone and antler were mainly used for fishing, and to a lesser extent hunting and gathering, as most of the 225 bone objects are fish hooks, harpoons, spearheads, arrowheads, and composite knives (Liang et al. 2020b).

2.2.2.3.3 Petrographic analysis

At Honghe (fig. a, b), three petrofabrics have been identified: one with deliberately added crushed shells, whose coarse inclusions are mostly shell fragments (Fig. 12-d); one without any shell fragments (Fig. 12-c); and one with a variable amount of shell inclusions, which could be natural or a mix of two fabrics (Fig. 12-e). However, all the pottery samples contain volcanic rock fragments and rare but very characteristic graphic textured granite (Fig. 12-f). In these three petrofabrics, the clay comes from the same or very close extraction locations, and the variations in the recipes might correspond to neighboring extraction locations or slight manufacturing disparities.

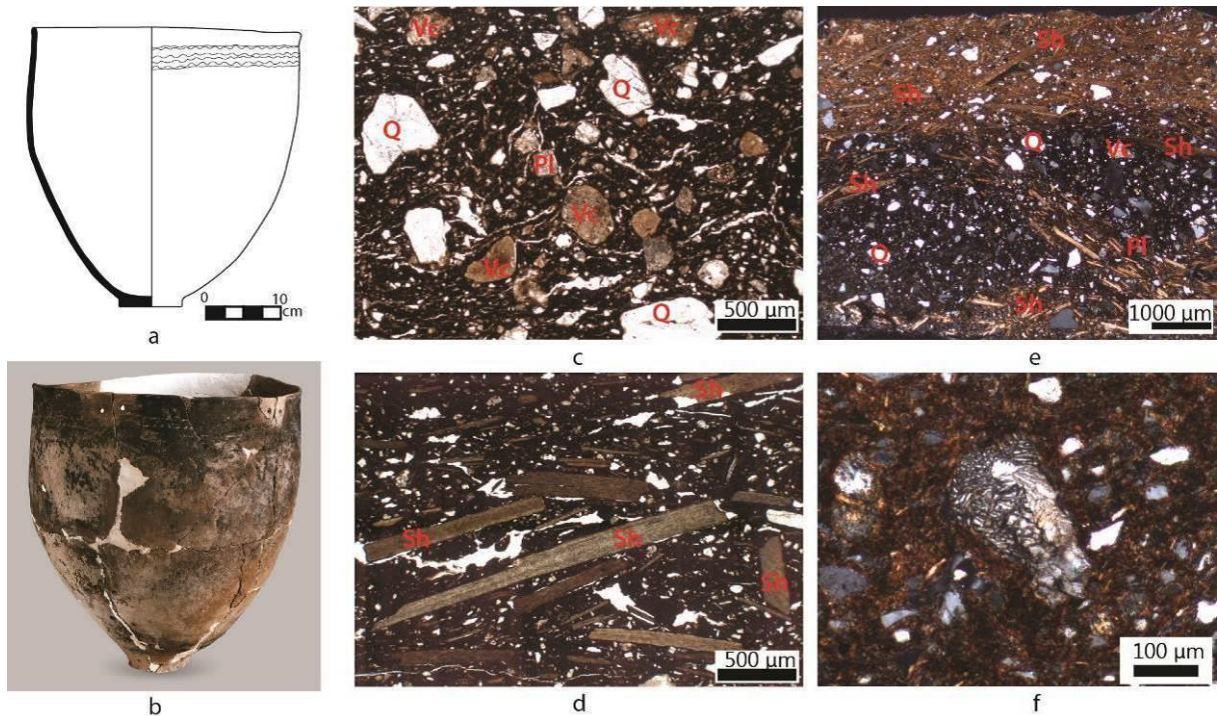


Fig. 12 Honghe: a. pottery drawing (F1:1); b. pottery photo (F1:1); c. quartz fabric, sample num. QH-07 x4 PPL; d. shell fabric, sample num. QH-03 x4 PPL; e. quartz + shell fabric, sample num. QH-04 x2 XP; f. detail of a graphic textured granite inclusion, sample num. QH-22 x10 XP. (Sh: Shell, Q: Quartz, Vc: Volcanic rock fragment, Pl: Plagioclase)

2.2.2.4 Bronze Age 2000-500 BC and Iron Age 500 BC-0

Less information is available for the sites from this period.

By the second millennium BC (the Bronze Age), shell temper was only still being used in Northwestern Jilin Province, in the lacustrine region south of the Chagan Lake, which was newly and densely occupied, most likely due to a drop in the water level (Fig. 13). Most of these sites had been continuously occupied since the Neolithic, and their subsistence strategy was still heavily based on fishing and hunting.

During the second half of the first millennium BC (Iron Age, or Hanshu culture phase II), STP appears at a few sites in the Bohai Bay but disappears in the Lower Nen River Valley, when animal domestication, specifically ovine animal husbandry, took a larger place in the subsistence regime (Fig. 13).

functional performance mean that local populations were taking full advantage of this resource, particularly in the absence of many other common tempering materials.

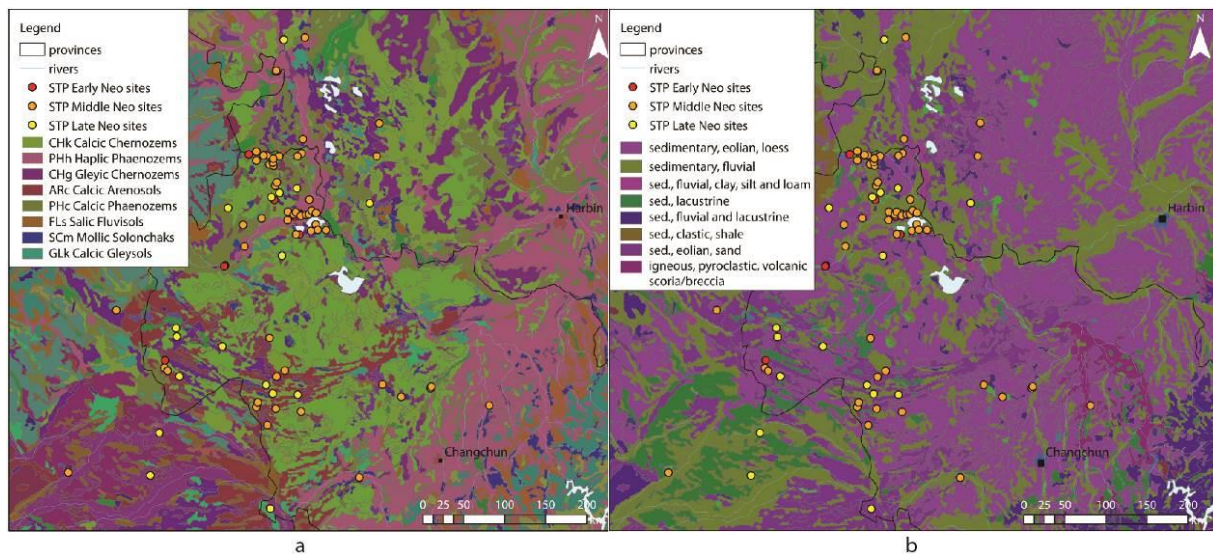


Fig. 14 STP Neolithic sites distribution and land conditions: a) sedimentology map, b) lithology map

Some organic tempers provide a technological advantage. For instance, because they are absorbent, plant fibers help to dry the clay and allow a vessel to be made in one sitting (Skibo et al. 1989; Skibo 2013: 6). By contrast, using shell temper constitutes quite a challenge. During firing, between 620°C and 850°C, calcite in the shells decomposes into burnt lime (transforming CaCO_3 into $\text{CaO} + \text{CO}_2$) (Rye 1976; Maritan et al. 2007). During the cooling phase and for several days after firing, the dehydrated decomposed calcite (or burnt lime/calcium oxide CaO) absorbs moisture, and can therefore move, gather, inflate, and form cracks inside the fabric (also called “lime spalling”) (Allegretta et al. 2016).

This difficulty can be avoided by using salt (Rye 1976; Stimmel et al. 1982; Skibo 1992: 37). Most of the lakeshore and riverside sediments in the Lower Nen River Valley and the Ke'erqin Basin contain salt. Because of the presence of Chernozems and meadow soils (Devyatova et al. 2015) in the Lower Nen River Valley, these flat lands of salt-affected soils are today subject to desertification and increased salinization processes, and salt was produced in these regions until the 1960s. Soil salt concentration reaches its maximum after the snow melts and before the rainy season begins, around April. At this time of the year, evaporation conditions are good, especially on flat land, next to a body of water, with a lot of wind and sun. Naturally salted soil seems to have been predominantly chosen to manufacture ceramics, it is also possible that salt could have been deliberately added to the fabric, but unfortunately, we know nothing about the production of salt before the medieval period in this region (Sebillaud et al. 2017).

Moreover, adding crushed shells as a temper or choosing a clay naturally containing shell fragments, as long as it also contains salt, enhances plasticity during shaping and decreases the risk of cracks during drying (Maritan et al. 2007). Because of the parallel orientation and the elongated shape of the fragments, coarse shell temper's thermal expansion is similar to that of the fired body, and thus, it intensifies resistance to repeated thermal shock, making the containers well-suited for cooking (Steponaitis 1984; Feathers 1989; Feathers 2006; Skibo 2013: 43-45).

Therefore, the use of shell temper seems to have been opportunistic, but conferred technical advantages on the finished ceramic vessels. It has not been subjected to a cultural

diffusion per se, and seems linked to the concomitant availability of large quantity of shells and salty soil.

The abundance of water in the landscape, the site locations on lake shores, the lake reed fibers in the earliest pottery fabric, tools made out of shells, and transportation and exchanges which might have at least partly taken place on water in summer or frozen water in winter, show that these human groups chose to use different aspects of their aquatic environment and developed related know-how and techniques. The lacustrine landscape was a key feature that attracted human populations and linked these communities together. The abundance of large shells, their presence in a funerary context, the presence of tools made of shell, and their importance in the subsistence economy all indicate that shell gathering might have been one of the practices that tied these communities together.

Furthermore, residue analyses on sherds from each of the four chronological phases of the Houtaomuga site (11th to 3rd millennia BC) show that from the earliest pottery production to the Late Neolithic, these vessels were used to cook freshwater shellfish (Kunikita et al. 2017; Wang and Sebillaud 2019; Keute 2022). Further functional analysis of use-alteration traces (Skibo 2013) and residues would help to clarify the diet of the human groups using STP, for example, if a functional difference in food preparation existed between the two types of petrofabrics at the Shuangta site.

The abundance of shells eaten and discarded at the sites, the fine-grained sediments (loess and silt), and the absence of lithic material made crushed shells a very attractive material for potters at the time: easy to obtain, light, suitable for repeated heating in cooking, and shock-resistant. The connection between shell temper use in environments where shell is abundantly available and shellfish as important dietary components shows the efficient use of resources by hunter-gatherers occupying these areas.

Furthermore, this research allows us to further refine the concept of “fishing-hunting-gathering” generally used to describe the subsistence mode of Neolithic Northeast China into more precise definitions. Subsistence was heavily dependent on shellfish in the Nen River Valley where STP was produced and used, while other subregions, without STP, present varied and complex ensembles of subsistence strategies, e.g. deer-based in the Liaoxi region and fish-based in the Sanjiang Valley. Our research also reveals large changes in subsistence strategies during the Bronze and Iron Ages.

In the Liaoxi region, at the Baiyinchanghan site (5900-5000 BC), faunal remains are dominated by deer (including red deer *Cervus elaphus*, elk *Cervus canadensis*, Siberian roe deer *Capreolus pygargus*), boar, aurochs, and bear (Neimenggu 2004 :546-574). It seems, therefore, that subsistence was largely based on big game hunting without any evidence for domestication, except for dogs. Some of the Xinglongwa culture (6200-5000 BC) sites appear to have been used all year long by at least part of the population. Small quantities of domesticated plant remains have been found, but they did not constitute a big part of the diet and economy. Discovery of specialized storage pits for fish and harpoons point to the important role played by fishing in subsistence. Microlithic tools also point to a hunting-fishing-gathering economy. Slightly later, the Zhaobaogou settlement (5100-4800 BC) was used all year long and the economy was based on deer hunting (Shelach 2006).

In the Sanjiang Valley, on the Ussuri River, at the Xiaonanshan site (of the eponymous culture ca. 7200-6800 BC) (Heilongjiang and Raohe 2019), the rather cold climate had a large temperature range, and no remains associated with agriculture have been found, but the site yielded many fish storage pits. The economy was based on fishing, and to a lesser extent on hunting and gathering.

At the Xinkailiu site (Heilongjiang 1979) (eponymous culture ca. 5500-4000 BC), fauna remains were largely dominated by fish (salmon, Amur carps *Cyprinus rubrofasciatus*, catfish *Siluriformes*, black carp *Mylopharyngodon piceus*) and bivalves, with low quantities of large

and small game such as deer (red deer, Père David deer *Elaphurus davidianus*, Eastern roe deer) and other even-toed ungulates, furry mammals (red fox, badger, wolf, brown bear), odd-toed ungulates, boar, birds, and soft-shell turtles. Excavation also yielded large quantities and varieties of fishing tools and numerous storage pits dedicated to fish preservation (Zhao et al. 2015).

In the Liaodong peninsula, during the period of the culture of the Lower Level of Houwa (4500-4000 BC), the climate was slightly warmer and wetter than today. Some researchers interpret the lithic tool assemblage of polished axes and ground stones as evidence of agricultural practices (Peng 2015), but they could also have been used to process wild plants. Bolas and net weights indicate hunting and fishing.

In the Liao River Valley, which has a similar climate, sites of the culture of the Lower Level of Xinle (5500-4500 BC) (Shenyang and Xinle 2018) yielded semi-subterranean houses restored and rebuild many times as well as grain silos, pointing to a higher degree of sedentarism and true agricultural production with a surplus. A large accumulation of fish bones and tools also suggest hunting and fishing.

To compare, in the Yellow River Valley, at Xinmi in Xinzhai in Henan Province, during the second half of the 3rd millennium BC, contemporaneous with the Honghe site, 83% of all animals found at the site were domesticated pigs, and an addition 5.3% were from other domesticated species (Liang et al. 2020b).

As in many other places in the world, hunter-gatherer groups thrived in Northeast China in inhospitable lands. People in many subregions used aquatic resources in their subsistence strategies, but there is not a universal association between this trait and STP production. The cold climate might have been a deterrent for farmers, but the abundance of easily exploited natural food resources made these regions attractive for non-agricultural groups, who lived “in relatively sedentary ways and were well established due to the abundance of aquatic resources” (Demoule 2022: 42, 51). Hunter-gatherer groups made the most ancient pottery in the world, in China, Japan, and Amazonia, where they “could live in a sedentary way due to the abundance of natural resources” (Demoule 2022: 47).

5. Conclusions

This research reveals that the use of shell temper in pottery production was mostly motivated by opportunism and that it provided some technical advantages. Moreover, an inclusive methodology, applicable in other regions of the world, sheds light on the use of a common and key resource in the subsistence of hunter-gatherers in Northeast China, and how these strategies changed during the Neolithic, Bronze Age, and Iron Age.

Through the study of published artifacts, direct analysis of sherds and thin-sections, and comparison with settlement, lithic, and faunal data, this research sheds new light on STP in Northeast China. It shows that STP emerged in the Lower Nen River Valley before expanding only into some parts of the Northeast China Plain. This distribution is explained by the exploitation of the water-dominated landscapes and uniquely rich aquatic resources provided by only some of the river valleys in this region.

This research demonstrates that a cross-cultural long-lasting practice, such as STP, can only be thoroughly reconstructed using multidisciplinary data. Far from a homogeneous territory, Northeast China encompasses various topographical regions, each presenting a unique set of harsh climate conditions and rich resources. Further attention to pottery production techniques and materials, along with better paleobotanical and archaeozoological data, will shed new light on other ancient complex cultural practices.

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.

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References

* References only used in the Supplementary Information tables

- Allegretta, I., Pinto, D., Eramo, G., 2016. Effects of grain size on the reactivity of limestone temper in a kaolinitic clay. *Applied Clay Science* 126, 223–234. <https://doi.org/10.1016/j.clay.2016.03.020>
- Bar-Yosef, O., Belfer-Cohen, A., 1989. The origins of sedentism and farming communities in the Levant. *Journal of World Prehistory* 3, 447–498. <https://doi.org/10.1007/BF00975111>
- Beijing daxue kaogu wenbo xueyuan, Henan sheng wenwu kaogu yanjiuyuan, Luohe shi wenwu kaogu yanjiusuo, Fudan daxue keji kaogu yanjiuyuan, 2022. Henan Luohe Yancheng qu Tuchengwang yizhi 2018 nian kaogu fajue yu chubu yanjiu (2018 Archaeological excavation and preliminary research on the Tuchengwang site in Yancheng, Luohe, Henan). *Huaxia kaogu* 3, 3–28.
- Berger, E., Brunson, K., Kaufman, B., Lee, G.-A., Liu, X., Sebillaud, P., Storozum, M., Barton, L., Eng, J., Feinman, G., Flad, R., Garvie-Lok, S., Hrivnyak, M., Lander, B., Merrett, D.C., Ye, W., 2021. Human adaptation to Holocene environments: Perspectives and promise from China. *Journal of Anthropological Archaeology* 63, 1–16. <https://doi.org/10.1016/j.jaa.2021.101326>
- Blackmore, L., Pearce, J., 2010. A dated type series of London medieval pottery: Part 5, Shelly-sandy ware and the greyware industries. *Museum of London Archaeology*. ed. London.
- Bronk Ramsey, C., 2009. Bayesian analysis of radiocarbon dates, *Radiocarbon* 51(1), 337–360.
- *Cai D., Zhang N., Zhu S., Chen Q., Wang L., Zhao X., Ma X., Royle T., Zhou H., Yang D. Y., 2018. Ancient DNA reveals evidence of abundant aurochs (*Bos primigenius*) in Neolithic Northeast China. *Journal of Archaeological Science* 98, 72–80.
- Chen J., 2014. Neimenggu Haminmangha yizhi chutu dongwu yicun ji xiangguan wenti (The fauna remains excavated at the Haminmangha site in Inner Mongolia and related questions) (Master thesis). Jilin University, Changchun.
- Chen Q., Ji P., Chen J., Wang C., 2015. Neimenggu Haminmangha Xinshiqi shidai yizhi chutu bangzhipin yanjiu (Research on shell objects from the Neolithic site of Haminmangha, Inner Mongolia). *Kaogu* 12, 98–105.
- Chen Z., 2016. Neimenggu Haminmangha yizhi gaizhi shiqi yanjiu (Research on modified lithic artifacts from the Haminmangha site, Inner Mongolia). *Bianjiang kaogu yanjiu* 319–329.
- Demoule, J.-P., 2022. *Homo migrans - De la sortie d’Afrique au grand confinement*, Payot. ed. Paris.
- Deru, X., Paicheler, J.-C., 2001. La céramique à dégraissant coquillier dans le nord-est de la Gaule, Montagnac. (Archéologie et histoire romaine, 4), in: *Histoire et céramologie en Gaule Mosellane (Sarlorlux)*. Journée d’études de Metz (Moselle), June 1988. pp. 23–35.
- Devyatova, T.A., Yablonskykh, L.A., Alaeva, L.A., Belik, A.V., Negrobova, E.A., Rummyantseva, I.V., 2015. Water-salt regime of chernozems in the Central Chernozem Region. *Arid Ecosyst* 5, 243–248. <https://doi.org/10.1134/S2079096115040022>
- Duan, T., 2013. Case for the petrographic analysis of ceramic thin sections: attempts to source pottery from the Hongshan Culture site of Weijiawopu, Inner Mongolia. *Asian Archaeology* 1, 44–51.
- Duan, T., Ma, S., Li, S., Chen, Y., 2018. Petrographic analysis of pottery from the Haminmangha site (2010–2011), Inner Mongolia. *Asian Archaeology* 2, 43–50. <https://doi.org/10.1007/s41826-018-0014-3>
- Dumpe, B., Bērziņš, V., Stilborg, O., 2008. A dialogue across the Baltic on Narva and Ertebølle pottery. *Bericht der Romisch-Germanischen Kommission* 89, 409–441.
- Dung, N.K., Yamagata, M., Watanabe, S., Bellwood, P., 2011. Appendix 2: The Man Bac burial pottery – An illustrated corpus of the whole vessels from the burials in Cultural Unit III, in: Oxenham, M.F., Matsumura, H., Dung, N.K. (Eds.), *Man Bac: The Excavation of a Neolithic Site in Northern Vietnam*. ANU Press, pp. 169–185.

- Du Z., 2014. Zhongguo Dongbei nanbu diqu Xinshiqi shidai shikong kuangjia yu puxi geju yanjiu (Research on the chronological frame and cultural typology of the Neolithic in the south of Northeast China) (Ph. D. dissertation). Jilin University, Changchun.
- Du Z., Han F., 2019. Lun Xinglongwa wenhua de fenqi yu niandai (Discussing the sequencing and chronology of the Xinglongwa culture). *Kaogu* 3, 68–80.
- Duval, P., Sebillaud, P., Wang Yixue, in prep. Sherds of societies: Quantitative and petrographic analysis of Neolithic ceramics in Northeast China.
- Eramo, G., 2020. Ceramic technology: how to recognize clay processing. *Archaeol Anthropol Sci* 12, 164. <https://doi.org/10.1007/s12520-020-01132-z>
- Feathers, J.K., 1989. Effects of temper on strength of ceramics: Response to Bronitsky and Hamer. *American Antiquity* 54, 579–588. <https://doi.org/10.2307/280784>
- Feathers, J.K., 2006. Explaining shell-tempered pottery in Prehistoric Eastern North America. *Journal of Archaeological Method and Theory* 13, 89–133. <https://doi.org/10.1007/s10816-006-9003-3>
- Food and Agriculture Organization of the United Nations, 2006a. World reference base for soil resources 2006 - A framework for international classification, correlation and communication, ONU. ed. Rome.
- Food and Agriculture Organization of the United Nations, 2006b. Guidelines for soil description, FAO. ed. Rome.
- Gijanto, L., 2011. Socio-economic interaction and ceramic aesthetic: understanding West African ceramic production and use in context. *Azania: Archaeological Research in Africa* 46, 250–268. <https://doi.org/10.1080/0067270X.2011.621794>
- Guojia wenwuju (Ed.), 1993. Zhongguo wenwu dituji, Jilin fence (Cultural relics atlas of China, Jilin), Zhongguo ditu chubanshe. Beijing.
- Guojia wenwuju (Ed.), 2003. Zhongguo wenwu dituji, Neimenggu fence (Cultural relics atlas of China, Inner Mongolia), Xi'an ditu chubanshe. Xi'an.
- Guojia wenwuju (Ed.), 2009. Zhongguo wenwu dituji, Liaoning fence (Cultural relics atlas of China, Liaoning), Xi'an ditu chubanshe. Xi'an.
- Guojia wenwuju (Ed.), 2015. Zhongguo wenwu dituji, Heilongjiang fence (Cultural relics atlas of China, Inner Heilongjiang), Wenwu chubanshe. Beijing.
- Heilongjiang sheng wenwu kaogu gongzuodui, 1979. Mishan xian Xinkailiu yizhi (The Xinkailiu site, Xinmi District). *Kaogu xuebao* 4, 491–518.
- *Heilongjiang sheng wenwu kaogu yanjiusuo, Jilin daxue kaoguxi, 1998. Heilongjiang Zhaoyuan xian Xiaolaha yizhi fajue baogao (Excavation report on the Xiaolaha Site, Zhaoyuan District, Heilongjiang), *Kaogu xuebao* 1, 61-101.
- Heilongjiang sheng wenwu kaogu yanjiusuo, Raohe xian wenwu guanlisuo, 2019. Heilongjiang Raohe xian Xiaonanshan yizhi 2015 nian III qu fajue jianbao (2015 season preliminary excavation report on zone III of the Xiaonanshan site, Raohe District, Heilongjiang). *Kaogu* 8, 3–20.
- *Heilongjiang sheng wenwu kaogu yanjiusuo, 2019a. Heilongjiang Tailai xian Dongmingga Xinshiqi shidai yizhi fajue jianbao (Preliminary excavation report on the Neolithic Site of Dongmingga, Tailai District, Heilongjiang). *Kaogu* 8, 21-45.
- *Heilongjiang sheng wenwu kaogu yanjiusuo, 2019b. Heilongjiang Qiqiha'er shi Honghe yizhi Xinshiqi shidai yicun fajue jianbao (Preliminary excavation report on the Neolithic Site of Honghe, Qiqiha'er City, Heilongjiang), *Kaogu* 8, 46-70.
- Herbert, J.M., 2008. The history and practice of shell tempering in the Middle Atlantic: A useful balance. *Southeastern Archaeology* 27, 265–285.
- Jaffe, Y.Y., Castellano, L., Shelach-Lavi, G., Campbell, R.B., 2020. Mismatches of scale in the application of paleoclimatic research to Chinese archaeology. *Quaternary Research* 1–20. <https://doi.org/10.1017/qua.2020.60>
- Jilin daxue kaogu jiaoyanshi, 1989. Nong'an Zuojiashan Xinshiqi shidai yizhi (The Neolithic site of Zuojiashan, Nong'an). *Kaogu xuebao* 187–212.
- Jilin daxue Bianjiang kaogu yanjiu zhongxin, Jilin sheng wenwu kaogu yanjiusuo, 2013. Jilin Baicheng Shuangta yizhi Xinshiqi shidai yicun (The Neolithic remains of the Shuangta Site, Baicheng, Jilin). *Kaogu xuebao* 4, 501-538.
- Jilin daxue Bianjiang kaogu yanjiu zhongxin, Jilin sheng wenwu kaogu yanjiusuo, Changchun shi wenwu baohu yanjiusuo, Nong'an xian wenwu guanlisuo, 2018. Jilin Nong'an xian Zuojiashan yizhi Xinshiqi shidai yicun 2015 nian fajue jianbao (Preliminary report on the excavation of Neolithic remains at the Zuojiashan site in Nong'an District, Jilin). *Kaogu* 2, 12–25.
- Jilin sheng wenwu kaogu yanjiusuo, 1988. Jilin Zhenlai xian Huangjiaweizi yizhi fajue jianbao (Preliminary excavation report on the Huangjiaweizi site, Zhenlai District, Jilin). *Kaogu* 2, 141–149.
- Jilin sheng wenwu kaogu yanjiusuo, Baicheng diqu bowuguan, Changling xian wenhua ju, 1992. Jilin Changling xian Yaojingzi Xinshiqi shidai yizhi (The Neolithic site of Yaojingzi, Changling District, Jilin). *Kaogu* 8, 673–688.
- Keute, J., 2022. Understanding the interplay of subsistence, ceramic technology, and local environments in the emergence of pottery in Northeast Asia through residues (Ph.D. dissertation). Oxford University, Oxford.

- Kunikita, D., Wang, L., Onuki, S., Sato, H., Matsuzaki, H., 2017. Radiocarbon dating and dietary reconstruction of the Early Neolithic Houtaomuga and Shuangta sites in the Song-Nen Plain, Northeast China. *Quaternary International*, Emergence of the world's oldest pottery 441, 62–68. <https://doi.org/10.1016/j.quaint.2017.01.031>
- Liang Q., Chen Q., Wang C., 2020a. Jilin Da'an shi Houtaomuga yizhi chutu niaolei yicun yanjiu (Research on birds' remains excavated at the Houtaomuga site, Da'an, Jilin). *Renleixue xuebao* 29, 118–126.
- Liang Q., Zhang W., Chen Q., Tian H., 2020b. Heilongjiang Qiqiha'er Honghe yizhi chutu de guqi (The bone artifacts excavated at the Honghe site, Qiqiha'er, Heilongjiang). *Renlei xuebao* 39, 323–336.
- Liu S., Cui J., Wang L., 2017. Jilin Da'an Houtaomuga yizhi chutu taopian keji jiance fenxi (Archaeometric analysis of the sherds unearthed at the Houtaomuga site, in Da'an, Jilin). *Bianjiang kaogu yanjiu*, 21, 335–352.
- Li W., 2021. Gudai zhitao suoyong niantu ji chanheliao—jian ji yinwen yingtao yu yuanshi ci yuanliao de qubie (Clay and temper used in ancient pottery – The differences in raw materials between impressed decoration hardware and primitive porcelain). *Wenwu Chunqiu* 1, 39–46.
- Li, Y., 2020. Neimenggu Aohanqi Xinglonggou yizhi chutu taoqi yanxiang yu chengfen de chubu fenxi (Preliminary petrographic and compositional analysis of potteries unearthed at the Xinglonggou site in Aohanqi, Inner Mongolia). *Sichuan wenwu* 4, 110–118.
- *Ma L., Xiang S., Fu W., 2005. Heilongjiang sheng Qiqiha'er shi Tengjiagang yizhi san zuo Xinshiqi shidai muzang de qingli (The excavation of three Neolithic burials at the Tengjiagang site, Qiqiha'er, Heilongjiang). *Beifang wenwu* 1, 1-4.
- Maritan, L., Mazzoli, C., Freestone, I., 2007. Modelling changes in mollusc shell internal microstructure during firing: Implications for temperature estimation in shell-bearing pottery. *Archaeometry* 49, 529–541. <https://doi.org/10.1111/j.1475-4754.2007.00318.x>
- Miksic, J.N., Teck, Y.C., 1992. Compositional analysis of pottery from Kota Cina, North Sumatra: Implications for regional trade during the Twelfth to Fourteenth centuries A.D. *Asian Perspectives* 31, 57–76.
- Nachtergaele, F., Van Velthuizen, H., Verelst, L., Wiberg, D., 2012. *Harmonized World Soil Database (version 1.2)*, FAO, IIASA, ISRIC, ISSCAS, JRC. ed. Rome.
- Nanjing bowuguan, Yixing shi wenwu guanli weiyuanhui, 2009. Jiangsu Yixing Luotuodun yizhi fajue baogao (Excavation report of the Luotuodun site in Yixing, Jiangsu). *Dongnan wenhua* 5, 26–44.
- Neimenggu wenwu kaogu yanjiusuo, 2004. Baiyinchanghan - Xinshiqi shidai yizhi fajue baogao (Excavation report on the Baiyinchanghan Neolithic site), *Kexue chubanshe*. ed. Beijing.
- Nishida Y., 1987. Elasu C iseki shutsudo no kaigara konwa doki ni tsuite (On the shell-tempered potteries unearthed at the Elasu-C site). *Tôkyô daigaku bungakubu kôkogaku kenkyûshitsu kenkyû kiyô* 6, 45–55.
- *Onuki S., Kunikita D., Yoshida K., 2013. Yuan Dongbei bu Xinshiqi shidai de yanjin - cong Elasu C yizhi caiji taoqi de xince niandai tanqi (Evolution of the Neolithic in the Far Northeast region – Departing from the new dates of the potteries collected at the Elasu-C site), in: *Zhongguo shehui kexueyuan Kaogu yanjiusuo, Heilongjiang sheng wenwu kaogu yanjiusuo, Qiqihar shi Ang'angxi qu renmin zhengfu* (Eds.), *Angangxi kaogu wenji* (Collection of articles on Angangxi archaeology). Beijing, pp. 247–250.
- Peng B., 2015. Dongbei diqu Xinshiqi shidai zhongqi de fangzhi jiegou yu nongye chuanbo (The transmission of agriculture and the structure of houses during the Middle Neolithic in the Northeast region). *Heilongjiang kexue* 6, 71–73, 65.
- Quinn, P.S., 2022. *Thin section petrography, geochemistry and scanning electron microscopy of archaeological ceramics*, Archaeopress. ed. Oxford.
- Reimer, P.J., Austin, W.E.N., Bard, E., Bayliss, A., Blackwell, P.G., Bronk Ramsey, C., Butzin, M., et al., 2020. The IntCal20 northern hemisphere radiocarbon age calibration curve (0–55 cal kBP). *Radiocarbon* 62(4), 725–757.
- Rieger, A.-K., Möller, H., 2012. Northern Libyan Desert ware: New thoughts on 'shell-tempered ware' and other handmade pottery from the Eastern Marmarica (north-west Egypt). *Libyan Studies* 43, 11–31. <https://doi.org/10.1017/S0263718900000030>
- Rye, O.S., 1976. Keeping your temper under control: Materials and the manufacture of Papuan pottery. *Archaeology and Physical Anthropology in Oceania* 11, 106–137.
- Sebillaud, P., Liu, X., Wang, L., 2017. Investigation on the Yinjiawopu site, a medieval salt production workshop in Northeast China. *Journal of Field Archaeology* 47, 1–15. <https://doi.org/10.1080/00934690.2017.1358030>
- Sebillaud, P., Williams, J., Liu, X., Wang, L., 2021. Changing settlement patterns and subsistence strategies in Northeast China: Results of the Yueliang regional survey. *Archaeological Research in Asia* 25, 1–19. <https://doi.org/10.1016/j.ara.2020.100250>
- Shelach, G., 2006. Economic adaptation, community structure, and sharing strategies of households at early sedentary communities in northeast China. *Journal of Anthropological Archaeology* 25, 318–345. <https://doi.org/10.1016/j.jaa.2005.11.007>
- Shenyang shi wenwu kaogu yanjiusuo, Xinle yizhi bowuguan, 2018. Xinle yizhi fajue baogao (Excavation report on the Xinle site), *Wenwu chubanshe*. ed. Beijing.
- Skibo, J.M., Schiffer, M.B., Reid, K.C., 1989. Organic-tempered pottery: An experimental study. *American Antiquity* 54, 122–146. <https://doi.org/10.2307/281335>

- Skibo, J.M., 1992. Pottery function - A use-alteration perspective, Springer. ed. New York.
- Skibo, J.M., 2013. Understanding pottery function, Springer. ed. New York.
- Sorresso, D.C., Quinn, P.S., 2020. Re-examining shell-tempered Chickasaw pottery in post-contact Mississippi, USA. *Journal of Archaeological Science: Reports* 32, 102415. <https://doi.org/10.1016/j.jasrep.2020.102415>
- Spataro, M., Oras, E., Lucquin, A., Bērziņš, V., 2021. Hunter-fisher-gatherer pottery production and use at the Neolithic shell-midden of Rīņņukalns, Latvia. *Antiquity* 95, 1446–1463. <https://doi.org/10.15184/aqy.2021.127>
- Steponaitis, V.P., 1984. Technological studies of prehistoric pottery from Alabama: physical properties and vessel function, in: *The many dimensions of pottery: ceramics in archaeology and anthropology*. Amsterdam, pp. 89–122.
- Stimmel, C., Heimann, R.B., Hancock, R.G.V., 1982. Indian pottery from the Mississippi Valley: Coping with bad materials., in: Olin, J.S., Franklin, A.D. (Eds.), *Archaeological ceramics*. Washington, pp. 219–228.
- Tang Z., Liu W., Wang L., 2017a. Jilin Da'an Houtaomuga yizhi baofen fenxi chubu yanjiu (Preliminary research on the pollens discovered at the Houtaomuga site, Da'an, Jilin). *Bianjiang kaogu yanjiu* 21, 381–386.
- Tang Z., Wang L., Duan T., Jin X., Zhang Q., Zhang M., 2017b. Jilin Baicheng Shuangta Xinshiqi shidai yizhi de dongwu yicun jiqi huanjing (Fauna remains and environment of the Neolithic site of Shuangta, Baicheng, Jilin). *Renlei xuebao* 36, 537–552.
- Tang, Z., Lee, H., Wang, L., Sebillaud, P., Fang, Q., Lee, G.-A., 2020. Plant remains recovered from the Houtaomuga site in Jilin Province, Northeast China: A focus on Phase I (12,900–11,000 cal. BP) and Phase II (8,000–7,000cal. BP). *Archaeological Research in Asia* 22, 100192. <https://doi.org/10.1016/j.ara.2020.100192>
- Vybornov A., Andreev K., Kudashev A., Kulkova M. 2021. The Development of early pottery in the forest zone of the Middle Volga region (Eastern Europe). *Documenta Praehistorica* 48, 2-13
- Wang L., Huo D., Fang Q., 2017. Jilin Da'an Houtaomuga yizhi fajue de zhuyao shouhuo (Main results from the excavation of the Houtaomuga site in Da'an, Jilin). *Bianjiang kaogu yanjiu* 21, 321–333.
- Wang L., 2018. Houtaomuga Xinshiqi shidai yicun ji xiangguan wenti yanjiu (Research on the Neolithic remains of the Houtaomuga site). *Kaogu xuebao* 2, 141–164.
- Wang, L., Sebillaud, P., 2019. The emergence of early pottery in East Asia: New discoveries and perspectives. *Journal of World Prehistory* 32, 73–110. <https://doi.org/10.1007/s10963-018-9126-y>
- Wang, X., 2018. Houtaomuga yizhi 2013 nian chutu dongwu guge ji xiangguan wenti yanjiu (Research on the animal bones excavated from the Houtaomuga Site in 2013) (Master thesis). Jilin University, Changchun.
- Wang, Y., 2018. Houtaomuga yizhi 2014 nian chutu dongwu yicun yanjiu (Research on the animal bones excavated from the Houtaomuga Site in 2013) (Master thesis). Jilin University, Changchun.
- Weinstein, R.A., Dumas, A.A., 2008. The spread of shell-tempered ceramics along the northern coast of the Gulf of Mexico. *Southeastern Archaeology* 27, 202–221.
- Xiao X., 2014. Jilin Da'an Houtaomuga yizhi rengu yanjiu (Research on human remains from the Houtaomuga site, Da'an, Jilin) (Ph.D. dissertation). Jilin University, Changchun.
- Zhang M., 2011. Shuangta yizhi yiqi de dongwu liyong fangshi yanjiu (Research on the use of animals during phase I of the Shuangta site) (Master thesis). Jilin University, Changchun.
- Zhang Z., 2015. Houtaomuga yizhi (2011-2012) Xinshiqi shidai dongwu yicun yanjiu (Research on the Neolithic fauna remains of the Houtaomuga site [2011-2012]) (Master thesis). Jilin University, Changchun.
- *Zhao B., 2003. Dongbei shiqi shidai kaogu (Archaeology of the Stone Age in the Northeast). Jilin daxue chubanshe, Changchun.
- Zhao B., He Q., Zhao J., 2015. Comparative analysis of economic activities during the Neolithic in the Sanjiang Plain and the Middle and Lower Heilongjiang River Valley. *Asian Archaeology* 3, 27–38.
- Zhao B., Yu H., 2016. Zuojiashan xiaceng wenhua xintan (New discussion on the culture of the Lower Level of Zuojiashan). *Bianjiang kaogu yanjiu* 19, 117–148.
- Zheng J., Zhu Y., Ji P., 2014. Shilun Haminmangha wenhua (On the Haminmangha culture). *Bianjiang kaogu yanjiu* 15, 247–263.
- *Zhongguo shehui kexueyuan kaogu yanjiusuo, 1992. Zhongguo kaoguxue C14 niandai shujuji (1965-1991) (Chinese archaeology radiocarbon dates data set (1965-1991)), Wenwu chubanshe, Beijing.
- *Zhongguo shehui kexueyuan Kaogu yanjiusuo kaogu Keji shiyan yanjiu zhongxin tanshi shiyanshi, 2017. Fangshexing tansu ceding niandai baogao (43) (Radiocarbon dating report (43)), *Kaogu* 7, 82-87.
- *Zhu Y., 2016. Haminmangha yizhi jingji xingtai yanjiu : yige juzhu moshi yu shengtai huanjing weilun de tuidao (Research on the economic mode at the Haminmangha Site: A derivation of the paradox between the residential model and the ecological environment). *Bianjiang kaogu yanjiu* 19, 305-318.
- Zuo J., Wang C., Gao Z., Zhang J., He X., Ling M., 1997. Henan Wuyang Jiahu yizhi taopian de yanjiu (Research on the pottery sherds from the Jiahu site in Wuyang, Henan). *Wenwu* 12, 81–83.

Supplementary Materials

Table 1 Radiocarbon dates of STP sites

Site	Period	Sample	C14 date BP	Calibrated date (cal. BC)	Reference/Laboratory
Houtaomuga phase I	Early Neolithic	Ditch 12DHAIIG22 Charred organic residue	10820±130	11130BC (94.3%) 10666BC 10576BC (1.1%) 10557BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase I	Early Neolithic	Ditch 11DHAIIG18 Vegetable fiber tempered shard	10949±33	10978BC (95.0%) 10808BC 11008BC (0.4%) 11002BC	Zhongguo 2017/Xi'an
Houtaomuga phase I	Early Neolithic	Ditch 12DHAIIG22 Shell	10700±60	10808BC (94.6%) 10666BC 10572BC (0.8%) 10564BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase I	Early Neolithic	Pit 12DHAIH146 Vegetable fiber tempered shard	10550±50	10750BC (95.4%) 10526BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase I	Early Neolithic	Ditch 12DHAIIG21 Charred organic residue	10500±60	10740BC (72.3%) 10479BC 10448BC (7.2%) 10371BC 10364BC (7.6%) 10298BC 10292BC (7.5%) 10220BC 10170BC (0.9%) 10154BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase I	Early Neolithic	Ditch 12DHAIIG21 Charred organic residue	10510±50	10740BC (85.2%) 10502BC 10405BC (3.0%) 10376BC 10356BC (3.9%) 10308BC 10282BC (3.3%) 10243BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase I	Early Neolithic	Ditch 12DHAIIG21 Charred organic residue	10490±60	10733BC (65.7%) 10477BC 10451BC (27.7%) 10217BC 10206BC (0.6%) 10192BC 10175BC (1.4%) 10152BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase I	Early Neolithic	Ditch 12DHAIIG22 Shell	10490±50	10728BC (73.6%) 10482BC 10444BC (1.1%) 10421BC 10410BC (5.4%) 10372BC 10360BC (7.5%) 10302BC 10288BC (7.2%) 10224BC 10167BC (0.5%) 10156BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase I	Early Neolithic	Ditch 12DHAIIG21 Shell	10470±50	10710BC (0.5%) 10700BC 10675BC (56.8%) 10476BC 10452BC (35.4%) 10216BC 10207BC (0.8%) 10191BC 10181BC (2.0%) 10152BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase I	Early Neolithic	Layer 11DHAIIT1006(3) Vegetable fiber tempered shard	10460±50	10671BC (49.3%) 10475BC 10454BC (46.2%) 10152BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase I	Early Neolithic	Ditch 12DHAIIG21 Shell	10460±60	10706BC (0.2%) 10701BC 10674BC (93.8%) 10147BC 10136BC (1.4%) 10109BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase I	Early Neolithic	Ditch 12DHAIIG22 Charred organic residue	10430±50	10661BC (13.5%) 10586BC 10548BC (79.7%) 10146BC 10138BC (2.3%) 10107BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase I	Early Neolithic	Ditch 12DHAIIG21 Shell	10410±50	10646BC (6.3%) 10593BC 10542BC (88.4%) 10092BC 10066BC (0.7%) 10055BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase I	Early Neolithic	Ditch 12DHAIIG21 Shell	10400±50	10638BC (3.8%) 10598BC 10536BC (89.8%) 10091BC 10077BC (1.8%) 10054BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase I	Early Neolithic	Pit 12DHAIH189 Charred organic residue	10330±60	10526BC (94.6%) 9983BC 9952BC (0.8%) 9937BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase I	Early Neolithic	Ditch 12DHAIIG22 Catfish bone	10380±30	10524BC (95.4%) 10098BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase I	Early Neolithic	Ditch 12DHAIIG22 Charred organic residue	10300±50	10513BC (16.8%) 10398BC 10381BC (4.1%) 10348BC 10323BC (5.6%) 10274BC 10249BC (67.2%) 9926BC 9908BC (1.7%) 9884BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase I	Early Neolithic	Pit 12DHAIH233 Vegetable fiber tempered shard	10210±60	10484BC (1.5%) 10446BC 10372BC (0.3%) 10361BC 10300BC (0.2%) 10290BC 10221BC (1.5%) 10169BC 10155BC (89.0%) 9737BC 9724BC (2.6%) 9667BC 9572BC (0.3%) 9561BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase I	Early Neolithic	Pit 12DHAIH233 Charred organic residue	10060±50	9866BC (92.6%) 9444BC 9425BC (2.9%) 9396BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase I	Early Neolithic	Pit 11DHAIH248 Dog bone	10016±52	9791BC (95.4%) 9330BC	Zhongguo 2017/Xi'an
Houtaomuga	Early	Pit 12DHAIH189	9900±50	9656BC (3.5%) 9609BC	Kunikita et al.

phase I	Neolithic	Charred organic residue		9550BC (5.4%) 9483BC 9456BC (86.6%) 9256BC	2017/Tokyo
Houtaomuga phase I	Early Neolithic	Ditch 12DHAIIG22 Charred organic residue	9770±90	9452BC (77.5%) 9046BC 9026BC (18.0%) 8824BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase I	Early Neolithic	Tomb 11DHAIIM45 Human bone	9750±30	9292BC (93.9%) 9198BC 9180BC (1.5%) 9166BC	Zhongguo 2017/Beijing
Shuangta phase I	Early Neolithic	Tomb 07TSIIM10 Human bone	9550±45	9151BC (95.4%) 8752BC	Jilin and Jilin 2013/Beijing University
Shuangta phase I	Early Neolithic	Layer 07TSIIT1414(1) Charred organic residue	9400±60	9111BC (0.6%) 9096BC 9048BC (1.5%) 9024BC 8830BC (91.1%) 8540BC 8513BC (2.2%) 8480BC	Kunikita et al. 2017/Tokyo
Shuangta phase I	Early Neolithic	Layer 07TSIIT406(2):4 Charred organic residue	7820±40	6798BC (0.2%) 6795BC 6774BC (91.1%) 6564BC 6552BC (4.2%) 6507BC	Kunikita et al. 2017/Tokyo
Shuangta phase I	Early Neolithic	Shards' pile 07TSIIC1:2 Charred organic residue	7450±50	6422BC (95.4%) 6230BC	Kunikita et al. 2017/Tokyo
Shuangta phase I	Early Neolithic	Layer 07TSIIT107(2) Charred organic residue	7400±50	6398BC (79.9%) 6212BC 6190BC (15.5%) 6088BC	Kunikita et al. 2017/Tokyo
Shuangta phase I	Early Neolithic	Shards' pile 07TSIIC2:3 Charred organic residue	7260±45	6226BC (95.4%) 6029BC	Kunikita et al. 2017/Tokyo
Shuangta phase I	Early Neolithic	Shards' pile 07TSIIC2:1 Charred organic residue	7125±40	6070BC (75.8%) 5970BC 5952BC (19.7%) 5912BC	Kunikita et al. 2017/Tokyo
Tengjiagang	Middle Neolithic	Layer Human bone	7575±85	6592BC (95.4%) 6244BC	Zhongguo 1992
Tengjiagang	Middle Neolithic	83ATM1 Human bone	6981±69	5989BC (95.4%) 5729BC	Ma et al. 2005
Tengjiagang	Middle Neolithic	94ATM1 Human bone	4741±87	3702BC (1.1%) 3680BC 3656BC (94.3%) 3353BC	Ma et al. 2005
Houtaomuga phase II	Middle Neolithic	Pit 12DHAIH246 Charred organic residue	7085±45	6060BC (93.1%) 5882BC 5861BC (2.4%) 5847BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase II	Middle Neolithic	Pit 11DHAIH132 :1 Charred organic residue	7080±60	6068BC (95.4%) 5834BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase II	Middle Neolithic	Tomb 11DHAIIM56 Human bone	7075±30	6020BC (95.4%) 5888BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga phase II	Middle Neolithic	Ditch 11DHAIH8:2 Charred organic residue	6930±50	5971BC (3.4%) 5951BC 5914BC (92.0%) 5722BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase II	Middle Neolithic	Pit 11DHAIH93 Charred organic residue	6810±40	5761BC (95.4%) 5626BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase II	Middle Neolithic	Ditch 12DHAIH13 Charred organic residue	6755±40	5725BC (92.8%) 5620BC 5580BC (2.7%) 5570BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase II	Middle Neolithic	Tomb 11DHAIIM32 Human bone	6680±30	5660BC (95.4%) 5535BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga phase II	Middle Neolithic	Tomb 11DHAIIM54B Human bone	6495±25	5518BC (4.1%) 5500BC 5482BC (19.5%) 5465BC 5450BC (71.8%) 5376BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga phase II	Middle Neolithic	Tomb 11DHAIIM54A Human bone	6450±25	5476BC (95.4%) 5368BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga phase II	Middle Neolithic	Tomb 11DHAIIM54C Human bone	6430±25	5475BC (90.7%) 5356BC 5349BC (4.8%) 5331BC	Zhongguo 2017/Beijing and Xi'an
Xinglongwa	Middle Neolithic	House F119(3) Charcoal	7470±115 7260±115	6566BC (0.7%) 6551BC 6508BC (94.7%) 6072BC 6394BC (92.3%) 5971BC 5951BC (3.2%) 5912BC	Zhongguo 1992/Zhao 2003: 180
Xinglongwa	Middle Neolithic	House F119(4) Charcoal	7240±95 7040±95	6370BC (4.5%) 6298BC 6268BC (87.9%) 5972BC 5950BC (3.0%) 5915BC 6068BC (95.4%) 5733BC	Zhongguo 1992/Zhao 2003: 180
Xinglongwa	Middle Neolithic	House F119(2) Charcoal	6895±205 6700±205	6221BC (3.5%) 6121BC 6108BC (91.9%) 5475BC 6014BC (94.3%) 5299BC 5256BC (1.2%) 5222BC	Zhongguo 1992/Zhao 2003: 180
Xinglongwa	Middle Neolithic	House F121(2) Charcoal	6965±95 6770±95	6018BC (93.2%) 5706BC 5696BC (2.3%) 5669BC 5878BC (0.9%) 5866BC 5844BC (93.1%) 5517BC 5500BC (1.4%) 5482BC	Zhongguo 1992/Zhao 2003: 180
Xinglongwa	Middle Neolithic	House F121(4) Charcoal	6694±48	5714BC (94.7%) 5526BC 5491BC (0.7%) 5486BC	Zhao 2003: 180

Xinglongwa	Middle Neolithic	House F1180(3) Charcoal	6775±105	5886BC (2.4%) 5857BC 5850BC (93.0%) 5482BC	Zhao 2003: 180
Xinglongwa	Middle Neolithic	House F194(2) Charcoal	6603±107	5722BC (95.4%) 5363BC	Zhao 2003: 180
Xinglongwa	Middle Neolithic	House F200(4) Charcoal	6543±128	5714BC (93.2%) 5300BC 5256BC (2.2%) 5222BC	Zhao 2003: 180
Xinglongwa	Middle Neolithic	House IF133(3) Charcoal	5865±90 5700±90	4948BC (95.4%) 4500BC 4770BC (0.4%) 4764BC 4725BC (95.1%) 4352BC	Zhongguo 1992
Xinglongwa	Middle Neolithic	House IF101(3) Charcoal	5660±170 5500±170	4936BC (92.7%) 4224BC 4199BC (1.2%) 4164BC 4128BC (0.4%) 4111BC 4100BC (1.1%) 4062BC 4714BC (95.4%) 3974BC	Zhongguo 1992
Xinglongwa	Middle Neolithic	House IF142(1) Charcoal	5735±85 5570±85	4784BC (3.8%) 4742BC 4734BC (86.9%) 4441BC 4423BC (4.8%) 4368BC 4610BC (95.4%) 4249BC	Zhongguo 1992
Baiyinchanghan	Middle Neolithic	House F25 Charcoal	7040±100	6075BC (95.4%) 5724BC	Zhao 2003: 180
Baiyinchanghan	Middle Neolithic	House F13 Charcoal	6590±85	5664BC (95.4%) 5373BC	Zhao 2003: 180
Angangxi/Elasu C	Middle Neolithic	Charred organic residue	6630±35	5625BC (84.1%) 5512BC 5506BC (11.3%) 5482BC	Onuki et al. 2013
Angangxi/Elasu C	Middle Neolithic	Charred organic residue	6610±40	5620BC (29.4%) 5580BC 5571BC (66.1%) 5480BC	Onuki et al. 2013
Angangxi/Elasu C	Middle Neolithic	Charred organic residue	6510±40	5558BC (95.4%) 5373BC	Onuki et al. 2013
Zhaobaogou	Middle Neolithic	House F6(1) Charcoal	6220±85 6040±85	5364BC (95.4%) 4950BC 5209BC (93.1%) 4778BC 4755BC (2.3%) 4728BC	Zhongguo 1992/Zhao 2003:214
Zhaobaogou	Middle Neolithic	House F2(2) Charcoal	6210±85 6030±85	5360BC (95.4%) 4943BC 5208BC (6.3%) 5154BC 5126BC (89.1%) 4723BC	Zhongguo 1992/Zhao 2003: 212
Zhaobaogou	Middle Neolithic	House F7(2) Charcoal	6155±95 5980±95	5311BC (95.4%) 4846BC 5208BC (3.1%) 5161BC 5122BC (1.3%) 5093BC 5080BC (90.1%) 4656BC 4636BC (0.9%) 4616BC	Zhongguo 1992/Zhao 2003: 214
Zuojiashan phase I	Middle Neolithic	Layer BBNZT11(3) Shell	6100±80 5930±80	5284BC (0.6%) 5274BC 5217BC (93.7%) 4831BC 4816BC (1.2%) 4799BC 5026BC (0.3%) 5018BC 5011BC (95.1%) 4604BC	Jilin 1989/Zhongguo1992
Houtaomuga phase III	Middle Neolithic	House 11DHAIIF2 Charcoal	5403±32	4342BC (83.9%) 4228BC 4196BC (8.8%) 4167BC 4094BC (2.8%) 4070BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga phase III	Middle Neolithic	House 15DHAIF22(1) :67 Charred organic residue	5380±40	4336BC (59.1%) 4219BC 4204BC (17.3%) 4161BC 4133BC (19.1%) 4056BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase III	Middle Neolithic	House 11DHAIIF4 Charcoal	5352±32	4325BC (13.3%) 4288BC 4264BC (48.1%) 4156BC 4138BC (34.0%) 4052BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga phase III	Middle Neolithic	House 11DHAIIF3 Charcoal	5335±29	4317BC (4.6%) 4297BC 4254BC (46.3%) 4153BC 4142BC (44.5%) 4051BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga phase III	Middle Neolithic	House 11DHAIIF4 Charcoal	5330±29	4314BC (2.7%) 4300BC 4252BC (45.5%) 4152BC 4144BC (47.3%) 4050BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga phase III	Middle Neolithic	Pit 12DHAIVH44 Charred organic residue	5210±35	4221BC (2.6%) 4201BC 4164BC (8.0%) 4132BC 4061BC (84.9%) 3955BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase III	Middle Neolithic	Ditch 11DHAIIF6 Charcoal	5200±25	4049BC (95.4%) 3961BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga phase III	Middle Neolithic	Pit 12DHAIIF157(2):17 Charred organic residue	5100±40	3978BC (95.4%) 3794BC	Kunikita et al. 2017/Tokyo

Houtaomuga phase III	Middle Neolithic	Tomb 11DHAIIM50 Human bone	5020±30	3946BC (47.9%) 3828BC 3822BC (47.6%) 3708BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga phase III	Middle Neolithic	House 11DHAIIF6 Charcoal	5030±25	3946BC (90.5%) 3762BC 3738BC (5.0%) 3713BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga phase III	Middle Neolithic	House 11DHAIIF6 Charcoal	4990±25	3932BC (11.8%) 3876BC 3804BC (75.8%) 3701BC 3681BC (7.9%) 3655BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga phase III	Middle Neolithic	House 11DHAIIF6 Charcoal	4980±25	3901BC (4.1%) 3879BC 3800BC (77.7%) 3696BC 3689BC (13.7%) 3653BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga phase III	Middle Neolithic	House 11DHAIIF6 Charcoal	4975±25	3892BC (1.7%) 3882BC 3798BC (93.8%) 3652BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga phase III	Middle Neolithic	Layer 11DHAIIT1307(2) Charred organic residue	4920±35	3771BC (95.4%) 3641BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase III	Middle Neolithic	Ditch 11DHAIIG1 Charcoal	4890±30	3763BC (3.8%) 3737BC 3714BC (91.7%) 3632BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga phase III	Middle Neolithic	House 11DHAIIF1 Charcoal (hearth)	4790±40	3646BC (92.3%) 3513BC 3424BC (1.8%) 3410BC 3395BC (1.4%) 3384BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga phase III	Middle Neolithic	Tomb 11DHAIIM79 Charcoal	4785±27	3636BC (95.4%) 3526BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga III	Middle Neolithic	House 11DHAIIF1 Charcoal (hearth)	4730±40	3632BC (38.1%) 3550BC 3544BC (22.2%) 3492BC 3460BC (35.2%) 3376BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga III	Middle Neolithic	House 11DHAIIF1 Charcoal (hearth)	4740±35	3634BC (70.9%) 3496BC 3451BC (0.8%) 3446BC 3439BC (23.8%) 3378BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga III	Middle Neolithic	House 11DHAIIF1 Charcoal	4695±35	3622BC (8.3%) 3582BC 3531BC (87.2%) 3370BC	Zhongguo 2017/Beijing and Xi'an
Yuanbaogou	Middle Neolithic	Pit 85JNBYH5 Animal bone	5490±145 5330±145	4673BC (1.6%) 4635BC 4616BC (91.8%) 4036BC 4026BC (2.0%) 3988BC 4452BC (91.5%) 3902BC 3879BC (3.9%) 3800BC	Zhongguo 1992
Wutaishan	Middle Neolithic	House 2017NWAIF2:6 Animal bone	5460±30	4356BC (45.5%) 4312BC 4303BC (50.0%) 4250BC	Beta Analytics
Wutaishan	Middle Neolithic	House 2018NWAIF2 ②:74 Animal bone	5360±30	4328BC (18.7%) 4286BC 4268BC (24.5%) 4216BC 4206BC (24.1%) 4158BC 4136BC (28.1%) 4054BC	Beta Analytics
Wutaishan	Middle Neolithic	House 2017NWAIF6:15 Animal bone	5260±30	4230BC (15.2%) 4195BC 4168BC (34.5%) 4092BC 4082BC (45.8%) 3984BC	Beta Analytics
Wutaishan	Middle Neolithic	Pit 2017NWAIF8:z17 Animal bone	5140±30	4040BC (6.4%) 4017BC 3994BC (61.2%) 3928BC 3876BC (27.8%) 3804BC	Beta Analytics
Dongmingga	Middle Neolithic	House F4	5075±30	3956BC (95.4%) 3796BC	Heilongjiang 2019a/Beijing
Dongmingga	Middle Neolithic	House F1	4850±25	3702BC (4.4%) 3684BC 3656BC (66.4%) 3626BC 3578BC (24.7%) 3532BC	Heilongjiang 2019a/Beijing
Dongmingga	Middle Neolithic	Tomb M4	4785±20	3636BC (95.4%) 3527BC	Heilongjiang 2019a/Beijing
Dongmingga	Middle Neolithic	House F5	4770±25	3636BC (95.4%) 3518BC	Heilongjiang 2019a/Beijing
Haminmangha	Late Neolithic	House F18 Charcoal	4715±30	3626BC (21.9%) 3560BC 3534BC (23.5%) 3492BC 3464BC (50.1%) 3374BC	Zhu 2016/Beijing University
Haminmangha	Late Neolithic	House F21 Charcoal	4720±30	3628BC (27.3%) 3558BC 3536BC (23.0%) 3492BC 3462BC (45.1%) 3375BC	Zhu 2016/Beijing University
Haminmangha	Late Neolithic	House F23 Charcoal	4605±45	3520BC (81.0%) 3324BC 3233BC (8.4%) 3178BC 3158BC (6.1%) 3107BC	Zhu 2016/Beijing University
Haminmangha	Late Neolithic	House F24 Charcoal	4590±35	3509BC (31.4%) 3428BC 3382BC (43.8%) 3322BC 3234BC (12.2%) 3178BC 3160BC (8.1%) 3106BC	Zhu 2016/Beijing University
Haminmangha	Late Neolithic	House F26 Charcoal	4645±40	3522BC (95.4%) 3358BC	Zhu 2016/Beijing University
Haminmangha	Late Neolithic	House F37:1 Human bone	4600±25	3498BC (44.7%) 3436BC 3380BC (49.6%) 3338BC	Zhu 2016/Beijing University

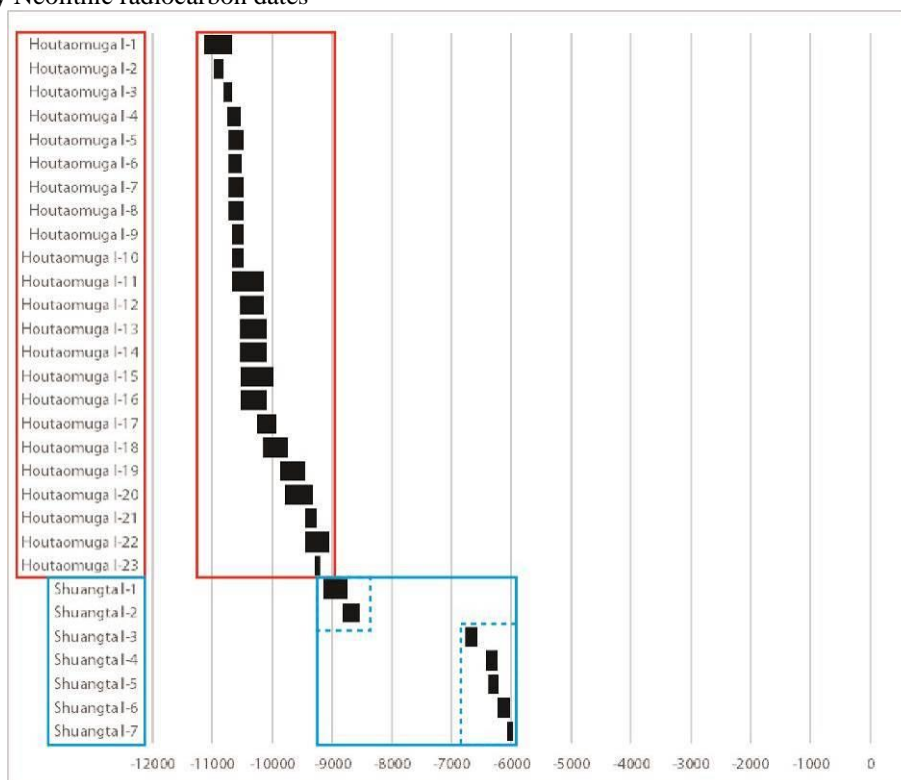
				3206BC (1.2%) 3196BC	
Haminmangha	Late Neolithic	House F37:2 Human bone	4690±20	3524BC (24.6%) 3490BC 3466BC (70.9%) 3374BC	Zhu 2016/Beijing University
Haminmangha	Late Neolithic	House F37:3 Human bone	4615±25	3504BC (63.7%) 3430BC 3380BC (31.7%) 3348BC	Zhu 2016/Beijing University
Haminmangha	Late Neolithic	House F40:1 Human bone	4570±20	3486BC (2.5%) 3472BC 3374BC (70.9%) 3330BC 3216BC (15.3%) 3186BC 3154BC (6.7%) 3120BC	Zhu 2016/Beijing University
Haminmangha	Late Neolithic	House F40:2 Human bone	4645±25	3515BC (75.3%) 3422BC 3413BC (5.5%) 3393BC 3385BC (14.6%) 3362BC	Zhu 2016/Beijing University
Haminmangha	Late Neolithic	House F40:5 Human bone	4660±20	3516BC (84.1%) 3391BC 3386BC (11.3%) 3368BC	Zhu 2016/Beijing University
Haminmangha	Late Neolithic	House F40:6 Human bone	4535±25	3365BC (27.7%) 3308BC 3299BC (2.3%) 3284BC 3274BC (0.9%) 3267BC 3242BC (64.5%) 3102BC	Zhu 2016/Beijing University
Haminmangha	Late Neolithic	House F40:7 Human bone	4450±40	3338BC (38.6%) 3208BC 3196BC (50.6%) 3008BC 2986BC (6.3%) 2932BC	Zhu 2016/Beijing University
Xinle Lower Level	Late Neolithic	House 78r1F2103 Charcoal	6620±150 6430±150	5833BC (94.8%) 5305BC 5246BC (0.7%) 5228BC 5640BC (95.4%) 5040BC	Zhongguo 1992/Shenyang and Xinle 2018
Longshanlu-Xinle Lower Level	Late Neolithic	House 2014HXF1 Charcoal	6200±30	5292BC (4.8%) 5265BC 5220BC (9.1%) 5196BC 5191BC (81.6%) 5046BC	Shenyang and Xinle 2018/Beijing
Xinle Lower Level	Late Neolithic	House 2016SXF16-1 Hazelnut shell	6205±30	5296BC (7.5%) 5260BC 5220BC (9.4%) 5196BC 5190BC (78.5%) 5046BC	Shenyang and Xinle 2018/Beijing
Xinle Lower Level	Late Neolithic	House 2016SXF16-2 Hazelnut shell	6165±35	5212BC (95.4%) 5008BC	Shenyang and Xinle 2018/Beijing
Xinle Lower Level	Late Neolithic	Pit 73SXH2 Charcoal	6145±120 5975±120	5360BC (95.4%) 4791BC 5210BC (95.0%) 4597BC 4564BC (0.4%) 4555BC	Zhongguo 1992/Shenyang and Xinle 2018
Xinle Lower Level	Late Neolithic	544 Millet seed	6040±30	5026BC (95.4%) 4842BC	Shenyang and Xinle 2018/Beijing
Longshanlu-Xinle Lower Level	Late Neolithic	House 2014HXF3 Charcoal	6020±25	4995BC (95.4%) 4839BC	Shenyang and Xinle 2018/Beijing
Xinle Lower Level	Late Neolithic	344 Apple seed	5970±25	4940BC (95.4%) 4785BC	Shenyang and Xinle 2018/Beijing
Xinle Lower Level	Late Neolithic	345 Chestnut shell	5970±30	4944BC (93.2%) 4781BC 4750BC (2.2%) 4730BC	Shenyang and Xinle 2018/Beijing
Xinle Lower Level	Late Neolithic	House 2016SXF2 Millet seed	5910±30	4878BC (0.5%) 4874BC 4846BC (95.0%) 4712BC	Shenyang and Xinle 2018/Beijing
Houtaomuga phase IV	Late Neolithic	Pit 11DHAIIIH85 Charred organic residue	4420±45	3331BC (22.7%) 3216BC 3188BC (5.4%) 3152BC 3131BC (67.4%) 2915BC	Kunikita et al. 2017/Tokyo
Houtaomuga phase IV	Late Neolithic	Pit 11DHAIIIH85 Charred organic residue	4420±35	3327BC (18.3%) 3228BC 3183BC (3.4%) 3156BC 3110BC (73.8%) 2918BC	Kunikita et al. 2017/Tokyo
Zuojiashan phase III	Middle Neolithic	Pit PH3H17 Animal bone	4375±80 4250±80	3338BC (18.9%) 3208BC 3195BC (76.5%) 2883BC 3086BC (1.8%) 3058BC 3030BC (93.6%) 2580BC	Jilin 1989/Zhongguo 1992
Honghe	Late Neolithic	Tomb M105 Human bone	3960±30	2571BC (32.8%) 2516BC 2502BC (52.7%) 2400BC 2383BC (10.0%) 2346BC	Heilongjiang 2019b/Beta Analytics
Honghe	Late Neolithic	Tomb M103 Human Bone	3900±30	2468BC (95.4%) 2294BC	Heilongjiang 2019b/Beta Analytics
Xiaolaha phase I-B	Late Neolithic	Ditch G3002 Animal bone	3688±104	2452BC (1.4%) 2420BC 2406BC (1.5%) 2376BC 2352BC (88.5%) 1872BC 1847BC (4.1%) 1774BC	Heilongjiang and Jilin 1998
Houtaomuga V	Bronze Age	Tomb 11DHAIIIM25 Charcoal	2470±35	766BC (92.7%) 462BC 437BC (2.8%) 420BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga VI	Iron Age	Tomb 12DHAIVM2 Charcoal	2299±23	405BC (80.4%) 356BC 280BC (15.0%) 232BC	Zhongguo 2017/Beijing and Xi'an
Houtaomuga VI	Iron Age	Tomb 12DHAIVM3 Charcoal	2316±28	414BC (85.5%) 356BC 280BC (9.9%) 232BC	Zhongguo 2017/Beijing and Xi'an

Xiaolaha phase III	Iron Age	House F0001 Charcoal	2127±103	394BC (94.8%) 80AD 98AD (0.6%) 109AD	Heilongjiang and Jilin 1998
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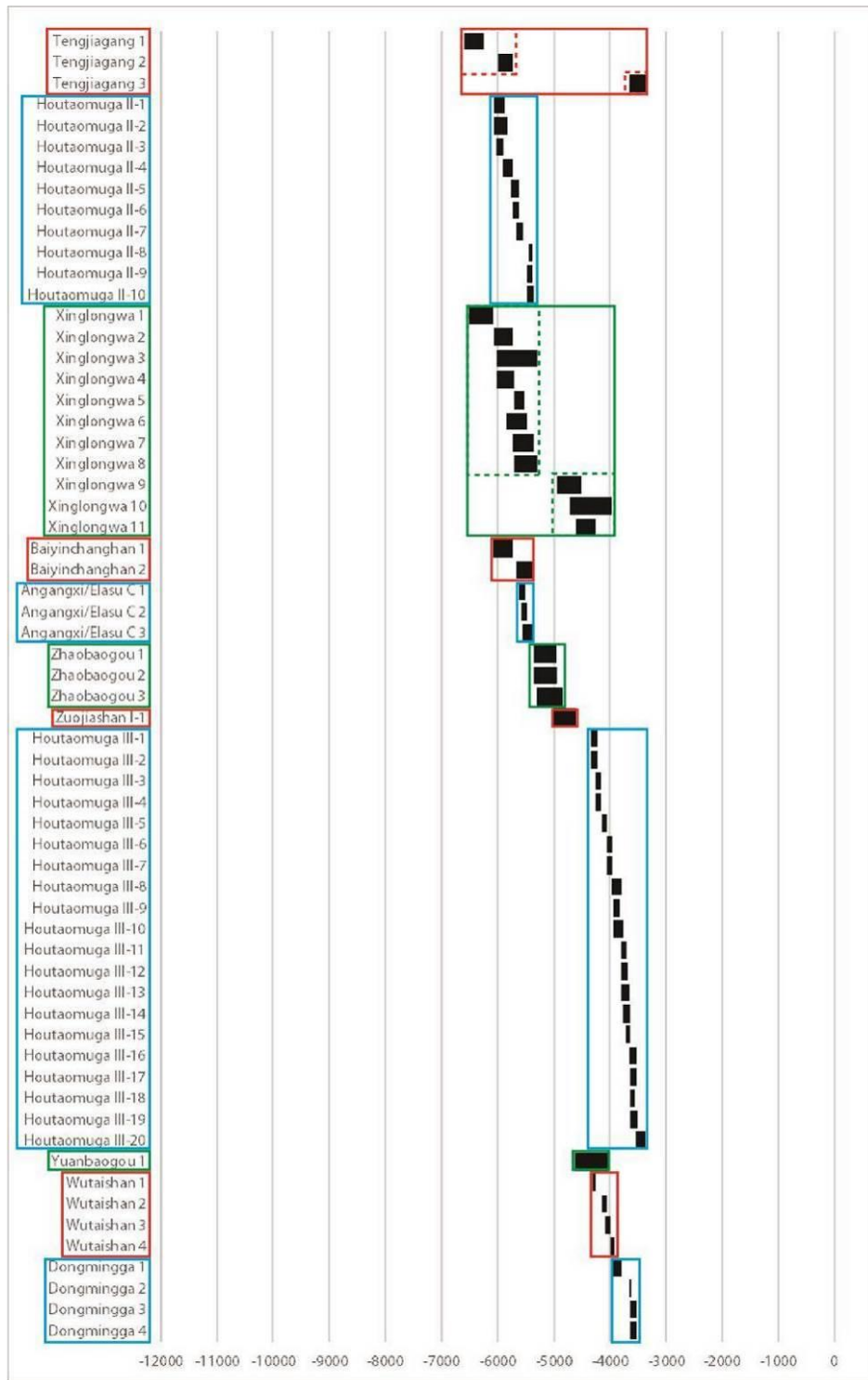
Table 2 Shuangta site phase I thermoluminescence dates (Jilin and Jilin 2013/Beijing University)

Sample	Date BP
Ditch 07TSIIG3-South Pottery shard	TL 10162±630
Ditch 07TSIIG3-North Pottery shard	TL 9445±710
Pit 07TSIIC1 Pottery shard	TL 10400±600
Pit 07TSIIC2 Pottery shard	TL 10202±1000
Pit 07TSIIT107(2) Pottery shard	TL 9679±750

Graph 1 Early Neolithic radiocarbon dates



Graph 2 Middle Neolithic radiocarbon dates



Graph 3 Late Neolithic, Bronze Age, and Iron Age radiocarbon dates

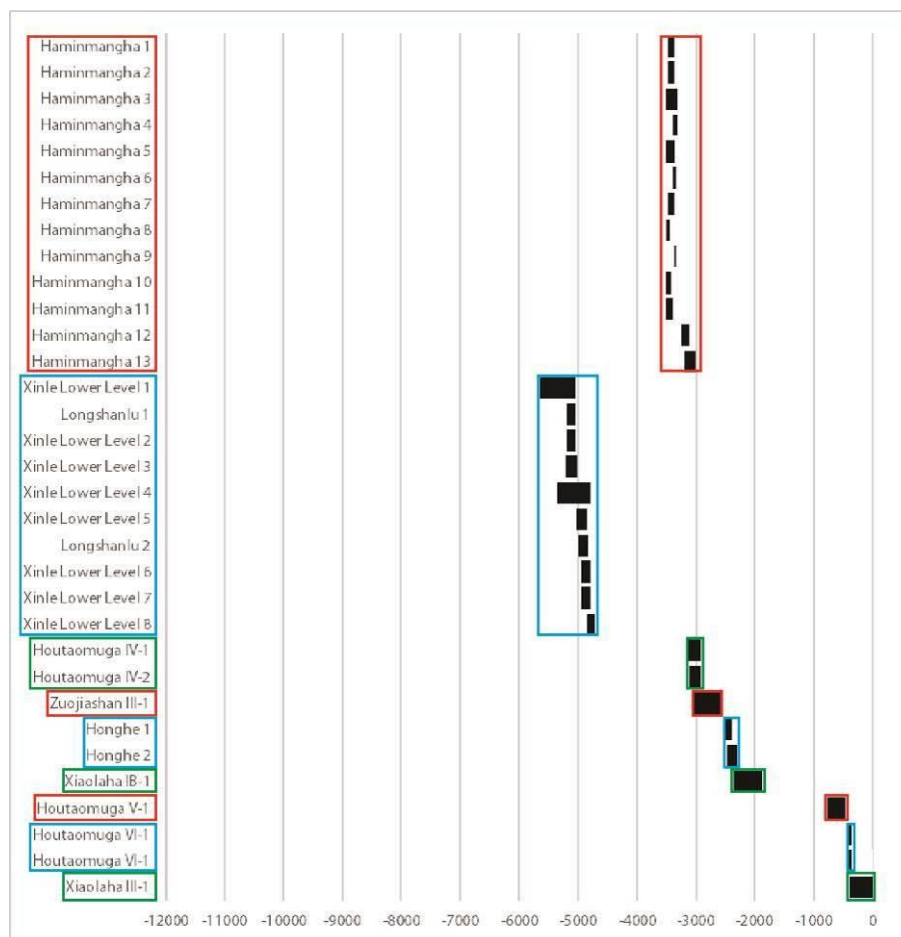


Table 3 List of petrographic analysis samples

Num.	US	Site / Phase	Location	Fabric description	Shell inclusion frequency*
DH01	12DHAIIG018(1)	Houtaomuga I	Lower Nen river	DH-1 Organic temper	Few
DH02	12DHAIIG018(1)	Houtaomuga I	Lower Nen river	DH-1 Organic temper	Rare
DH03	12DHAIIG018(1)	Houtaomuga I	Lower Nen river	DH-1 Organic temper	None
DH04	12DHAIIG018(1)	Houtaomuga I	Lower Nen river	DH-1 Organic temper	Few
DH05	12DHAIIG268(1)	Houtaomuga I	Lower Nen river	DH-1 Organic temper	Rare
DH06	12DHAIIG018(1)	Houtaomuga I	Lower Nen river	DH-1 Organic temper	Rare
DH07	11DHAIIG002(1)	Houtaomuga II	Lower Nen river	DH-2 Shell fabric	Predominant
DH08	11DHAIIG003(1)	Houtaomuga II	Lower Nen river	DH-2 Shell fabric	Predominant
DH09	11DHAIIG003(1)	Houtaomuga II	Lower Nen river	DH-3 Calcareous fabric	Frequent
DH10	11DHAIIG003(1)	Houtaomuga II	Lower Nen river	DH-2 Shell fabric	Dominant
DH11	11DHAIIG003(1)	Houtaomuga II	Lower Nen river	DH-2 Shell fabric	Dominant
DH12	11DHAIIG014(1)	Houtaomuga II	Lower Nen river	DH-2 Shell fabric	Predominant
DH13	11DHAIIG001(1)	Houtaomuga III	Lower Nen river	DH-4 Shell+quartz fabric	Common
DH14	11DHAIIG001(1)	Houtaomuga III	Lower Nen river	DH-4 Shell+quartz fabric	Frequent
DH15	11DHAIIG070(1)	Houtaomuga III	Lower Nen river	DH-4 Shell+quartz fabric	Common
DH16	11DHAIIG070(1)	Houtaomuga III	Lower Nen river	DH-4 Shell+quartz fabric	Common
DH17	11DHAIIG001(1)	Houtaomuga III	Lower Nen river	DH-4 Shell+quartz fabric	Common
DH18	14DHAIIF018(2)	Houtaomuga IV	Lower Nen river	DH-4 Shell+quartz fabric	Common
DH19	12DHAIIVH018(1)	Houtaomuga IV	Lower Nen river	DH-4 Shell+quartz fabric	Common
DH20	14DHAIIF014(1)	Houtaomuga IV	Lower Nen river	DH-4 Shell+quartz fabric	Common
DH21	14DHAIIF014(2)	Houtaomuga IV	Lower Nen river	DH-3 Calcareous fabric	Common
DH22	11DHAIIG085(1)	Houtaomuga IV	Lower Nen river	DH-4 Shell+quartz fabric	Few
TTC01	07TTCIII	Changtuozhi	Lower Nen river	TTC-1 Volcanic rock	Few
TTC02	07TTCIII	Changtuozhi	Lower Nen river	TTC-2 Granitic fabric	Common
TTC03	07TTCIII	Changtuozhi	Lower Nen river	TTC-3 Shell+organic	Dominant
TTC04	07TTCIII	Changtuozhi	Lower Nen river	TTC-4 Coarse fabric	Frequent
TTC05	07TCIB	Changtuozhi	Lower Nen river	TTC-5 Shell fabric	Predominant
TTC06	07TCIB	Changtuozhi	Lower Nen river	TTC-5 Shell fabric	Predominant
TS01	07TSIIT119(2)	Shuangta I	Lower Nen river	TS-1 Organic fabric	None

TS02	07TSIIT130(2)	Shuangta I	Lower Nen river	TS-1 Organic fabric	None
TS03	07TSIIT109(2)	Shuangta I	Lower Nen river	TS-2 Coarse organic fabric	Few
TS04	07TSIIT(1)	Shuangta I	Lower Nen river	TS-3 Shell fabric	Predominant
TS05	07TSIIT102(2)	Shuangta I	Lower Nen river	TS-3 Shell fabric	Dominant
TS06	07TSIIT306(2)	Shuangta I	Lower Nen river	TS-3 Shell fabric	Predominant
TS08	07TSIIT106(2)	Shuangta I	Lower Nen river	TS-3 Shell fabric	Predominant
TS09	07TSIIT110(2)	Shuangta I	Lower Nen river	TS-3 Shell fabric	Predominant
QH01	15QHF006(1)	Honghe	Upper Nen river	QH-2 Quartz+shell fabric	Common
QH02	15QHF006(1)	Honghe	Upper Nen river	QH-1 Shell fabric	Predominant
QH03	15QHF006(1)	Honghe	Upper Nen river	QH-1 Shell fabric	Predominant
QH04	15QHF006(1)	Honghe	Upper Nen river	QH-1 Shell fabric	Predominant
QH05	15QHF006(1)	Honghe	Upper Nen river	QH-1 Shell fabric	Predominant
QH06	15QHF006(1)	Honghe	Upper Nen river	QH-2 Quartz+shell fabric	Frequent
QH07	15QHF007(1)	Honghe	Upper Nen river	QH-3 Quartz fabric	None
QH08	15QHF007(1)	Honghe	Upper Nen river	QH-2 Quartz+shell fabric	Few
QH09	15QHF007(1)	Honghe	Upper Nen river	QH-2 Quartz+shell fabric	Few
QH10	15QHF007(1)	Honghe	Upper Nen river	QH-2 Quartz+shell fabric	Rare
QH11	15QHF007(1)	Honghe	Upper Nen river	QH-2 Quartz+shell fabric	Common
QH12	15QHF007(1)	Honghe	Upper Nen river	QH-2 Quartz+shell fabric	Few
QH13	14QHF001(2)	Honghe	Upper Nen river	QH-1 Shell fabric	Predominant
QH14	14QHF001(2)	Honghe	Upper Nen river	QH-1 Shell fabric	Dominant
QH15	14QHF001(2)	Honghe	Upper Nen river	QH-1 Shell fabric	Predominant
QH16	14QHF001(2)	Honghe	Upper Nen river	QH-1 Shell fabric	Predominant
QH17	14QHF001(2)	Honghe	Upper Nen river	QH-1 Shell fabric	Predominant
QH18	14QHF001(2)	Honghe	Upper Nen river	QH-2 Quartz+shell fabric	Common
QH19	14QHF004(1)	Honghe	Upper Nen river	QH-2 Quartz+shell fabric	Few
QH20	14QHF004(1)	Honghe	Upper Nen river	QH-2 Quartz+shell fabric	Common
QH21	14QHF004(1)	Honghe	Upper Nen river	QH-2 Quartz+shell fabric	Frequent
QH22	14QHF004(1)	Honghe	Upper Nen river	QH-3 Quartz fabric	None
QH23	14QHF004(1)	Honghe	Upper Nen river	QH-2 Quartz+shell fabric	Common
QH24	14QHF004(1)	Honghe	Upper Nen river	QH-2 Quartz+shell fabric	Common
QH25	14QHF002(1)	Honghe	Upper Nen river	QH-2 Quartz+shell fabric	Few
QH26	14QHF002(1)	Honghe	Upper Nen river	QH-3 Quartz fabric	None
QH27	14QHF002(1)	Honghe	Upper Nen river	QH-2 Quartz+shell fabric	Few
QH28	14QHF002(1)	Honghe	Upper Nen river	QH-2 Quartz+shell fabric	Few
QH29	14QHF002(1)	Honghe	Upper Nen river	QH-2 Quartz+shell fabric	Frequent
QH30	14QHF002(1)	Honghe	Upper Nen river	QH-2 Quartz+shell fabric	Rare
QH31	14QHF002(1)	Honghe	Upper Nen river	QH-2 Quartz+shell fabric	Common
NW01	17NWAIF006(2)	Wutaishan	Yitong River Valley	NW-1 Fine quartz fabric	None
NW02	17NWDIF001(1)	Wutaishan	Yitong River Valley	NW-1 Fine quartz fabric	None
NW03	18NWAIF013(1)	Wutaishan	Yitong River Valley	NW-1 Fine quartz fabric	None
NW04	18NWAIF1507(3)a	Wutaishan	Yitong River Valley	NW-1 Fine quartz fabric	None
NW05	17NWDIT0303(3)	Wutaishan	Yitong River Valley	NW-3 Microcline fabric	None
NW07	17NWDIT0301(3)	Wutaishan	Yitong River Valley	NW-2 Polycrystalline quartz fabric	None
NW08	17NWDIF001(1)	Wutaishan	Yitong River Valley	NW-2 Polycrystalline quartz fabric	None
NW09	17NWDIF001(1)	Wutaishan	Yitong River Valley	NW-3 Microcline fabric	None
NW10	17NWDIF002(1)	Wutaishan	Yitong River Valley	NW-3 Microcline fabric	None
NW11	17NWDIT0202(3)	Wutaishan	Yitong River Valley	NW-2 Polycrystalline quartz fabric	None
NW12	17NWDIT0202(3)	Wutaishan	Yitong River Valley	NW-2 Polycrystalline quartz fabric	None
NW13	17NWDIT0304(3)	Wutaishan	Yitong River Valley	NW-2 Polycrystalline quartz fabric	None
NW18	17NWDIT0302(3)	Wutaishan	Yitong River Valley	NW-4 Shell fabric	Predominant
NW19	17NWDIT0303(3)	Wutaishan	Yitong River Valley	NW-4 Shell fabric	Predominant
NW20	17NWDIT0202(3)	Wutaishan	Yitong River Valley	NW-4 Shell fabric	Predominant
NW21	17NWDIT0301(3)	Wutaishan	Yitong River Valley	NW-1 Fine quartz fabric	None
NW22	17NWDIT0302(3)	Wutaishan	Yitong River Valley	NW-4 Shell fragments fabric	Predominant
NW23	17NWDIT0302(3)	Wutaishan	Yitong River Valley	NW-1 Fine quartz fabric	None
NW24	18NWAIF008(2)	Wutaishan	Yitong River Valley	NW-1 Fine quartz fabric	None

* Frequency labels: predominant (>70%), dominant (70-50%), frequent (50-30%), common (30-15%), few (15-5%), rare (<5%), absent (0%) (Quinn 2022: 98-113).

Table 4 STP sites dataset

Site	Status of the site: excavated/surveyed	Period	Cultural attribution	Shell temper	Frequency of shell- tempered sherds	Fiber- temper	Frequency of fiber- tempered sherds	Sand temper	Sand temper grain size	Frequency of sand- tempered sherds
Jubaoshan	Excavated	Late Neolithic	Haminmangha culture	Present	n/a	Absent	None	Present	n/a	n/a
Tengjiagang	Excavated	Middle Neolithic	Huangjiaweizi culture	Present	n/a	Absent	None	Present	n/a	Majority
Haminmangha	Excavated	Late Neolithic	Haminmangha culture	Present	Minority	Absent	None	Present	Thin and very thin	Majority
Pianliancheng	Inventory survey	Middle Neolithic	culture of the Lower Level of Zuojiashan	Present	n/a	Absent	None	Present	n/a	n/a
Zuojiashan	Excavated	Middle Neolithic	culture of the Lower Level of Zuojiashan	Present	Minority	Absent	None	Present	Thin	Majority
Zuojiashan	Excavated	Middle Neolithic	culture of the Upper Level of Zuojiashan	Present	Predominant	Absent	None	Present	n/a	Few
Liangjiazi	Inventory survey	Middle Neolithic	culture of the Lower Level of Zuojiashan	Present	Minority	Absent	None	Present	Thin	Majority
Yuanbaogou nan	Inventory survey	Middle Neolithic	culture of the Lower Level of Zuojiashan	Present	n/a	Absent	None	Present	Thin	n/a
Xiaochengzi	Inventory survey	Bronze Age	Xituanshan culture	Present	Minority	Absent	None	Present	Thin and very thin	Majority
Wutaishan	Excavated	Middle Neolithic	culture of the Lower Level of Zuojiashan	Present	Few	Absent	None	Present	Thin	Majority
Changshan	Excavated	Middle Neolithic	n/a	Present	Minority	Absent	None	Present	Coarse, thin and very thin	Majority
Zhengjiatun xituozhi	Inventory survey	Late Neolithic	Hongshan culture	Present	n/a	Absent	None	Present	Coarse and very thin	n/a
Mutoubanla	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	Thin	n/a
Shuangta	Excavated	Early Neolithic	culture of Shuangta phase I	Present	Predominant	Absent	None	Present	n/a	Few
Changxin nanshan	Inventory survey	Late Neolithic	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Houtaomuga	Excavated	Early Neolithic	culture of Houtaomuga phase I	Present	Few	Present	Predominant	Absent	None	None
Houtaomuga	Excavated		Huangjiaweizi culture	Present	Predominant	Absent	None	Absent	None	None
Houtaomuga	Excavated		culture of Houtaomuga phase III	Present	Majority	Absent	None	Present	Thin	Few
Houtaomuga	Excavated	Late neolithic	culture of Houtaomuga phase IV	Present	n/a	Absent	None	Present	n/a	n/a
Renjiashan houshan	Inventory survey	Neolithic	n/a	Present	Predominant	Absent	None	Absent	None	None

Minzhong	Inventory survey	Neolithic	n/a	Present	Predominant	Absent	None	Absent	None	None
Qiantaogesu	Inventory survey	Neolithic	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Houdiwopu	Systematic survey	Middle Neolithic	culture of Houtaomuga phase III	Present	Predominant	Absent	None	Absent	None	None
Houxinhuang	Systematic survey	Middle Neolithic	Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Predominant	Absent	None	Absent	None	None
Zouderen	Systematic survey	Early Neolithic	culture of Houtaomuga phase I - Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Predominant	Present	Few	Absent	None	None
Chujiawopu	Systematic survey	Middle Neolithic	Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Predominant	Absent	None	Absent	None	None
Dongcaijiadian xinan	Systematic survey	Middle Neolithic	Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Predominant	Absent	None	Absent	None	None
Dongshantou	Systematic survey	Middle Neolithic	Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Predominant	Absent	None	Absent	None	None
Erjingzi	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	Very thin	n/a
Tantu beigangzi	Inventory survey	Middle Neolithic	n/a	Present	n/a	Absent	None	Present	Coarse and thin	n/a
Donghatuqi	Inventory survey	Middle Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Fengshuishan	Inventory survey	Middle Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Nahanshao	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	Thin	n/a
Qian'erlong nangang	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Taipingshan	Inventory survey	Neolithic	n/a	Present	Minority	Absent	None	Present	Thin	Majority
Haointailai beigang	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Erjingzi xigang	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	Very thin	n/a
Gedaloushan	Inventory survey	Neolithic	n/a	Present	Predominant	Absent	None	Absent	None	None
Shuanglongshan	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Houbutai	Inventory survey	Early Neolithic	culture of Houtaomuga phase I	Present	n/a	Absent	None	Present	n/a	n/a
Taolagao beigang	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Sukema	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Naodaiwopu	Inventory survey	Middle Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a

Haoshentu xishan	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Yingtai	Inventory survey	Middle Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Dongfanghong	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	Very thin	n/a
Caojiatun beigang	Inventory survey	Bronze Age	n/a	Present	n/a	Absent	None	Present	Very thin	n/a
Wulantu beigang	Excavated	Middle Neolithic	culture of Houtaomuga phase III	Present	Predominant	Absent	None	Present	n/a	Few
Tuanjie	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Erdaogangzi	Inventory survey	Middle Neolithic	n/a	Present	Predominant	Absent	None	Absent	None	None
Xingyecun	Inventory survey	Neolithic	n/a	Present	Majority	Absent	None	Present	Very thin	Minority
Duanjiadian	Inventory survey	Neolithic	n/a	Present	Predominant	Absent	None	Present	n/a	Few
Tiancaizhan donggang	Inventory survey	Neolithic	n/a	Present	Predominant	Absent	None	Absent	None	None
Yao'erliba	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	Thin	n/a
Langangangzi	Inventory survey	Neolithic	n/a	Present	Predominant	Absent	None	Absent	None	None
Dagang	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Daguantun	Inventory survey	Middle Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Xiangyang nangang	Excavated	Middle Neolithic	culture of Houtaomuga phase III	Present	Minority	Absent	None	Present	Thin	Majority
Suogutai	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Longfengshan	Inventory survey	Middle Neolithic	n/a	Present	n/a	Absent	None	Present	Coarse and very thin	n/a
Huangjiaweizi	Excavated	Middle Neolithic	Huangjiaweizi culture	Present	Predominant	Absent	None	Present	n/a	Few
Daqinghe	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Xiaoqinghe	Inventory survey	Neolithic	n/a	Present	Predominant	Absent	None	Absent	None	None
Shuangbaodai	Inventory survey	Middle Neolithic	n/a	Present	Majority	Absent	None	Present	n/a	Minority
Sifangshan	Inventory survey	Middle Neolithic	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Houshaoli	Systematic survey	Bronze Age	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Boliyingzi	Inventory survey	Middle Neolithic	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Haositai	Inventory survey	Bronze Age	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Dongtaiping	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Majiaweizi	Inventory survey	Neolithic	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Baomin machang bei	Inventory survey	Early Neolithic	culture of Houtaomuga phase I	Present	Predominant	Absent	None	Absent	None	None
Taoshentu	Inventory survey	Late Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a

Naqihai beishan	Inventory survey	Bronze Age	n/a	Present	Majority	Absent	None	Present	n/a	Minority
Zhanghai cun nangang	Inventory survey	Bronze Age	n/a	Present	Predominant	Absent	None	Present	n/a	Few
Yaohangnai	Inventory survey	Late Neolithic	n/a	Present	Predominant	Absent	None	Absent	None	None
Bagedai	Inventory survey	Bronze Age	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Hulitai xishan	Inventory survey	Middle Neolithic	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Qian'erlong xibeigang	Inventory survey	Bronze Age	n/a	Present	Predominant	Absent	None	Absent	None	None
Zhushan	Inventory survey	Bronze Age	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Yuanbaotu	Inventory survey	Late Neolithic	n/a	Present	Few	Absent	None	Present	n/a	Predominant
Mitai	Inventory survey	Bronze Age	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Baolitonbeigang	Inventory survey	Neolithic	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Tuanshanzi	Inventory survey	Bronze Age	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Hatuqi xigang	Inventory survey	Bronze Age	n/a	Present	Predominant	Absent	None	Absent	None	None
Erligatu donggang	Inventory survey	Bronze Age	n/a	Present	Predominant	Absent	None	Absent	None	None
Qinjiashan	Inventory survey	Bronze Age	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Fenghuangtuozi	Inventory survey	Bronze Age	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Weihai xibei I hao didian	Systematic survey	Middle Neolithic	Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Predominant	Absent	None	Absent	None	None
Weihai xibei II hao didian	Systematic survey	Early Neolithic	culture of Houtaomuga phase I - Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Predominant	Present	Few	Absent	None	None
Weihai bei	Systematic survey	Early Neolithic	Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Minority	Present	Majority	Absent	None	None
Weihai	Systematic survey	Middle Neolithic	Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Predominant	Absent	None	Absent	None	None
Xi'anzhao xinan	Systematic survey	Middle Neolithic	Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Predominant	Absent	None	Absent	None	None
Fuxin	Systematic survey	Early Neolithic	Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Majority	Present	Minority	Absent	None	None
Fuxin xinan II hao didian	Systematic survey	Middle Neolithic	culture of Houtaomuga phase I - Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Predominant	Absent	None	Absent	None	None

Xi'erlong xinan	Systematic survey	Early Neolithic	Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Predominant	Present	Few	Absent	None	None
Sijiazidong	Systematic survey	Middle Neolithic	Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Predominant	Absent	None	Absent	None	None
Nanmo	Systematic survey	Middle Neolithic	Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Predominant	Absent	None	Absent	None	None
Dailaigangzi	Systematic survey	Middle Neolithic	Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Predominant	Absent	None	Absent	None	None
Guoying yuchang dongbei	Systematic survey	Middle Neolithic	culture of Houtaomuga phase I - Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Predominant	Absent	None	Absent	None	None
Moshihai bei	Systematic survey	Middle Neolithic	Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Predominant	Absent	None	Absent	None	None
Moshihai dong	Systematic survey	Middle Neolithic	Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Predominant	Absent	None	Absent	None	None
Yaojingzi	Excavated	Middle Neolithic	Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Minority	Absent	None	Present	n/a	Majority
Tiejiaoshan	Inventory survey	Middle Neolithic	Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Minority	Absent	None	Present	n/a	Majority
Hamaqin	Inventory survey	Middle Neolithic	culture of Houtaomuga phase I - Huangjiaweizi culture – culture of Houtaomuga phase III	Present	n/a	Absent	None	Present	Coarse	n/a
Xituozi	Inventory survey	Middle Neolithic	Huangjiaweizi culture – culture of Houtaomuga phase III	Present	Few	Absent	None	Present	Coarse, thin and very thin	Predominant
Gongyefu xigang	Inventory survey	Middle Neolithic	n/a	Present	n/a	Absent	None	Present	Very thin	n/a
Tongjiadian xigang	Inventory survey	Late Neolithic	n/a	Present	n/a	Absent	None	Present	Thin and very thin	n/a
Lengjia tuozi xibeigang	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Houshiqihaotun beigang	Inventory survey	Neolithic	n/a	Present	Minority	Absent	None	Present	Thin	Majority
Beidianzi	Inventory survey	Neolithic	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Beizhengzhen nangang	Inventory survey	Late Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a

Wanfu	Inventory survey	Neolithic	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Yongsheng	Inventory survey	Neolithic	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Zhongxing	Inventory survey	Middle Neolithic	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Qianshiliuhaotun xigang	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	Coarse	n/a
Wangxiangzheng	Inventory survey	Middle Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Xijiushiyaotun	Inventory survey	Neolithic	n/a	Present	Predominant	Absent	None	Absent	None	None
Gongyefu beigang	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Guangrongtuozhi	Inventory survey	Neolithic	n/a	Present	Few	Absent	None	Present	Very thin	Predominant
Dong Jiushisanhaotun	Inventory survey	Late Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Xishiwuhaotun beigang	Inventory survey	Bronze Age	n/a	Present	Few	Absent	None	Present	Thin and very thin	Predominant
Qishiliuhaotun donggang	Inventory survey	Bronze Age	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Xiaoliuhaotun	Inventory survey	Bronze Age	n/a	Present	Few	Absent	None	Present	n/a	Predominant
Xishijiuhaotun	Inventory survey	Bronze Age	n/a	Present	Predominant	Absent	None	Absent	None	None
Xibashiyihaotun nangang	Inventory survey	Bronze Age	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Qianbashibaohaotun dongbeigang	Inventory survey	Bronze Age	n/a	Present	n/a	Absent	None	Present	Coarse	n/a
Qianbashibaohaotun beigang	Inventory survey	Bronze Age	n/a	Present	Predominant	Absent	None	Absent	None	None
Taipingchuan	Inventory survey	Bronze Age	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Hou'ershahaotun xibeigang	Inventory survey	Bronze Age	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Hou'ershahaotun dongbeigang	Inventory survey	Bronze Age	n/a	Present	n/a	Absent	None	Present	Coarse	n/a
Chuanzijing nangang	Inventory survey	Middle Neolithic	culture of the Lower Level of Zuojiashan	Present	n/a	Absent	None	Present	n/a	n/a
Xiyuzijing xigang	Inventory survey	Neolithic	n/a	Present	Few	Absent	None	Present	n/a	Predominant
Dashizijing nan	Inventory survey	Neolithic	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Dashi xibeigang	Inventory survey	Bronze Age	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Zhenzijing	Inventory survey	Bronze Age	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Caizijing	Inventory survey	Bronze Age	n/a	Present	Predominant	Absent	None	Absent	None	None
Caozijing	Inventory survey	Bronze Age	n/a	Present	n/a	Absent	None	Present	Coarse	n/a

Chuizijing	Inventory survey	Bronze Age	n/a	Present	n/a	Absent	None	Present	Very thin	n/a
Gongzijing	Inventory survey	Bronze Age	n/a	Present	Predominant	Absent	None	Absent	None	None
Caozijing xinan	Inventory survey	Bronze Age	n/a	Present	Majority	Absent	None	Present	n/a	Minority
Bingzijing	Inventory survey	Bronze Age	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Dongjinzijing	Inventory survey	Bronze Age	n/a	Present	Predominant	Absent	None	Absent	None	None
Xi shuangzijing	Inventory survey	Bronze Age	n/a	Present	Predominant	Absent	None	Absent	None	None
Xizhizijing	Inventory survey	Bronze Age	n/a	Present	Predominant	Absent	None	Absent	None	None
Yanzijing	Inventory survey	Bronze Age	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Wangzijing	Inventory survey	Bronze Age	n/a	Present	n/a	Absent	None	Present	Coarse	n/a
Anzijing	Inventory survey	Bronze Age	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Lingzijing	Inventory survey	Bronze Age	n/a	Present	Majority	Absent	None	Present	n/a	Minority
Chaozijing	Inventory survey	Bronze Age	n/a	Present	Predominant	Absent	None	Absent	None	None
Aobaoshan	Inventory survey	Late Neolithic	n/a	Present	n/a	Absent	None	Present	Coarse, thin and very thin	n/a
Tuanjie	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	Coarse	n/a
Xinglong yuchang	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	Coarse	n/a
Donghalamaotou	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Yaohalamaotou	Inventory survey	Neolithic	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Zhangjiantuozi	Inventory survey	Late Neolithic	n/a	Present	Minority	Absent	None	Present	Thin	Majority
Dongbeituozi	Inventory survey	Neolithic	n/a	Present	Predominant	Absent	None	Absent	None	None
Xiangjiawopu xinan	Inventory survey	Late Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Baiyintuhaitun	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	Thin	n/a
Jubaoshanhoutun	Inventory survey	Neolithic	n/a	Present	Minority	Absent	None	Present	Coarse	Majority
Miaopu nangang	Inventory survey	Middle Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Fangjiaweizi	Inventory survey	Middle Neolithic	n/a	Present	n/a	Absent	None	Present	Very thin	n/a
Kaoshantun	Inventory survey	Bronze Age	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Tongfamuchang dongbeigang	Inventory survey	Bronze Age	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Qianyongxingtun dong	Inventory survey	Bronze Age	n/a	Present	Predominant	Absent	None	Absent	None	None
Qianyongxingtun xi	Inventory survey	Bronze Age	n/a	Present	Predominant	Absent	None	Absent	None	None
Huanzishan	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a

Huangjiawopu	Inventory survey	Bronze Age	n/a	Present	n/a	Absent	None	Present	Very thin	n/a
Xihaotemangha	Inventory survey	Bronze Age	n/a	Present	n/a	Absent	None	Present	Coarse	Majority
Qingshantou	Inventory survey	Neolithic	n/a	Present	n/a	Absent	None	Present	Thin	n/a
Bolahu	Inventory survey	Bronze Age	n/a	Present	n/a	Absent	None	Present	Coarse	n/a
Wufu	Inventory survey	Neolithic	n/a	Present	Predominant	Absent	None	Present	n/a	Few
Honghe	Excavated	Late Neolithic	Angangxi culture	Present	Predominant	Absent	None	Absent	None	None
Angangxi shengli sandui yihao	Excavated	Middle Neolithic	culture of Houtaomuga phase III	Present	Minority	Absent	None	Present	n/a	Majority
Dongmingga	Excavated	Middle Neolithic	culture of Houtaomuga phase III	Present	Predominant	Absent	None	Absent	None	None
Songshulin	Inventory survey	Neolithic	n/a	Present	Predominant	Absent	None	Absent	None	None
Dongwenggenshan	Inventory survey	Middle Neolithic	n/a	Present	n/a	Absent	None	Absent	None	None
Zhuo'er	Inventory survey	Middle Neolithic	n/a	Present	Minority	Absent	None	Present	n/a	Majority
Liangkeshu	Inventory survey	Neolithic	n/a	Present	Minority	Absent	None	Present	Very thin	Majority
Nanda cun	Inventory survey	Neolithic	n/a	Present	Predominant	Absent	None	Absent	None	None
Changjiaweizi	Inventory survey	Middle Neolithic	n/a	Present	Predominant	Absent	None	Absent	None	None
Huxiantang	Inventory survey	Middle Neolithic	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Pingqiao	Inventory survey	Neolithic	n/a	Present	Predominant	Absent	None	Absent	None	None
Xiaolaha	Excavated	Late Neolithic	Angangxi culture	Present	Minority	Absent	None	Present	n/a	n/a
Niuchang	Excavated	Middle Neolithic	n/a	Present	n/a	Absent	None	Present	Very thin	n/a
Houqikeshu	Excavated	Iron Age	n/a	Present	n/a	Absent	None	Present	Coarse, thin and very thin	n/a
Shuikouxi	Inventory survey	Iron Age	n/a	Present	n/a	Absent	None	Present	Very thin	None
Dongyingdong	Inventory survey	Iron Age	n/a	Present	Predominant	Absent	None	Absent	None	None
Linchang dongbei	Inventory survey	Iron Age	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Shangzaoshan	Inventory survey	Iron Age	n/a	Present	n/a	Absent	None	Present	Thin	n/a
Shangfan	Inventory survey	Iron Age	n/a	Present	n/a	Absent	None	Present	n/a	n/a
Shangtaizi	Inventory survey	Iron Age	n/a	Present	n/a	Absent	None	Present	Thin and very thin	n/a
Zhengjia	Inventory survey	Iron Age	n/a	Present	n/a	Absent	None	Present	Thin	n/a
Changtuozi-3	Inventory survey	Early Neolithic	culture of Houtaomuga phase I – Type A of Changtuozi	Present	Predominant	Absent	None	Absent	None	None
Yaobotu	Excavated	Late Neolithic	Haminmangha culture	Present	Predominant	Absent	None	Present	n/a	Few

Xiaopaozi	Inventory survey	Middle Neolithic	Xinglongwa culture	Present	Minority	Absent	None	Present	n/a	Majority
Bayantaohai	Inventory survey	Middle Neolithic	n/a	Present	Minority	Absent	None	Present	n/a	n/a
Tuanjietun nangang	Inventory survey	Late Neolithic	Haminmangha culture	Present	n/a	Absent	None	Present	n/a	n/a

