The rise of Shimao 2800–1300 BC in the North Loess Plateau, China:

An exploration of the climate, demographic, economic, material culture influences

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Abstract

The recognition in 2011 of the extraordinary Shimao site (ca. 2300–1800 cal. BC) in the North Loess Plateau as late Neolithic China's largest stone fortification, has overturned our understanding of the development of complex societies in northern China. The 400-hectare stone fortification of Shimao lies at the heart of the climate-sensitive region (hereafter the Shimao region), which located at the junction of modern-day south-central Inner Mongolia, northern Shaanxi and northern Shanxi, featuring numerous stone fortifications during the period ca. 2800–1300 cal. BC. The settlements in this region have the unusual combinations of herd animals, millet, ceramic tripods, and high-valued jade and bronze artefacts, suggesting a development in wealth and social economy. The central question addressed in this thesis is how and why Shimao, along with the surrounding settlements, flourished in the south sector of the region.

Currently, we cannot determine what drove the growth and complexity of Shimao and other similar sites because the development process in demography and social economy in the Shimao region is poorly understood—the problem has not been interrogated from a wholistic regional perspective. A more precise chronology is also required to provide context to identify changes over time and space. The first problem addressed is a review of all the radiocarbon dates from the published literature; these dates are scrutinised for quality and then subjected to Bayesian modelling for a firmer chronology. The other sources of information—settlement size and distribution, economic basis as judged from faunal abundances and mortality profiles, and ceramic tripods associated with food preparation—are considered within this chronological framework in order to identify new development during the Shimao period.

The findings suggest that population shifted and became concentrated in the south sector of the region, with the development of a new socio-economic network, which contained Shimao and the surrounding sites. Within this network, Shimao acted as a ritual centre with a highly concentrated population and attracted people from the surrounding area; meanwhile, people in this network adopted and used herd animals and new forms of ceramic tripods in their own ways. The findings also suggest that the form of urbanism

developed at and around Shimao is unique: a central role can be seen at Shimao in social and ritual contexts, but centralisation and clear urban-rural relations among sites cannot be identified in animal and ceramic economies. Both the pulling factor from Shimao and the climate factor, which may have introduced indirect and gradual influences on human decision and activities, were significant for the success of Shimao and the wider region.

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Chapter 1

Introduction

The extraordinary site of Shimao, in the North Loess Plateau, was rediscovered in 2011 (Shaanxi et al., 2013). This site is now recognised as the largest stone fortification in late Neolithic China and is currently dated to 2300–1800 cal. BC (Sun et al., 2018).[1] This fortification was originally thought to be part of the Great Wall, built during the more recent dynastic periods. Shimao is extraordinary in a number of ways. First is its great size–excavations suggest that the site is at least 400 hectares in size, suggesting the involvement of a large labour-force and hence population (Jaang et al., 2018). Second is its location—near the edge of the dry Loess Plateau and in a region far north of the heartland of Chinese Neolithic agricultural developments. Third is its apparently rapid rise and the appearance of a relatively large number of sites in the immediate region, with similar features but much less extensive. The striking discoveries from Shimao (Shaanxi, 2016a), and its location in relation to the many smaller sites have led to suggestions that it served as a political, ritual and economic centre (Sun, 2016; Sun et al., 2018). Together with the surrounding settlements, a hierarchical system also seemed to have formed (Wang & Guo, 2016), and Shimao has recently been described as the first urban centre in the North Loess Plateau (Sun et al., 2018), as well interpreted from an urbanism perspective (He et al., 2021; Owlett et al., 2018a, 2018b; Sheng et al., 2021; Womack et al., 2021).

[1] BC is used throughout the thesis when it comes to dates because it is what most of the archaeological literatures uses. Where palaeoclimatic and environmental studies use BP to refer to dates, the dates from these studies will be converted to BC where necessary.

The settlements around Shimao and in the broader area of the North Loess Plateau that share similar features of subsistence, built environment and material culture, draw our attention to the need to understand the process through which such an unprecedently large stone fortification emerged. These groups of settlements, with numerous stone-walled fortifications, are distributed at the junction of modern-day south-central Inner Mongolia, northern Shaanxi and northern Shanxi provinces along the Yellow River valley (Figure 1.1). This area is part of the border area of China that has been called the 'arc',[2] referring to regions 'from Sichuan in the west, through Qinghai and the Hexi Corridor in Gansu, across parts of Shaanxi, Shanxi, and Inner Mongolia, to northern Hebei and Chifeng in Liaoning in the east' (Figure 1.1) (Rawson, 2013, 2015). Because these settlements are considered as a regional unity for the purposes of this thesis, the region is referred to as the 'Shimao region' hereafter. It refers to the settlement groups located in the North Loess Plateau that shared a similar subsistence, built environment and material culture, but not necessarily a shared cultural identity. The name Shimao is used to represent the study area because the site of Shimao itself combines in one place the characteristic features of the area as a whole: namely, the scale and distinctive features of fortification structures, ritual performance, and the appearance of herd animals (sheep, goat and cattle), ceramic tripods, jades and bronzes.

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[2] The border area was first named as the *banyue xing didai* by Tong Enzheng (1987) and translated as the 'crescent-shaped cultural-contact zone' in Hein (2014). It refers to the region covers the plateau area in Qinghai, Ningxia, Inner Mongolia, Liaoning and Jilin that shared similar environmental precondition and cultural features of using microliths and stone-construction graves.

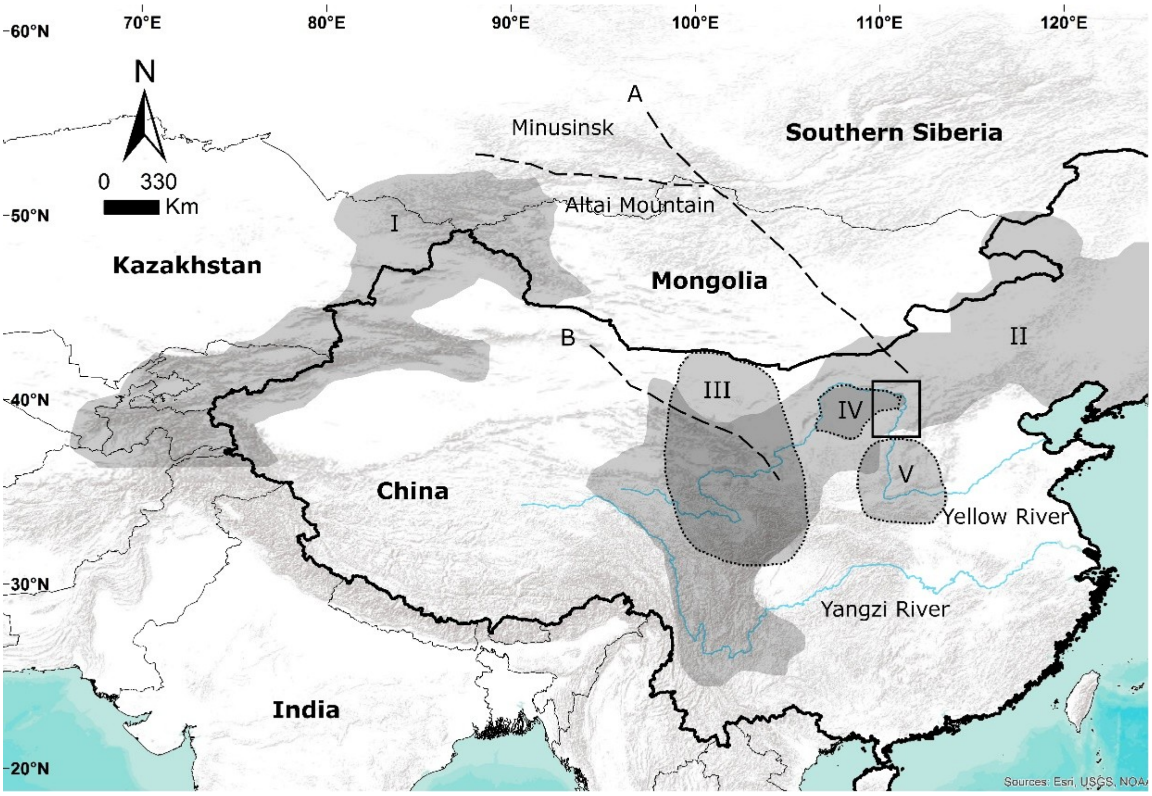


Figure 1.1. Regions (shaded area) and routes (dash lines) mentioned in Chapter 1. I: Inner Asian Mountain Corridor; II: the 'arc' defined by Rawson (2013, 2015) referring to regions 'from Sichuan in the west, through Qinghai and the Hexi corridor in Gansu, across parts of Shaanxi, Shanxi, and Inner Mongolia, to northern Hebei and Chifeng in Liaoning in the east'; III: Ejin River Transfer Zone defined by Jaang (2015) referring to the Ejin river valley to the Helan mountains, covers most portions of Gansu, Qinghai, and Ningxia provinces and the western portion of Inner Mongolia; IV: Ordos region; V: middle Yellow River valley. A: the 'steppe road' defined by Mei (2003) referring to the route 'runs from the northern frontier of China through Mongolia to southern Siberia and further west'; B: Hexi Corridor. The square shows the Shimao region located at the junction of today south-central Inner Mongolia, northern Shaanxi and northern Shanxi provinces along the Yellow River valley.

The rise and fall of the settlements in the Shimao region fall within a period of, in a wider pictureof the major transitions in early China at between 2500 and 1600 BC, which has often been linked to a drier and more fluctuating climate around this time (Dai, 2016a, Sun et al., 2018, Wang et al., 2014a). Before the rediscovery of Shimao, the Laohushan settlement group in the north sector of the region has already been suggested to have fall due to the drier climatic condition (Dai, 2016a; Sun et al., 2018; Tian, 1997; Tian & Guo, 2004; Wei, 2003; Wei & Cao 1999), based solely upon the palaeo-climatic and environmental studies done in 1988 (Tian & Guo, 2004). It is now thought that Shimao and the surrounding sites emerged after the collapse of Laohushan settlements (Sun et al. 2018). The climate in northern China has been suggested to have become drier between 2500 and 2000 BC. The drier climate has been widely interpreted as a consequence of the southwards retraction of the East Asian Summer Monsoon (EASM) belt (An et al., 2000; Chen et al., 2015a; Dong et al., 2018; Hosner et al., 2016; Jiang & Liu, 2007; Wagner et al., 2013). The drying trend may have had significant impacts on the Shimao region itself, but also on the regions to the north where the dry condition may have been much more severe, if the EASM retreated southwards. Linking the intervals of climatic events with archaeological ones, however, requires a precise chronology of these events at the first place (Jaffe & Hein, 2020; Jaffe et al., 2020).

According to the currently accepted chronology, from 2800 BC onwards, this region experienced dramatic transitions in demographic shift, population growth, subsistence mode, built environment and material culture (Hu et al., 2016; Sun, 2016; Sun & Shao, 2017; Sun et al., 2018; Wang & Sun, 2011), which seemed to be synchronous with the rise of Shimao from 2300–1800 BC. However, these developmental trajectories across the region remain poorly understood, because, until more published data became available in recent years, there was a gap in respect to knowledge of the developmental trajectories in the south sector of the region. It is thought that the population increased in the south sector of the Shimao region from 2800–2500 BC onwards (Sun, 2016; Zhang, 2017). This seems to suggest that population density shifted or even people moved southwards across the region (Dai, 2016a). This process was in line with the appearance of the largest site Shimao and surrounding smaller sites (Sun, 2016), the introduction of herding (Hu et al., 2016; Wang et al., 2014b; Yang et al., 2017), and the common use of ceramic tripods (Shao, 2019). A southwards developmental trajectory remains hypothetical given uncertainties in the timing. The current chronological sequence for this region in this period is built mainly upon ceramic typology, along with consideration of a limited number of radiocarbon dates. Further, there are issues in sampling methodology and interpretation of these dates, so that as a result the chronological sequence for the Shimao region, and the occupation dates of individual sites is currently uncertain. The lack of firm chronologies represents an impediment to understand the developmental trajectories in demography and socio-economy and to postulate on the context of Shimao with the sites surrounding and preceding it.

Currently, evidence related to population growth is mainly based on number of sites from archaeological surveys. What we have already known is that number of sites and larger walled sites increase in the Neolithic period, but this alone cannot be directly linked to population growth. Aside from the uncertainty of the dates of these sites, whether the settlement scale or population had increased and became concentrated at the time when Shimao emerged is also uncertain. Evidence for changes in subsistence mode is the adoption of herding, accompanying with the already developed millet cultivation and wild-game hunting. We have already known that domesticated herds (sheep, goat and cattle) appeared at more locations and in greater number at several sites—Shimao, Muzhuzhuliang, Zhaimaoliang, Xinhua, Zhukaigou and Huoshiliang—mainly in the south sector of the region during the time when Shimao emerged. However, this observation alone does not tell us about whether the preferences for animal species and ways of consumptions for herd animals differed between Shimao and the surrounding sites. The evidence for changes in material culture is reflected from the adoption and modification of ceramic tripods around and before the time when Shimao emerged. These tripods were previously thought to have first adopted in the Daihai Lake area in the north sector of the region. Recently, we have now learnt that they were also common in the south. The missing link is that it is uncertain when and where ceramic tripods were first adopted and how different ceramic types and forms spread across the Shimao region. It is therefore uncertain whether the intensive adoption and/or modification of tripods was synchronous with the emergence of Shimao together with other developments.

Consideration of the above leads to a requirement for a firm chronology in order to assess how the climate, demographic, economic and material culture influences gave rise to Shimao and the surrounding sites in the south sector of the Shimao region between 2300 and 1800 BC. Since the Shimao site was rediscovered in 2011, the new data published in recent years (mostly from the south sector of the region) have not yet been synthesised together with those published previously (mostly from the north sector of the region). It is therefore timely to explore all the sites together (both walled and non-walled) as a single unity in order to review the developmental trajectories across the region. Both evidence and information published recently and previously will be considered together. The hypothesis is that the timing of climate change was synchronous with demographic movement, settlement expansion and concentration when Shimao and the surrounding sites emerged, at the same time, a new form of socio-economic system developed reflected from the use of herd animals and ceramic tripods; and this whole process eventually gave rise to Shimao and the surrounding sites.

1.1 Aims and objectives

This thesis aims to identify the demographic and socio-economic transition processes in their chronological, spatial, economic, and material cultural contexts in order to understand better how and why the stone-fortification sites and particularly Shimao, which exemplifies the rise of the Shimao region, emerged in the south sector of the region between 2300 and 1800 BC. This is to understand whether populations likely moved southwards across the region, thus potentially boosting the population size and/or facilitating population concentration in the south, forming Shimao; and whether the use of herd animals and ceramic tripods became important and specialised when Shimao emerged. Multiple sources of published data and information, from palaeoclimatic and environmental studies, radiocarbon dates, settlement size and locations, qualification and locations of herd animals and pottery are considered.

These data and information are used to identify the said developmental trajectories through conducting quantitative analyses and showing the spatiotemporal patterns that reflect the results of these analyses on maps, when applicable.

The general objectives of this research are to: 1) establish a firmer context for the chronology of Shimao and the other smaller sites, 2) identify the shifting trend of human occupation across the region within the chronological context established in objective 1, 3) identify the scale and distribution of sites across the region within the chronological context established in objective 1, 4) identify the prevalence of herd animals and differences in herd management between Shimao other smaller sites , 5) identify the prevalence and distribution of different shapes of base and forms of ceramic across the region within the chronological context established in objective 1, 6) synthesis the patterns derived from objectives 2–4 to explain the climate, demographic, economic and material culture influences to the rise of Shimao. In this way, the thesis will provide a context to position the remarkable development of Shimao in a fuller context.

The thesis attempts to identify the currently poorly understood developmental trajectories in terms of demography and socio-economy across the Shimao region. The discussion on the said development process tends to be hypothetical in that it is simply based on superficial evidence, which limits us to understand the context of this region in the wider picture. The consideration of the recently published data in the south sector of the Shimao region, where Shimao emerged, with the previously published data for the entire the region will provide an overview of the transition process of the entire region. However, the approaches and methodologies applied in different parts of the thesis, as well as the consideration of all the sites as a single region has never been done previously. This will therefore help us better understand the developments and transitions across the region from a new perspective. Each of these analyses alone will contribute to the understanding of demographic and socio-economic developmental trajectories. The reconsideration of the chronological framework is especially significant because the chronology is always indeterminate, and a comprehensive re-examination is overdue. In a broader sense, this research will redefine the position, not only of Shimao, but also the North Loess Plateau as a region, in the context of the development process in early China, as well as the long-distance interaction within the wider network involving eastern Eurasia and Central Plains of China. Along with the new findings contributed from this research, this will help future studies to reconsider and reinterpret these wider processes.

1.2 The concepts of urbanism and state formation

The discovery of the large settlement of Shimao shows a need to reconsider the position of Shimao and more broadly the North Loess Plateau in the development process of early China. The concept of urbanism is useful in framing this thesis because the analysis in demographic and socio-economic aspects can tell us about the form of urbanism developed at Shimao. This concept was first raised by Childe (1950). He identified ten traits for the earliest states and cities as follows: increased settlement size, full-time craft specialization, social stratification, political organisation–state formation, monumental public buildings, writing, predictive science, concentration of agricultural surplus, foreign trade and sophisticated artistic style (Childe, 1950). Although Childe’s criteria did not become universal, the trait of large-scale settlement and higher population density has been considered as a broad and the most basic definition of urbanism (e.g. Flad, 2018; Owlett et al., 2018b; Underhill, 2018; Smith, 2009). The traits of craft specialization, concentration of agricultural surplus, social stratification and political organisation have also been considered as fundamental traits for urbanism (Smith, 2009).

The discussions of urbanism in China are relatively new and has changed over the last two decades as we have better understand the archaeological contexts of the sites such as Liangzhu, Taosi and Shimao. These new discoveries have provided us different perspectives on the urbanisation process developed at these sites (e.g. Brunson et al., 2016; Campbell et al., 2021, He, 2018a; Liu, 2019b; Liu et al., 2019; Refrew & Liu, 2018; Xu, 2018). In the past, Yinxu Anyang, which is located in the Central Plains, was often taken as the first major city based on the criteria more applicable to the settlements in Mesopotamia, including writing and metalwork. Now we understand that there are a great variety of urban forms for different settlements. This has led to a more nuanced view on identifying urbanism with a wide range of evidence, including but not limited to: 1) size of a large settlement comparing to surrounding settlements and the hierarchical structure formed by them, 2) organisation of labour force invested in public construction with some sorts of planning and management, 3) social stratification or manipulation of resources, objects and ritual practice by a specific group of people, and 4) diversity in food consumption drawn from different sources such as animals from husbandry and millet from crop fields.

While there is no consensus to define urbanism, and we now understand that early China involved a unique form of urbanism that goes beyond the traditional definitions (Yates, 1997), scholars have inclined to identify urbanism in a broader sense or focused on specific features. Flad (2018) has summarized different studies of urbanism and provided a definition of urbanism with four broad features: 1) large scale of settlement size with large population size and high density, 2) differentiation of urban sites from rural sites as well as non-urban sites, 3) the centrality of the proposed urban site in the broader region, and 4) ritual, sacrificial and violent performance can be seen at the proposed urban centre. He has also attempted to explore the urbanism features at Yinxu, Henan and Sanxingdui, Sichuan through these four aspects in order to provide an approach to interpret urbanism to different parts of the world. Similarly, Owlett et al. (2018b) have adopted a more flexible definition for urbanism, which refers to 1) large site size and/or high population density, 2) socio-political and ritual centrality within a regional polity, and 3) intra-site social and cultural differentiation and diversity. Some scholars have put their focus on the political, economic and ritual functions of the urban centre to its hinterland (e.g. He, 2018a; Sun et al., 2018), or see the development of cities is a result of population growth, settlement concentration, and a new production and exchange systems that come along with the formation of states (see Owlett et al., 2018b). Campbell et al. (2021) however has pointed out that the forms of urbanism are various at different time and locations; the features for urbanism can include having large public construction, large population size, investment in public goods and centralisation in political and social contexts. Since Shimao has recently been proposed as an urban centre with its important political, economic and ritual functions serving the surrounding smaller sites (Sun et al., 2018), we need to develop information to show ways in which Shimao can be considered as an urban centre and its form of urbanism.

The concept of state formation is also relevant as the position of Shimao in the context of the development process in early China will also be discussed in this thesis. The concept is relevant when it comes to the discussion of the development of complex societies in early China. As with the concept of a city, a state has been defined differently in various approaches (Liu, 2009a): 1) Xia Nai's approach defines a region as having a state-level political organisation if it has class differentiation, and an urban centre with political, religious and economic activities, involving writing and metallurgy; 2) Su Bingqi's approach defines a state as having the features of walled settlements, jade objects with dragon designs, large public architecture and burial differentiation, and 3) the social archaeological approach defines a state as a society with a minimum of two social strata of the ruling class and the commoner class, involving a minimum of four tiers of settlement hierarchy in the broader region. At present, Erlitou in Henan Central Plain is thought to be the most plausible earliest state-like society that we know today, based on the synthesis of the above approaches (Liu, 2009a; Liu & Chen 2003), although applying these definitions to the cases in early China is still controversial (Jaffe et al., forthcoming; Shelach & Jaffe, 2014; Shelach & Pines, 2006).

1.3 Borderland matrix approach

Since the Shimao region is located at the border area in the north sector of China, the studies of formation and development process of this region is associated to frontier studies. Frontier here is defined as the zone that separates one or more types of political or cultural units (Parker, 2006). In the case of the Shimao region, it is visualised as a frontier that separated the pastoralist and agriculturist communities, and the political or cultural entities of the Eurasian steppe to the north, and Central Plains of China to the south. This thesis applies the approach of the 'borderland matrix', proposed by Parker (2006), which considers the changes of different boundaries over time in order to understand the factors and mechanisms of the changes and developmental trajectory of the Shimao region. This model considers the formation and development of frontiers through a continuum of boundary dynamics including geographic, political, demographic, cultural and economic (Parker, 2006). Other scholars have also suggested considering multiple boundaries. For example, Lightfoot and Martinez (1995) discuss how frontier boundaries including linguistic, cultural, tribal and ethical are arbitrary and blurred in the archaeological record, and thus should be examined at different scales of temporal and spatial analysis. Similarly, Manning (1996) mentioned the need to consider a wider range of evidence, such as exchange of crops, domesticated animals, technology, materials, political institutions and family structure, when considering cross-cultural interaction. However, Parker (2006), sets out five major boundaries and suggests that the kind of smaller boundaries suggested by the scholars above, such as linguistic, should be assigned to one of those larger categories of cultural boundary.

This research is carried out with this approach, with various ranges of evidence from different boundaries being considered. These include palaeoclimatic and palaeoenvironmental evidence, radiocarbon dates, settlement size, faunal remains and ceramic tripods. According to the boundaries suggested by Parker (2006), palaeoclimatic and palaeoenvironmental evidence relate to climatic conditions belong to the geographic boundary. Radiocarbon dates relate to chronology, and distribution of occupation belongs to the demographic boundary. Exploration of faunal remains in relate to consumption of herd animals in subsistence economy belongs to the economic boundary but more relevant to social economy because it can be related to a self-sustained economy or a market-related economy. Ceramic tripods are themselves artefacts and part of the material culture created by people and this part therefore belongs to the cultural boundary.

Although there are issues in linking climate change to human response because of the mismatches of climatic and archaeological data, the potential role of climate change and external factors, such as new technological knowledge and ideas are still worth exploring. The reason is that the new technological knowledge and ideas, such as herding and stone-walled buildings, which we see in the Shimao region, were potentially consequences of population movement, since these required precise knowledge maintained by the local users and a significant labour force (Linduff & Mei, 2009). These are considered together with the local developmental trajectory in the region in this thesis, therefore, for an all-round approach. Parker (2006)'s approach, with its emphasis on the interplay between different boundaries that form the frontier over time fits this purpose well. These different boundaries can be explored independently and put together as different lenses to broaden the horizon of our understanding of transition processes across the region.

However, Parker only emphasises the changes over time but not the spatial changes of the continuum. As suggested by Lightfoot & Martinez (1995), both spatial and temporal analysis together are significant for studying frontier development since the continuum of the boundaries does not change only over time but also across a region. Indeed, even a small study area could show a very different spatiotemporal pattern. This is particularly useful in that the Shimao region can be divided into north and south sectors as well as into different areas. The advantage of combining the approach of a continuum of boundary dynamics with a spatiotemporal presentation is that it can provide a comprehensive pattern of the developmental trajectory over space and time across the Shimao region, which is something that we do not understand very well at present.

1.4 Methodology, data and sources

This research is literature-based, based on studies of published data available in the literature. Both walled and non-walled settlement sites in the Shimao region are considered in this research. The reason for studying these sites within a wider region is that they shared similar material cultures and built environment, and therefore should be considered together to identify the developmental trajectories in demography and socio-economy across the region.

The settlement sites from south-central Inner Mongolia, and their information, were mainly identified from the collection of Inner Mongolia archaeological reports from books (e.g. Neimenggu, 1994, 1997; Yang, 2000), surveys, brief and detailed excavation reports for individual sites (e.g. Neimenggu & Ordos, 2000; Tian, 1986), and journal papers that provide information about relevant sites (e.g. Baotou, 1984; Fu, 1989; Sun, 2000; Wei & Cai, 1999;

Wei & Wang, 1990), with the consideration of the Atlas of Chinese Cultural Relics of Inner Mongolia (Guojia wenwuju, 2003). Information for Shimao and the surrounding sites were mainly identified from brief and detailed excavation reports for individual sites (e.g. Shaanxi, 2002; Shaanxi & Yulin, 2005; Wang & Guo, 2015), the yearbook of archaeology in China (e.g. Li, 2007), the cultural relics newspaper, *Zhongguo Wenwubao* (e.g. Jia, 2015), and also the consideration of the Atlas of Chinese Cultural Relics for Shaanxi and Shanxi provinces (Guojia wenwuju, 1998; 2006). These materials are accessible from university libraries, through the inter-library loan service, and the online database of Chinese literature, such as CNKI. These data are mostly published in Chinese, mainly come from the national journals such as *Kaogu*, *Kaogu yu wenwu* and *Wenwu*. Another major source is the edited volumes published by the provincial archaeological institutes, such as that of Inner Mongolia and Shaanxi. The sites identified from these sources show that the Shimao region has at least 95 settlement sites among which 59 are walled. Only those sites whose occupation period, location and nature can be identified are considered in this research. These comprise 53 sites, including 24 walled sites. The information in relate to locations, coordinates, site size, whether the site is walled, and whether they contained herd animals, ceramic tripods, jade and bronzes were collected and recorded as the major database of this research (Table 1.1).

Site	Province	Area	Coordinate	Size (ha)	Wall	Moat	Pottery	Domestic herd animals	Millet	Jade	Copper/ bronze	Reference
Ashan	Inner Mongolia	South of Daqing Mountain	110.18, 40.57	5	Y	N	Y	N	N	N	N	Batou, 1984; Neimenggu & Baotou, 1984; Wei, 2003; Wei & Cao, 1999; Wei & Cui, 1994
Shamujia	Inner Mongolia	South of Daqing Mountain	110.33, 40.57	0.048	Y	N	Y	N	N	N	N	Baotou 1984; Sun, 2000; Wei, 2003; Wei & Cao, 1999; Wei & Cui, 1994
Heimaban	Inner Mongolia	South of Daqing Mountain	110.40, 40.57	2	Y	N	Y	N	N	N	N	Baotou 1984; Wei, 2003; Wei & Cao, 1999; Wei & Cui, 1994
Xishata	Inner Mongolia	South of Daqing Mountain	109.97, 40.98	2.1	N	N	Y	N	N	N	N	Baotou 1984; Wei, 2003; Wei & Cao, 1999; Wei & Cui, 1994
Weijun	Inner Mongolia	South of Daqing Mountain	110.48, 40.58	4	Y	N	N	N	N	N	N	Baotou 1984; Liu, 1988; Wei, 2003; Wei & Cao, 1999; Wei & Cui, 1994
Laohushan	Inner Mongolia	Dahai Lake	112.26, 40.45	13	Y	N	Y	N	N	N	N	Tian, 1986; Yang, 2000
Yuanzigou	Inner Mongolia	Dahai Lake	112.57, 40.60	30	N	N	Y	N	N	N	N	Yang, 2000
Bancheng	Inner Mongolia	Dahai Lake	112.31, 40.49	10	Y	N	Y	N	N	N	N	Neimenggu, 1991: 194; Yang, 2000
Yangchanggou	Inner Mongolia	Dahai Lake	112.49, 40.59	?	N	N	Y	N	N	N	N	Neimenggu & Beijing, 1991
Sandaogou	Inner Mongolia	Dahai Lake	112.46, 40.56	?	N	N	Y	N	N	N	N	Neimenggu & Beijing, 2004
Xibaiyu	Inner Mongolia	Dahai Lake	112.21, 40.45	9	Y	N	Y	N	N	N	N	Yang, 2000
Damiaopo	Inner Mongolia	Dahai Lake	112.60, 40.63	25	Y	N	Y	N	N	N	N	Yang, 2000
Mianpo	Inner Mongolia	Dahai Lake	112.23, 40.48	7	N	N	Y	N	N	N	N	Yang, 2000
Zhukaigou	Inner Mongolia	Ordos city	110.43, 39.64	50	N	N	Y	Y	N	Y	Y	Huang, 1996; Neimenggu & Ordos, 2000; Tian, 1988; Tian & Han, 2003; Tian & Guo, 1988
Dakou	Inner Mongolia	Qingshui River valley	111.12, 39.39	3	N	N	Y	?	Y	N	N	Ji & Ma, 1979
Baicaota	Inner Mongolia	Qingshui River valley	111.36, 39.92	?	Y	N	Y	N	N	N	N	Neimenggu, 1994: 183–204
Xiaoshaowan	Inner Mongolia	Qingshui River	111.36, 39.85	0.4	Y	N	Y	N	N	N	N	Neimenggu, 1994: 225–234; Wei &

Site	Province	Area	Coordinate	Size (ha)	Wall	Moat	Pottery	Domestic herd animals	Millet	Jade	Copper/ bronze	Reference
Zhaizisheng	Inner Mongolia	Qingshui River valley	111.35, 39.91	3	Y	N	Y	N	N	N	N	Neimenggu, 1994: 174–182; Wei & Cao, 1999
Zhaizita	Inner Mongolia	Qingshui River valley	111.34, 39.74	5	Y	N	Y	?	N	N	N	Neimenggu, 1991: 161-164; Wei & Cao, 1999; Neimenggu, 1997: 280–326
Erliban	Inner Mongolia	Qingshui River valley	111.28, 39.75	6	N	N	Y	N	N	N	Y	Neimenggu, 1991: 161-164; Neimenggu, 1994: 246–260
Gaojiaping	Inner Mongolia	Qingshui River valley	111.29, 39.81	5	N	N	Y	?	N	N	N	Neimenggu, 1994: 261-271
Guandi	Inner Mongolia	Qingshui River valley	111.30, 39.73	2	N	N	Y	N	N	N	N	Neimenggu, 1997: 85–119
Nanhao	Inner Mongolia	Qingshui River valley	111.28, 39.81	2.5	N	N	Y	N	N	N	N	Neimenggu, 1997: 205–224
Xiaomiao	Inner Mongolia	Qingshui River valley	111.29, 39.79	0.7	N	N	Y	N	N	N	N	Neimenggu, 1994: 272–277
Yongxingdian	Inner Mongolia	Qingshui River valley	111.28, 39.81	?	N	N	Y	?	N	Y	N	Neimenggu, 1994: 235–245
Zhaizigedan	Inner Mongolia	Qingshui River valley	111.36, 39.93	5	Y	N	N	N	N	N	N	Wang & Yang, 1999
Damiaogedan	Inner Mongolia	Qingshui River	111.33, 39.80	4	N	N	Y	N	N	N	N	Fu, 1989
Qingchaotai	Inner Mongolia	Qingshui River valley	111.20, 39.84	5	N	N	Y	N	N	N	N	Neimenggu &Yikezhao, 1990
Xiata	Inner Mongolia	Qingshui River	111.42, 39.97	28	Y	Y	N	N	N	N	N	Li, 2007; Zhang & Ding, 2016
Houchengzui	Inner Mongolia	Qingshui River valley	111.51, 39.95	138	Y	N	Y	N	N	N	N	Cui, 2003; Neimenggu, 1997: 151–164
Bainiyaozi	Inner Mongolia	Qingshui River valley	111.40, 40.09	-	N	N	Y	N	N	N	N	Cui, 2014; Cui & Si, 1984; Neimenggu, 1991: 161-164
Xicha	Inner Mongolia	Qingshui River valley	111.40, 39.69	120	N	N	Y	Y	N	Y	Y	Neimenggu & Qingshuihe, 2001; Yang, 2007
Zhuangwoping	Inner Mongolia	Qingshui River valley	111.63, 39.98	3	N	N	Y	N	N	N	Y	Neimenggu, 1997: 165–178; Neimenggu, 2007
Bicun	Shanxi	Weifen River valley	110.89, 38.50	75	Y	N	Y	N	N	Y	N	Shanxi & Xingxian, 2016; Shanxi et al., 2017; Wang & Zhang, 2016

Site	Province	Area	Coordinate	Size (ha)	Wall	Moat	Pottery	Domestic herd animals	Millet	Jade	Copper/ bronze	Reference
Baiyagou	Shanxi	Weifen River valley	111.30, 38.51	120	Y	N	Y	N	N	N	N	Shanxi, 2017; Wang, 2017
Shilouloushan	Shaanxi	Yulin	110.29, 38.11	6	Y	Y	Y	?	N	Y	N	Shaanxi, 2016; Zhang & Ding, 2016
Muzhuzhuliang	Shaanxi	Yulin	109.94, 38.60	4	N	Y	Y	Y	Y	N	N	Guo, 2015; Guo, 2017; Wang & Guo, 2015; Yang et al., 2017
Shengedaliang	Shaanxi	Yulin	109.92, 38.60	4	N	Y	Y	N	Y	N	N	Chen et al., 2017a, 2017b; Guo, 2017; Guo et al., 2016b
Shimao	Shaanxi	Yulin	110.31, 38.56	400	Y	N	Y	Y	Y	Y	Y	Atahan et al., 2014; Hu et al., 2016; Shaanxi, 2016a; Shaanxi et al., 2013; Shaanxi et al., 2017; Sun, 2016; Sun & Shao, 2015, 2017
Xiata	Shaanxi	Yulin	111.43, 39.98	28	Y	N	N	N	N	N	N	Li, 2007; Zhang & Ding, 2016
Xinhua	Shaanxi	Yulin	110.02, 38.62	3	N	N	Y	Y	Y	Y	N	Atahan et al., 2014; Shaanxi & Yulin, 2005; Xue et al., 2005
Zhaimao	Shaanxi	Yulin	110.55, 38.82	17	Y	N	Y	N	N	N	N	Shaanxi, 2002
Zhaimaoliang	Shaanxi	Yulin	110.21, 38.39	3	Y	N	Y	Y	Y	N	N	Owlett et al., 2018; Shaanxi et al., 2018; Wei et al., 2018
Zhengzemao	Shaanxi	Yulin	111.01, 39.06	?	N	N	Y	?	N	N	N	Shaanxi &Yulin, 2000
Zhaishan	Shaanxi	Yulin	109.51, 37.54	2	Y	N	Y	N	N	Y	N	Shaanxi & Yulin, 2019
Huoshiliang	Shaanxi	Yulin	109.64, 38.36	10	N	N	N	Y	N	N	Y	Hu et al., 2008
Houzhaizimao	Shaanxi	Yulin	110.65, 37.54	21	Y	Y	Y	N	N	N	N	Shaanxi & Shaanxi, 2011
Wangyangpan	Shaanxi	Yulin	109.21, 38.01	?	N	N	Y	N	N	N	N	Shaanxi & Shaanxi, 2011
Wuzhuangguoliang	Shaanxi	Yulin	109.05, 37.82	30	N	N	Y	N	N	N	N	Guan et al., 2008; Hu & Sun, 2005; Shaanxi, 2011

Table 1.1. Major database includes the details and sources of all the settlement sites studied in this thesis.

The selection of sites here has its limitations, due to a common issue of indeterminate calendar dates of sites, and the reliance on the ceramic typology to form the chronology. This chronology is referred to as typo-chronology and is based on the assumption that a certain type or form of pottery shares the same date. For example, the sites in the Daihai Lake area are usually referred to Laohushan cultural sites, and the dates are given as Laohushan period, or even more problematically, early Longshan period, which should only be applied to the occupation in the Central Plains. The typo-chronology is then associated to calendar dates taking into account the limited radiocarbon date data. However, it must be noted, that the fact that sites share similar ceramic types does not necessarily mean that they were occupied in the exact same period. Rather, the occupation duration might be quite different between sites, even if they were overlapped (Jaffe et al., 2020). The lack of radiocarbon dates is also a problem when associating the typological groups with dates. Another issue is that sites that shared similar ceramic types and forms are traditionally referred to as a cultural group who shared the same culture and with the same cultural identity. Thus, the typo-chronology is used to form the cultural sequence of a region, assuming that the culture or the cultural groups developed one after another. The issue here is that the identification of ceramic types with specific populations is problematic, and ceramic types alone can hardly define one ethnic identity or political affinity (Hein, 2016, Jaffe and Hein, 2020). The term ‘culture’ and ‘cultural group’ used throughout the thesis, therefore, only refers to settlement groups that shared a similar ceramic type, or other features such as built environment and material culture.

While the above issue may limit the sites selected in this thesis, and the selected sites can only be assigned to periods defined by the typo-chronology, this is nevertheless the only way to identify potential sites and group them into different periods for further analysis. This thesis therefore adopts the current typo-chronology established for the Shimao region. Table 1.2 lists the sequence with the correlated conventional periods and dates, according to CASS (2010), Han (2003, 2008), Sun (2000, 2016), Tian & Guo (2004) and Wei & Cao (1999). Those in the Yulin area have not yet been labelled with any cultural periods, and while the sites in this area have been referred to as part of the Shimao or Zhaimao culture (Lu, 2002; Shao, 2019; Sun et al., 2021),[3] the term 'Shimao culture' will be tentatively adopted here for convenience sake, simply referring to the period when Shimao and other sites shared similar developed features. When the exact occupation period for individual sites is uncertain and currently cannot be identified, the best that can be done is to separate sites into phases (where applicable) and assign them to the correlated cultural periods as shown in Table 1.2. The selected sites are assigned to the four cultural periods in this way, and the complete details of assignation is listed in Table 1.3. The analyses in this thesis also follows this assignation when applicable. The date ranges shown in Table 1.2, nevertheless, may be adjusted after the reconsideration of the chronology of the Shimao region.

Date (BC)	Cultrual period in the Shimao region	Cultural period in Central Plains
2800-2500	Ashan III	Transition period from Yangshao to Longshan
2500-2300	Laohushan	Early Longshan
2300-1800	Dakou I/Shimao	Late Longshan
1800-1500	Early to middle Zhukaigou	Erlitou

Table 1.2. Currently accepted cultural sequence for the Shimao region based upon typo-chronology.

[3] Shimao culture has recently been assigned a date range of 2300–1800 BC in Sun et al. (2021), with the consideration of the dates from Shimao, Bicun and Zhaimaoliang.

Period (BC)	Correlated cultrual period	Site	Area	Reference
2800–2400	Yangshao/Longshan transition	Ashan III	South of Daqing Mountain	Baotou, 1984; Neimenggu & Baotou, 1984
		Shamujia	South of Daqing Mountain	Baotou, 1984
		Heimaban	South of Daqing Mountain	Baotou, 1984
		Natai	South of Daqing Mountain	Baotou, 1984
		Xiyuan	South of Daqing Mountain	Baotou, 1984, Xiyuan, 1990
		Weijun	South of Daqing Mountain	Tian & Guo, 2004: 331
		Zhukaigou (zone VII) II	Ordos city	Tian, 1988; Neimeggu, 1994
		Xiaoshaowan	Qingshui River valley	Wei & Cao, 1999
		Baicaota II	Qingshui River valley	Neimenggu, 1994: 183
		Nanhao	Qingshui River valley	Neimenggu, 1994: 224
		Zhaizita I	Qingshui River valley	Neimenggu, 1997: 280–326; Wei & Cao, 1999
		Houchengzui II	Qingshui River valley	Neimenggu, 1997: 151; Cui, 2003
		Bainiyaozi III	Qingshui River valley	Cui, 2014
		Huozhaizimao I	Yulin	Shaanxi & Shaanxi, 2011; Sun, 2016
		Zhaimao I	Yulin	Shaanxi, 2002
		Zhengzemao I	Yulin	Sun, 2016
		Wuzhuangguoliang	Yulin	Shaanxi, 2011
		Zhaishan	Yulin	Shaanxi & Yulin, 2009
		Shilouloushan I	Yulin	Shaanxi, 2016
2400–2000	Early Longshan	Laohushan	Daihai Lake	Yang, 2000
		Yuanzigou	Daihai Lake	Yang, 2000
		Bancheng (group I)	Daihai Lake	Yang, 2000
		Damiaopo	Daihai Lake	Yang, 2000
		Mianpo	Daihai Lake	Yang, 2000
		Zhukaigou I	Ordos city	Neimenggu & Ordos, 2000
		Yongxingdian	Qingshui River valley	Neimenggu, 1994
		Erliban	Qingshui River valley	Neimenggu, 1994: 260
		Zhaizishang II	Qingshui River valley	Neimenggu, 1994: 181
		Baicaota III	Qingshui River valley	Neimenggu, 1994: 183
		Zhaizita II	Qingshui River valley	Neimenggu, 1997: 280–326; Wei & Cao, 1999
		Houchengzui III	Qingshui River valley	Neimenggu, 1997: 151; Cui, 2003
		Guandi IV	Qingshui River valley	Neimenggu, 1997: 85–119
		Xiata	Qingshui River valley	Li, 2007; Zhang & Ding, 2016
		Xicha I	Qingshui River valley	Neimenggu & Qingshuihe, 2001; Tang et al., 2004
		Zhuangwoping III	Qingshui River valley	Neimenggu, 1997: 165–178
		Baiyagou	Weifen River valley	Shanxi, 2017
		Huozhaizimao II	Yulin	Shaanxi & Shaanxi, 2011; Sun, 2016
		Zhaimao II	Yulin	Shaanxi, 2002
		Zhaishan	Yulin	Shao, 2019; Sun, 2016; Shaanxi & Yulin, 2009
		Shilouloushan II	Yulin	Shaanxi, 2016

Period (BC)	Correlated cultrual period	Site	Area	Reference
2000‐1600	Late Longshan	Bancheng (group II)	Daihai Lake	Yang, 2000
		Zhukaigou II	Ordos city	Neimenggu & Ordos, 2000
		Dakou I	Qingshui River valley	Neimenggu, 1994: 125
		Bainiyaozi IV	Qingshui River valley	Cui, 2014
		Muzhuzhuliang	Yulin	Guo, 2015
		Shengedaliang	Yulin	Shaanxi et al., 2016
		Xinhua	Yulin	Sun, 2016
		Zhaimaoliang I‐II	Yulin	Wei et al., 2018
		Zhengzemao II	Yulin	Sun, 2016
		Shimao	Yulin	Shao, 2016
		Shiluoluoshan III	Yulin	Shaanxi, 2016
		Zhaimao	Yulin	Shaanxi, 2002
		Huoshiliang	Yulin	Hu et al., 2008
		Bicun	Weifen River valley	Shanxi & Xingxian, 2016
1600‐1300	Erlitou	Yangchanggou	Daihai Lake	Neimenggu & Beijing, 1991
		Sandaugou	Daihai Lake	Neimenggu & Beijing, 2004
		Zhukaigou III‐IV	Ordos city	Neimenggu & Ordos, 2000
		Qingcaota	Qingshui River valley	Neimenggu & Yikezhao, 1990
		Guandi V	Qingshui River valley	Neimenggu, 1997: 85–119
		Nanhao	Qingshui River valley	Neimenggu, 1994: 205‐224
		Dakou II	Qingshui River valley	Neimenggu, 1994: 125
		Gaojiaping	Qingshui River valley	Neimenggu, 1994: 261‐271
		early Xiaomiao	Qingshui River valley	Neimenggu, 1994
		Xicha II	Qingshui River valley	Neimenggu & Qingshuihe, 2001; Tang et al., 2004
		Zhaizita IV	Qingshui River valley	Neimenggu, 1997: 280‐326; Wei & Cao, 1999
		Zhuangwoping IV	Qingshui River valley	Neimenggu, 1997: 165‐178
		Houchengzui IV	Qingshui River valley	Neimenggu, 1997: 151; Cui, 2003
		Bainiyaozi V	Qingshui River valley	Cui, 2014

Table 1.3. Assignation of sites studied in this thesis to cultural periods.

1.5 Chapter structure

After this introduction chapter, Chapter 2 provides background information on the Shimao region and the environmental and archaeological settings. The palaeoclimatic and palaeoenvironmental studies will also be reviewed, and the linkage between climate change and cultural transitions will be discussed. Chapter 3 re-examines the chronological framework and explores the distribution of occupation. Chapter 4 explores the settlement size and distribution shape. Chapter 5 explores the prevalence and consumption of herd animals. Chapter 6 considers the genesis and prevalence of ceramic tripods. Chapter 7 synthesises the findings from Chapter 3–6, and discusses how climate, demographic economic and material culture influences give rise to Shimao and what we can understand about the settlement distribution and economic system formed by Shimao and other smaller sites. Chapter 8 concludes by surveying how the major findings help to answer the question how and why Shimao emerged at the particular location and timing, its significance, and direction of future research.

Chapter 2

The Shimao region: climate, environment and archaeological settings

2.1 Introduction

This chapter introduces the climate, environment and archaeological settings of the Shimao region. The existing palaeoclimate and palaeoenvironmental studies will be brought together in this chapter to review the possible timing of climate change in the Shimao region. At the same time, it will also review the background of the archaeology in the Shimao region, the problems of different sub-topics and how they will be addressed. including chronology, settlements, demographic changes, subsistence economy and material culture.

2.2 Climate and environment settings

2.2.1 The diverse environments between the arc, the steppe and the Central Plains of China

The Shimao region is located in an arid and semi-arid region around the north of the Loess Plateau in northern China, around the middle Yellow River valley (Figure 2.1). This region is part of the 'arc', located in between the eastern Eurasian steppe and the Central Plains of China (Figure 1.1). The environments of these three regions are usually defined as distinct from one another. The land of the arc is typically a mixture of steppe, desert and valley environments. It includes the Loess Plateau and Mu Us desert. It is high but varied with rolling hills in the Ordos and mountains further west. There are also large lower forest regions, especially in the northeast. The elevation ranges between 500 and 2000 metres (Han, 2003, Chapter 1, Han, 2008, Chapter 2). The mean annual precipitation (MAP) in China generally diminishes from east to west and from south to north; hence northeast and southwest China are relatively wetter than the northwest and north (Han, 2003; Tong, 1987). The isohyet runs in a northeast-southwest direction, and the arc is located in an area where MAP ranges between 400 and 800 mm (Han, 2003, Chapter 1, Han, 2008, Chapter 2). This kind of environment is particularly suitable for herding and for millet cultivation, which requires a MAP of as low as 50 mm and 350–550 mm, respectively. Except for the southwest, where the MAP is relatively high, between 750 and 1500 mm, and the highland area in Tibet can reach 2000 mm (Zhongguo, 1984, Chapter 5). The southwestern also experiences additional precipitation sources from the Indian Summer Monsoon during summer (Liu et al., 2015b). Today the northwest and north are covered by grassland and arid-steppe, while the northeast and southwest are covered by grassland and forest-grassland (Liu & Chen, 2012b).

Figure 2.1. The paleoclimate and paleoenvironment sites discussed in Chapter 2 and the archaeological sites located in the Shimao region considered in this thesis. The dash line shows the present location of the East Asian Summer Monsoon belt, based on the information from Dong et al. (2018: 32).

The area to the north and northwest of the arc, known as the steppe, is today a vast expanse across the mid-latitude zone of the Eurasian landscape that extends for 8500 km from the northeast of the Black Sea, along the north of the Caspian Sea, the north of Kazakhstan, to the Altai and the Mongolian steppe (Chernykh, 2008; Cunliffe, 2015; Kuzmina, 2008: 10). The landscape zones of the present-day Eurasian steppe were shaped around 8000 BC, covering forest and forest-steppe zone in the north, and foothills, semi-desert and desert in the south (Kuzmina, 2008: 11, 14–15). The steppe is affected by the continental climate, which generates an arid environment with less than 500 mm of MAP (Kuzmina, 2008: 10). The growing seasons are short here because of the cold winters. The vast and abundant grasslands in the steppe are favourable for mobile pastoralism, which is a routine migratory management of herd animals across defined distances annually. Steppe communities were highly mobile, although a small measure of cultivation has also been practised (Frachetti, 2009). The Central Plains of China are located in an area around the middle and lower Yellow River valley and as far south as the Dabie Mountains. Traditionally, the Wei River valley is added to this agricultural area. Here, the terrain is completely different from the steppe, with low and fertile lands dominated by forest, and favourable for cereal cultivation and raising pigs and dogs.

2.2.2 Climate of the Shimao region

Today, the Shimao region is located at the edge of the EASM belt. This belt extends in a southwest-northeast direction from eastern Inner Mongolia in northeast China to the north of the Loess Plateau in northern China and thence to the Tibetan Plateau in western China (Figure 2.2). The EASM is the major source bringing of precipitation from the south of China northwards to cover a large part of China during the summers (Figure 2.2). The winter monsoon brings cold and dry air from the high-latitude regions and provide a small amount of moisture to northwest and northern China during winter (Figure 2.2) (He et al., 2004). The Shimao region is located on a boundary between desert (mainly Mu Us desert) and loess (Figure 2.1). This means that the Shimao region itself is located at the climate- and environment-sensitive region, which is in general more sensitive than much of the southeast of China, especially the agricultural areas, where precipitation is steadier.

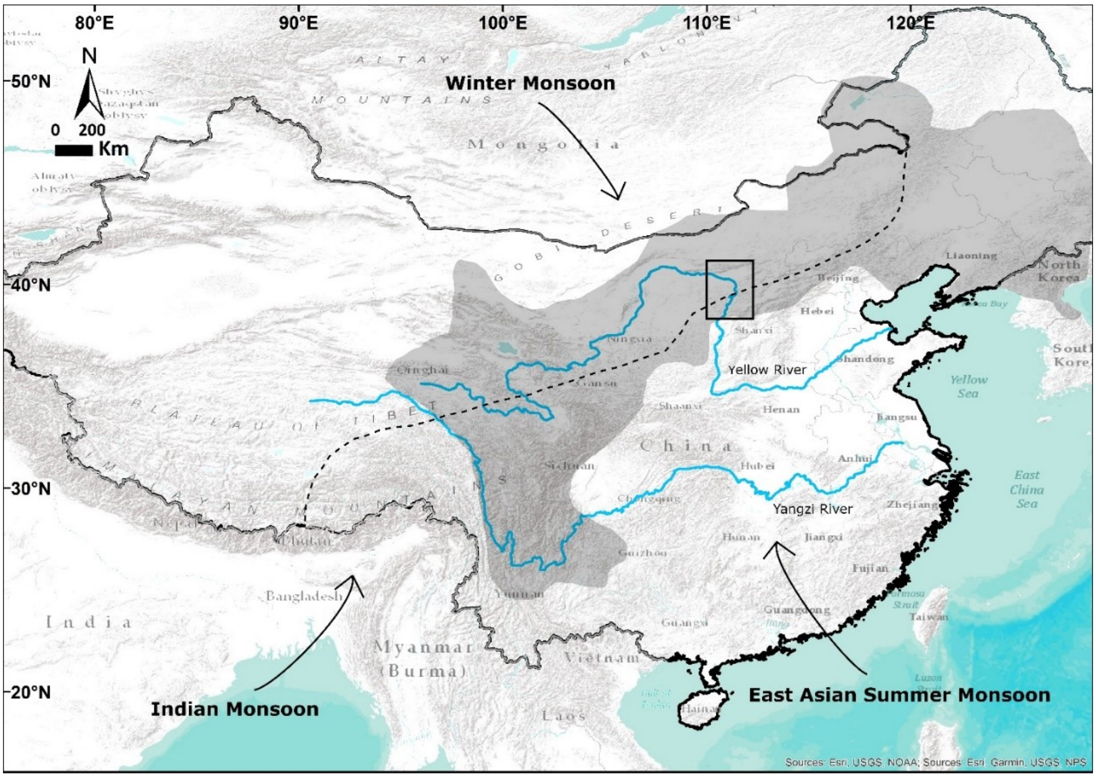


Figure 2.2. The directions of sources of the East Asian Summer Monsoon, Indian Monsoon (southwest monsoon) and the westerly (indicated by arrows). The shaded area shows the coverage of the 'arc'. The dash line shows the present location of the East Asian Summer Monsoon belt, according to Jiang & Liu (2007). The square shows the Shimao region.

The southeast of the Shimao region is relatively more humid and warmer than the northwest of the region. The mean annual precipitation (MAP) and mean annual temperature (MAT) in the region are around 150–450 mm and 5.5–8 °C, diminishing from southeast to northwest (Sun et al., 2018). The north sector of the region (central and southern Inner Mongolia) has a MAP of around 200–400 mm, while in the south (northern Shanxi and northern Shaanxi) it is around 400–600 mm (Han, 2003). Specifically, the areas in the Shimao region, including the south of Daqing Mountain, Daihai Lake, Qingshui River valley, Ordos and Yulin have different MAP and MAT. The modern MAP and MAT in the south of the Daqing Mountain area is around 354 mm and 7.5 °C (Johnson & Ingram, 2004), 423 mm and 5.1 °C in the Daihai Lake area (Xiao et al., 2004), 410 mm and 7.1 °C in the Qingshui River valley area (Wang, 2018: 407), 350–400 mm and 2–6 °C in Ordos city area (Huang, 1996), and 400 mm and 8.1 °C in the Yulin area (Wang et al., 2015). The elevation of most of the region is between 1000 and 1400 metres.

2.2.3 Palaeoclimate and palaeoenvironment in the Shimao region

The appearance of domesticated sheep/goat and cattle, wild or domesticated horses and Cape hare (*Lepus capensis*) at these sites indicates that the environment was dominated by grassland. The appearance of wild boar (*Sus scofa*), Sika deer (*Cervus nippon*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), Leopard (*Panthera pardus*) and bear (*Ursus sp*) reflects that there were mixed forests, forest grassland, scrubland and mountain nearby (Hu et al., 2008a, 2016; Huang, 1996). The appearance of *Felis bengalensis* and *Panthera tigris* at Huoshiliang also indicates that there was a certain area of forest nearby (Hu et al., 2008a). The appearance of pigs at these sites is also evidence that the climatic and environmental condition would have be favourable for agricultural activities, since surplus agricultural produce is required to support pig husbandry (Hu et al., 2008a).

Existing palaeoclimate and palaeoenvironmental studies for the Shimao region, as listed in Table 2.1, including the proxies of pollen-based lake sediments, palaeosol development and aeolian activities, which are considered as reliable and direct indicators of precipitation and temperature (Liu et al., 2015b), are synthesised here. The distribution of the sites from these palaeoclimatic and palaeoenvironmental studies are shown in Figure 2.1, alongside the archaeological sites studied in this thesis. These palaeoclimatic and palaeoenvironmental studies suggest that the Daihai Lake area likely experienced a colder, drier and more fluctuating climate from cal. 2500–2400 BC onwards (Peng et al., 2005; Xiao et al., 2004, 2006; Xu et al., 2010). The MAP and MAT were around 340 mm and 4.5 °C, which are slightly lower than today (Xu et al., 2010). Nearby the Ordos area, at Baahar Nuur Lake, the region seems to have become significantly drier from cal. 2400–2300 BC onwards as suggested by (Huang, 2017); and at Qigai Nuur Lake, from cal. 2000 BC onwards as suggested by (Sun & Feng, 2013). At the south-eastern edge of Mu Us desert, in the Yulin area, the studies inferred that the climate seemed to be colder and drier between cal. 3000 and 2000 BC, with varied ranges from different studies (Liu et al., 2014, 2015a, 2016; Zhao et al., 2016). Other studies suggest that this area was in general humid between cal. 3000 and 1500 BC as suggested by Liu et al. (2017) and Chen et al. (2015c), between cal. 2200 and 1000 BC as suggested by Liu et al. (2016), between cal. 2500 and 1000 BC as suggested by Li et al.'s (2003). Despite of the differences, the above studies as well as the studies from Cui et al. (2019) show that the climate in this area should be relatively more humid than the areas in the north sector of the Shimao region during 3000 and 1800 BC.

Location	Precipitation proxy	Dating method	Dating material	Archive	Reference
Daihai Lake area					
Daihai lake (DH99-A)	Rb/Sr of loess-palaeosol deposits	AMS	Terrestrial plant macrofossils or bulk organic fraction	Lake core	Jin et al., 2006
Daihai lake (DH99-A, DH99-B)	Total organic and inorganic carbon	AMS	Organic matter	Lake core	Xiao et al., 2006
Daihai lake (DH99-A, DH100-B)	Grain size	AMS	Organic matter	Lake core	Peng et al., 2005
Daihai lake (DH99-A)	Pollen-based	AMS	Organic matter	Lake core	Xu et al., 2010
Daihai lake (DH99-A)	Pollen-based	AMS	Organic matter	Lake core	Xiao et al., 2004
Daihai lake	Pollen-based	AMS	Lake sediment	Lake core	Li et al., 2004
Daihai lake (DH99-A, DH99-B)	Total organic carbon, grain size, pollen	AMS	Organic matter	Lake core	Sun et al., 2006
Ordos city area					
Baahar Nuur Lake	Pollen-based	AMS	Bulk basal sand	Lake core	Huang & Guo 2017
Qigai Nuur (QGN-2004)	Pollen-based	AMS	Bulk sediment	Lake core	Sun & Feng 2013
Yulin area					
Eastern Mu Us desert (Jinjie)	Magnetic susceptibility of surface soil	OSL and conventional radiocarbon dating	Organic matter	Palaeosol-aeolian section	Liu et al., 2014
Eastern Mu Us desert (Zhenbeitai)	Magnetic susceptibility of surface soil	AMS	Organic matter	Palaeosol-aeolian section	Liu et al., 2017
Eastern Mu Us desert (WJG)	Geochemical components from palaeosol-aeolian deposits	OSL	Aeolian and sand	Palaeosol-aeolian section	Liu et al., 2016
Eastern Mu Us desert (Zhenbeitai, SDG)	Grain size and total organic carbon of palaeosol-aeolian deposits	OSL, AMS and conventional radiocarbon dating	Bulk organic matters	Palaeosol-aeolian section	Jia et al., 2015
Eastern Mu Us desert (Jinjie)	Grain size and magnetic susceptibility of palaeosol-aeolian deposits	OSL and conventional radiocarbon dating	Aeolian deposition	Palaeosol-aeolian section	Zhao et al., 2016b
Eastern Mu Us desert (Jinjie)	Geochemical components from palaeosol-aeolian deposits	OSL and conventional radiocarbon dating	Organic matter	Palaeosol-aeolian section	Liu et al., 2015a
Southern MU Us desert (Jingbian)	Palaeosol-aeolian sequence	AMS	Organic matter	Trench section	Xiao et al., 2002
Southern MU Us desert (Midiwan)	Pollen-based and total organic carbon	AMS	Bulk organic matter	Peat section	Li et al., 2003
Eastern Mu Us desert (Zhenbeitai)	Magnetic susceptibility of palaeosol-aeolian deposits	OSL	Organic matter	Palaeosol-aeolian section	Chen et al., 2015c

Table 2.1. The paleoclimate and paleoenvironmental studies discussed in Chapter 2.

The source of a drying trend has been widely associated with the retreating EASM belt southwards. However, although the broad outlines of the movements and timing of the EASM are understood, this information is available only from proxy data with a broad geographic spread and is often poorly dated. The timing of that retraction is currently still a matter of debate.[4] The study done by An et al. (2000) suggests that the EASM belt retraction between 7000 and 4000 year BC, shifting gradually from northwest to southeast China (An et al., 2000).

The EASM is the dominant source of precipitation, and seasonality, amount and predictability, which are crucial for agriculture. This means that the direct influence that climate change might have had on human society is related to subsistence and food production (Jaffe et al., 2020). The further the EASM belt shifted southwards from the region, the less favourable the climatic conditions for subsistence activities in the region, especially since the south of Daqing Mountain area lay at the very end of the edge of the EASM belt (Figure 2.2). It also is situated at the present-day isohyets of MAP between 200 and 400 mm. This is in between the critical point for cultivating the arid-resisting broomcorn millet. Millet is a plant that can adapt to an arid environment and infertile soil, and with its short crop cycle, foxtail millet can be cultivated in regions with 450–550 mm MAP and 8–10 °C MAT (Lu et al., 2009). Broomcorn millet can adapt to even drier conditions than foxtail millet, surviving in regions with 350–450 mm MAP and 6–8 °C MAT (Lu et al., 2009). Since broomcorn millet was more common among the groups in the north sector of the Shimao region prior to 2200 BC and the proportion of foxtail millet increased during the Shimao period (Sheng et al., 2021), the climate in the south in this period seemed to be relatively wetter. Conversely, the more common use of broomcorn millet among groups in the north indicates that the climate and environment in this area was relatively drier. If the EASM belt did retreat, the condition in the north would be even drier and thereby unfavourable for cultivation, especially when the MAP fell below that point.

[4] It has been argued to have retracted in the transitional zone in northern China around 4500 cal. BC (Dong et al., 2018) and 2500 cal. BC (Jiang & Liu, 2007). Another study suggests that the EASM declined rapidly after 1300 BC (Chen et al., 2015a).

In ancient China, the so-called 4.2 ka BP event has been frequently linked to the collapse of Neolithic societies and the rise of Bronze Age societies in China (Jaffe et al., 2020). The cultural dynamics said to have been influenced by climate and environmental changes include migration, changing subsistence strategies, technological changes, occurrence of walled settlements and cultural interaction (Anderson et al., 2007; Lu, 2007). In the case of the Shimao region, population movement southwards, and the occurrence of walled settlements, have been causally linked to the drier climatic conditions by Han (2003), Tian (1997) and Tian & Guo (2004). Their arguments which assumed southward population movement driven by climatic factors is thought also to have brought herd animals to the south as well (Sun et al., 2018). The linking of these events is challenging, due to the fact that the evidence for palaeoclimate and palaeoenvironment and the timing of climate changes are only based on proxies from plants, soils and animals. Nevertheless, these lines of evidence are currently the best we can use to understand climate and environment conditions and the possible timing for changes in the past.

So far the proxies as discussed above imply that the possible timing for the drier, colder and fluctuating climatic condition is between cal. 2500 and 2000 BC in the north sector of the Shimao region, and the condition in the south of the Shimao region, especially the south-end area, would possibly be relatively wetter and more stable than the north. Another issue is to match the drier event with the archaeological events (Jaffe, 2020, Jaffe & Hein, 2020). The current discussion merely links the occupation time of settlements with the drier event (Sun et al., 2018), without considering the timing of changes in different archaeological events such as demographic shift and population growth. This practice does not allow a fruitful discussion on the influences that climate changes potentially had on human society, or, further, on how these factors together might have contributed to the rise of Shimao in the south of the region. In order to better understand the linkage between climate and archaeological events, the possible timing of climate change discussed here will be revisited in the discussion in Chapter 7, after the timings of possible changes in demography, settlement scale, animal economy and material culture are explored.

2.3 Archaeological setting

2.3.1 Previous and current studies of the Shimao region

The Shimao region is located at the junction of the southern and central Inner Mongolia region, northern Shaanxi and northern Shanxi provinces, along the middle Yellow River valley (Figure 2.3). This situates the Shimao region at the middle portion of the 'arc', and it formed one of the four major settlement groups along this area (Figure 1.1). This area is also known as the 'Northern Zone' used in Lin (1986) and Watson (1971). The other three areas are occupied by the Xiajiadian settlement groups to the northeast around western Liaoning and south-eastern Inner Mongolia, the Qijiaping settlement groups to the northwest around Gansu and part of the Inner Mongolia connecting Xinjiang to the northwest, and the Baodun settlement groups to the southwest (Figure 2.3).

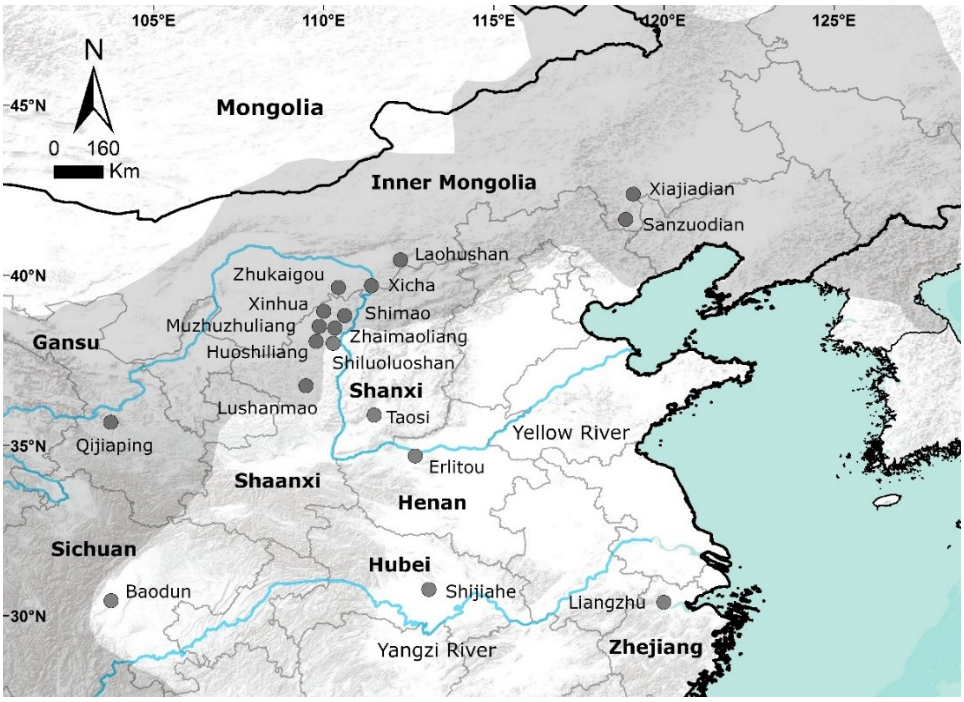


Figure 2.3. The sites mentioned in Chapter 2. The shaded area shows the coverage of the 'arc'.

The sites distributed in the Shimao region are generally divided into six areas: the south of Daqing Mountain, Daihai Lake, Qingshui River Valley, Ordos city, Yulin and Weifen River valley (Figure 2.4). The first four areas are located in the north sector of the region while the last two areas are located in the south. Discoveries of stone-walled sites in the north sector of the region are not new (Neimenggu & Yikezhao, 2006; Sun, 2000; Wei & Cao, 1999). Most were discovered and excavated between the 1970s and 1990s, as were the non-walled sites (Neimenggu, 1994; 1997). These sites were all backfilled and no further investigation and excavation works are taking place at the moment. The sites in the south, on the other hand, have been excavated relatively recently, mostly from the 1990s onwards, such as Xinhua (Shaanxi & Yulin, 2005), Zhaishan (Shaanxi & Yulin, 2009) and Zhaimao (Shaanxi, 2002). The investigation and excavation of some of the sites in this area, as at Shimao and Bicun, are still ongoing. Some new investigations have also taken place very recently and at present, as at Jiadamao and Miaoliang (Guo & Zhu, 2018; Hu, 2020; Shaanxi et al., 2019; Shao, 2019).

All the walled and non-walled settlement sites from the Shimao region considered in this thesis is shown in Figure 2.5.

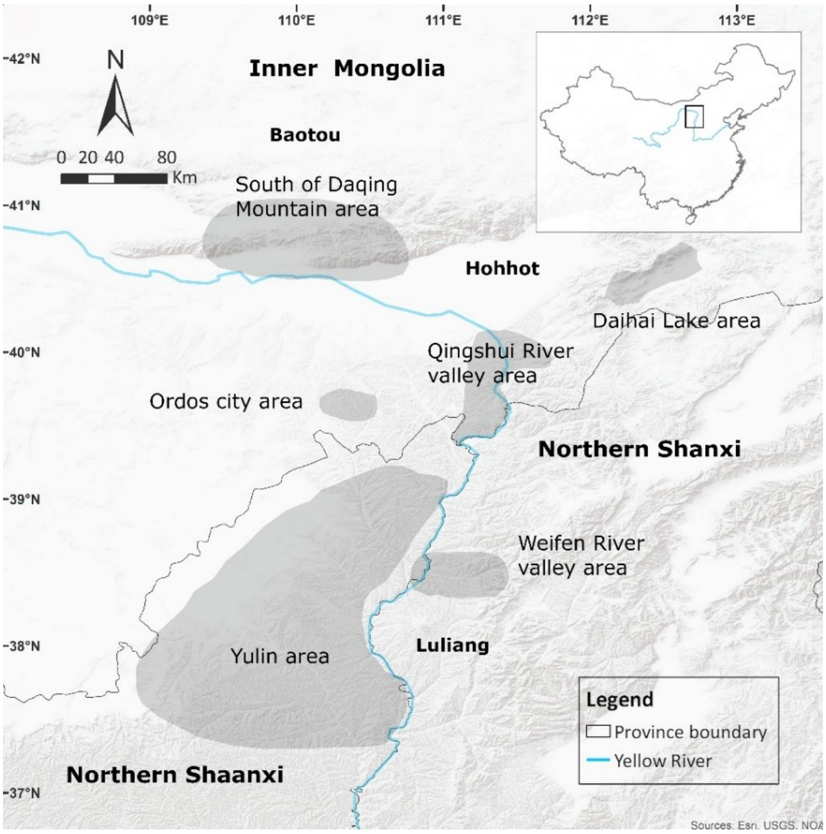


Figure 2.4. The six areas delimitated in the Shimao region based on the geographic locations where the settlement sites are distributed.

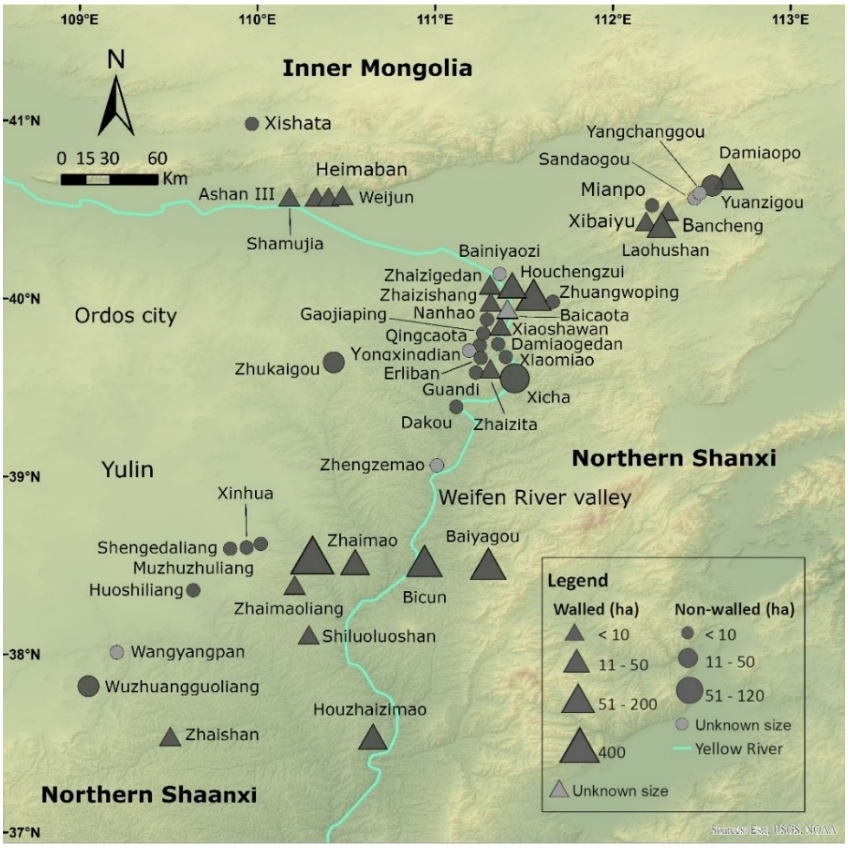


Figure 2.5. Map of the distribution of walled and non-walled settlement sites in the Shimao region based on the information recorded in Appendix I. Generated by ArcMap 10.8.

Before the rediscovery of Shimao and excavation at surrounding smaller sites, the discussion was limited to the stone fortifications in the north sector of the region (central-south Inner Mongolia), investigated and excavated between the 1970s and 1990s (Neimenggu, 1994; 1997, Nemienggu & Yikezhao, 2006; Sun, 2000; Tian & Guo, 2004: 328–341; Wei & Cao, 1999). Focus was put on their nature as defensive buildings and function for military, resource protection and security purposes (Sun, 2000; Wei & Cao, 1999). Since more information from Shimao and the surrounding sites has been published in recent years, this area has been included in the discourse of the development process in the North Loess Plateau in late Neolithic China. The new information from Shimao and the south of the region (northern Shaanxi) has focused on the construction, structures and military function of the extraordinary stone fortification at Shimao itself (Guo & Sun, 2018; Guo et al., 2016, 2020). The discussion of this area has also focused on the labour input needed for the stone fortifications (Zhang & Ding, 2016), the transition in subsistence economy, use of herd animals and food production (Cai et al., 2016; Hu et al., 2016; Owlett et al., 2018a; Yang et al., 2017) and transformation of pottery (Shao, 2019). Attention has also been devoted to interpreting Shimao's political and ritual roles (Jaang et al., 2018; Sun, 2016; Wang & Guo, 2016). Shimao has even recently been identified as an urban centre, indeed the first of the Neolithic period in the North Loess Plateau, mainly judged from its central role in political and ritual contexts for other settlements (Sun et al., 2018).

2.3.2 The context of the Shimao region in early China

The period of the rise and fall of Shimao lies between the two phases when rapid transformation took place in the late Neolithic China[5]. The first of these is around 2500 BC, when the major regional settlements in middle and lower Yangzi River valley as well as

[5] For the purpose of this research, 'China' refers mainly to the regions covering the arc as defined earlier: Central Plains at modern day Henan, southern Shaanxi, southern Shanxi and Shangdong provinces, and the eastern costal region.

eastern coastal area evolved and declined, and the second is around 1600 BC, when the first historical recorded Shang dynasty developed (Shelach & Jaffe, 2014). This timing also falls within the period when urbanism and state formation is thought to have been taken place in early China (Campbell et al., 2021; Liu, 2009b).

The major settlements along the middle and lower Yangzi River valley and eastern coastal areas, such as Liangzhu and Shijiahe, successively collapsed in the third millennium BC, but in this same period the four major settlements along the border area of ancient China developed (Figure 2.3). Zhang (2017) suggests that the number of sites dramatically increased across ancient China, including in the Yulin area in the south of the Shimao region from 2500 BC onwards. The sites in the Yulin area not only increased dramatically in number, but the site of Shimao, which is the largest stone fortification in the late Neolithic China also appeared around this time (Sun et al., 2018). Another fortification with similar features was at Sanzuodian in northeast China dated to the second millennium BC (Shelach et al., 2011). However, the site was constructed later than those in the Shimao region which first appeared around 2800 and lasted down until 1800 BC (Sun, 2016; Wagner et al., 2013). Overall, the distribution of the currently known sites suggests a shift in the locus of major settlements from eastern and south-eastern China to the northern regions including the 'arc' in the late third to early second millennium BC and finally in the Central Plains in the early to middle second millennium (Zhang et al., 2019). The development of Shimao, in this sense, is of great importance for tracing and exploring the early urbanism development in northern China, and its relationship with the earlier and distant site of Liangzhu and the co-existing site of Taosi, since it has been argued that these are examples of early urban centres (He, 2018a; Liu, 2009b; Renfrew & Liu, 2018).

Shimao developed within the period of rapid transformation in ancient China, which gave rise to the pre-dynastic settlement of Erlitou in the middle Yellow River valley (Zhang et al., 2019),[6] before the rise of the first dynasty Shang (Figure 1.1 and 2.3). However, the new discoveries from Shimao and surrounding sites reveal that the occupation in the Shimao region, or even in the 'arc', might have also gone through a demographic shift, with people moving towards the Henan Central Plain in the early second millennium BC. This situation may indicate that the rise of Shimao was an important step in the process within the wider development trajectory in of early China.

The connection between Shimao, to the south, Taosi and further south, Erlitou, has already been pointed out based on the shared features of jades, cooper/bronzes and mace heads between these areas (Figure 2.3) (Dai, 2016b; Jaang et al., 2018; Li, 2009; Rawson, 2017b; Shao, 2020). Metallurgical technology and practice of herding are also thought to have transmitted from Shimao to the regions of Taosi and then Erlitou, having originated in northwest China (Figure 2.3) (Brunson et al. 2016; Flad et al., 2007; Jaang, 2015; Jaang et al., 2018; Shao, 2020). In addition to these sites, the discoveries of the 200-hectare stone fortification at Lushanmao, in Shaanxi province, with its wall paintings and jade artefacts similar to those at Shimao (Ma et al., 2018; Zhao, 2018), also shows a southward linkage because Lushanmao is located between Shimao and Taosi (Figure 2.3). In this context, the developmental trajectory across the Shimao region needs to be reconsidered in order to redefine the position of this region in the wider state formation process. This topic is a widely debated in the current scholarship and Shimao has recently been placed into the discourse (see Jaffe, 2019). It is therefore necessary to introduce Shimao into the discussion because the development of complex societies in this part of northern China has long been neglected.

[6] For the discussion about considering Erlitou as a state or state-like society, see Liu (2009) and Liu & Chen (2003).

The position of the Shimao region is also important in the wider context of the interregional network across ancient China and eastern Eurasian steppe, since this is the period when metallurgy, herding, wheat and barley first appeared in ancient China, having originated from the west (Jones et al., 2011; Linduff, 2015; Sherratt, 2006). Metallurgy was first thought to have been invented locally in ancient China, but now evidence from Ejin River and then in the mid Hexi Corridor in northwest China indicates the possibility of transmission from eastern Eurasia to ancient China (Flad et al., 2007; Linduff & Mei, 2009; Mei, 2003) (Figure 1.1). This is plausible given that the earliest metals are in the form of small objects such as knives, earrings, bracelets and mace heads in the steppe tradition (Rawson, 2015, 2017a), which is different from the large bronze vessels and axes prevalent in the Central Plains (Rawson, 2015). This shows that people in the Central Plains likely adopted the metallurgical technology and produced objects in their own tradition, exemplified by the forms of bronze bells and vessels mimicking existing pottery types (Jaang, 2015; Mei, 2009; Rawson, 2017a). In the past decade, new transmission routes have been suggested, such as through the Inner Asian Mountain Corridor from southwest Asia to northwest China (Frachetti, 2012) as well as in the Ejin river region northeast of the Hexi Corridor (Jaang, 2015) (Figure 1.1).

The Shimao region in the North of Loess Plateau, which have long been neglected, is another location where the transmission may have taken place. Before the rediscovery of Shimao and ;nearby sites, the discussion mainly focused on Zhukaigou (Linduff, 1995; Mei, 2003; Wuen, 1993), based on the links of the Ordos-type bronzes (also referred to as the northern bronze complex) that are distributed in the middle and east portions of the ‘arc’, with those in Mongolia, south-eastern Siberia and the Minusinsk basin (Cao, 2014; Lin, 1986; Shelach-Lavi, 2015b; Tian & Guo, 1988) (Figure 1.1 and 2.3). The discovery of metals and herd animals at Shimao and the surrounding sites also indicates that metals and herd animals had become common in the north of Loess Plateau around the same time as in northwest China.

This is in line with the fact that, even though the earliest metals appeared in northwest China, they have also been discovered in Shaanxi and Shangdong, which implies that technologies and objects might have been transmitted from other areas in addition to northwest China.

In regard to this, Mei (2003) has already suggested that metallurgy might have been transmitted along what he called ‘the steppe road’, which connects the Altai region in southern Siberia to the Shimao region (Figure 1.1). The timing, nevertheless, should now be pushed back to the late third and early second millennium BC, rather than the suggested late second millennium BC. This additional route through the Ordos region (encompassing the Shimao region) into the Yellow River valley during the Shang period has also been mentioned by Rawson (2015) (Figure 1.1). Linduff (2015) also suggests that technology transmission should be considered across a broad region rather than as a unidirectional route and agrees that northeast China should not be neglected. This route has been suggested by Shelach-Lavi (2015b), based on the findings of animal-head bronze knives in northeast China, dated to as early as 1600 BC, and their association with the southern Siberia and the further west. Furthermore, because brass pieces dated between the fifth and third millennium BC have been discovered in the northeast (Mei et al., 2015). It is possible that metallurgy might already have been transmitted to northeast China at a much earlier period but did not immediately circulate around the region. All these suggestions show that the north and northeast of China is a key area of transmission for new technologies and objects. The Shimao region is of great importance in this wider context, especially when the fortification, herds and metals seemed to appear earlier than those in the northeast (as early as 2000–1900 BC) (Guo et al., 2016; Jaang, 2015), and position of the Shimao region will therefore be redefined in this thesis.

2.3.3 The discoveries from Shimao and the Shimao region

When the investigation at Shimao began in 1976, the site was initially thought to be part of the Great Wall, built during the dynastic periods (Sun et al., 2018). The site was then reinvestigated or excavated in 1981, 1986 and 2009, during which it was well-known for its jade artefacts, stone tombs and stone sculptures with human faces (Shaanxi et al., 2013). From the 1990s onwards, looting activities had become severe and caused irreversible damage to the site (Sun et al., 2018). It was not until 2011–2012, when systematic surveys and excavations were conducted at the site, that it came to be recognised as the largest late Neolithic stone fortification, dated to ca. 2300–1800 cal. BC (Shaanxi et al., 2013; Sun et al., 2018). Excavations and studies at Shimao have continued since then (Guo et al., 2020; He et al., 2021; Shaanxi et al., 2017, 2021; Sheng et al., 2021), and further excavations are still ongoing, in the surrounding area (e.g. Shaanxi, 2016b; Shaanxi et al., 2016a, 2018; Shao, 2019; Wang & Guo, 2015). The recently published excavation reports provide us with new information from the sites in the south of the Shimao region. Whereas the people in the border area, far from the Central Plains, used to be referred to as 'barbarians' (Linduff, 1995), the rediscovery of Shimao has completely overturned the traditional view that the North Loess Plateau did not contain a highly complex social system during the Longshan period (roughly from 2500–2000 BC) (Dai, 2016b: 250).

The Shimao site is 400 hectares in area, which is not only the largest fortification in this region, but also the largest fortified settlement built in late Neolithic northern China. Its complex structures and diversity of discoveries have no parallel in any other region at this time in ancient China (Shaanxi et al., 2013). The site was built with a three-layer wall structure: a platform surrounded by retaining walls (8 hectares), an inner enclosed area that includes the platform (210 hectares), and an outer enclosed area where the east gate is located, covering both the inner wall and the platform (>190 hectares) (Figure 2.6) (Guo et al., 2016; Sun et al., 2018). At Hanjiageda, located in the inner enclosure, house foundations and a cemetery with a stone-coffin tomb have been discovered (Figure 2.6) (Shaanxi, 2016a). Outside the outer enclosure, there is a structure at Fanzhuangzi,[7] which was thought to be an altar, has recently been identified as an outpost (Figure 2.6 and 2.7) (Shaanxi, 2016a: 139–143, 2021; Sun et al., 2021).

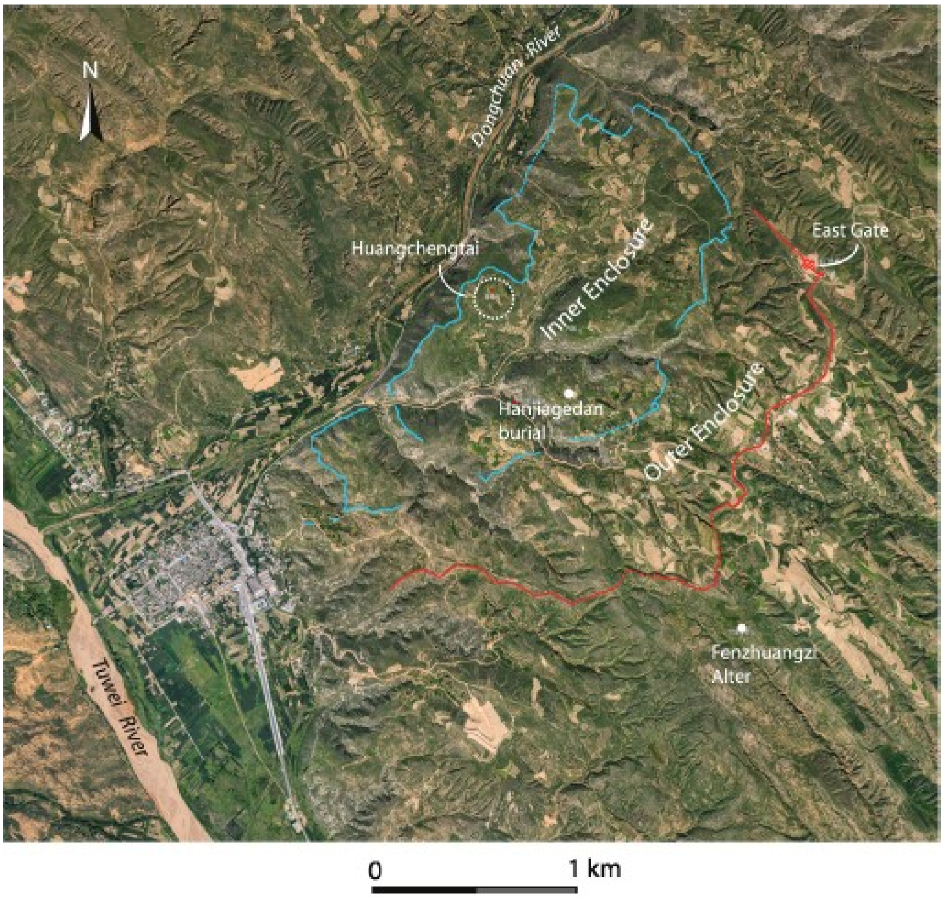


Figure 2.6. Aerial photo of the Shimao site, showing the three-layer wall structure and the locations of Huangchengtai, east gate, Hanjiagedan and Fanzhuangzi. Figure from Sun et al. (2018: 37).

[7] 'Fanzhuangzi' is the correct speeling but was spelt as 'Fenzhuangzi' in Figure 2.6

Figure 2.7. The ‘altar’ structure at Fanzhuangzi outside the enclosure of Shimao. Figure from Shaanxi (2016: 141).

The most distinctive feature of Shimao is the scale and structure of the walling. The building of the inner platform at Huangchengtai has been described as a ‘pyramid palace centre’ because of its shape, which was modified into eleven large terraces, diminishing in size, built one on top of another (Figure 2.8) (Jaang et al., 2018; Sun et al., 2018). Stone blocks were placed and dressed carefully to build these terraces (Jaang et al., 2018), and the surface of these stone blocks show signs of polishing (Shaanxi et al., 2017). More distinctively, the building of this platform involved large wooden beams laid between stone blocks as binding materials for reinforcement (Jaang et al., 2018, Shaanxi et al., 2013; 2017). This is seen in rotten wood exposed in the holes on the terrace walls, which are additionally supported by the stone pillars placed below these holes (Figure 2.8) (Guo et al., 2020; Shaanxi et al., 2017). Some eye-shaped stone blocks were also placed in the wall (Figure 2.8) (Shaanxi et al., 2017). In recent excavation seasons, several stone sections, even beams carved with faces and creatures have been discovered (Shaanxi et al., 2021; Xu, 2019). Some may have come from earlier sites. They all suggest sophisticated beliefs and craftsmanship. The discovery of carefully polished jade artefacts, mainly blades and discs, found placed in between the stone blocks on the terrace walls indicates that people deliberately chose these objects to be incorporated in the construction (Figure 2.9) (Sun et al., 2018). A large quantity of herd animals' bones and bone products were also discovered near the platform area, showing that this place might have served as a bone workshop (Figure 2.10).

Figure 2.8. Photos of the pyramid-shaped Huangchengtai platform with diminishing large platform steps at Shimao: a) stone pillars at second and the third terraces; b) structures of eye symbols from the wall; c) distant view of the second and the third terraces during excavation; d) general view of the pyramid-shaped platform before excavation. Figure and information from Jaang et al. (2018: 1012).

Figure 2.9. Photos of the wall at Huangchengtai platform, Shimao that shows the jade artefacts inserted between stone blocks. Figure from Shaanxi (2016: 90).

Figure 2.10. Photos of bone needles (left), bronze knives and stone mould (right) discovered outside the wall of Huangchengtai platform, Shimao. Figures from Shaanxi et al. (2017: 55) and Sun & Shao (2017), respectively.

Besides, the design and layout of the wall entrances at both the citadel gate at the Huangchengtai platform and the east gate at the outer enclosure are also distinctive. The structure of these gates involves watchtowers, U-shaped screen walls and wing walls (Figure 2.11 and 2.12) (Guo & Sun, 2018; Guo et al., 2020). The U- and L-shaped route through the entrance serves to screen the passages entering the gates (Guo & Sun, 2018; Guo et al., 2020; Sun et al., 2018). Other auxiliary structures include a series of baffled gates, corner towers, gate towers and bastions with defensive purposes (Figure 2.13) (Guo et al., 2016, 2020; Shao, 2016; Sun et al., 2018). The space between the bastions at the outer wall is around 30–40 m, which is an effective range for attacking with weapons (Jaang et al., 2018; Sun et al., 2018). This, along with the arrowheads discovered at the site (Sun et al., 2018), suggests that the construction might have been associated with violent activities such as warfare. Currently, there is no evidence of extreme violent activities such as destruction of the wall and burials, as seen at Taosi (Han, 2010). It is therefore uncertain whether the fortification served for military defensive purpose.

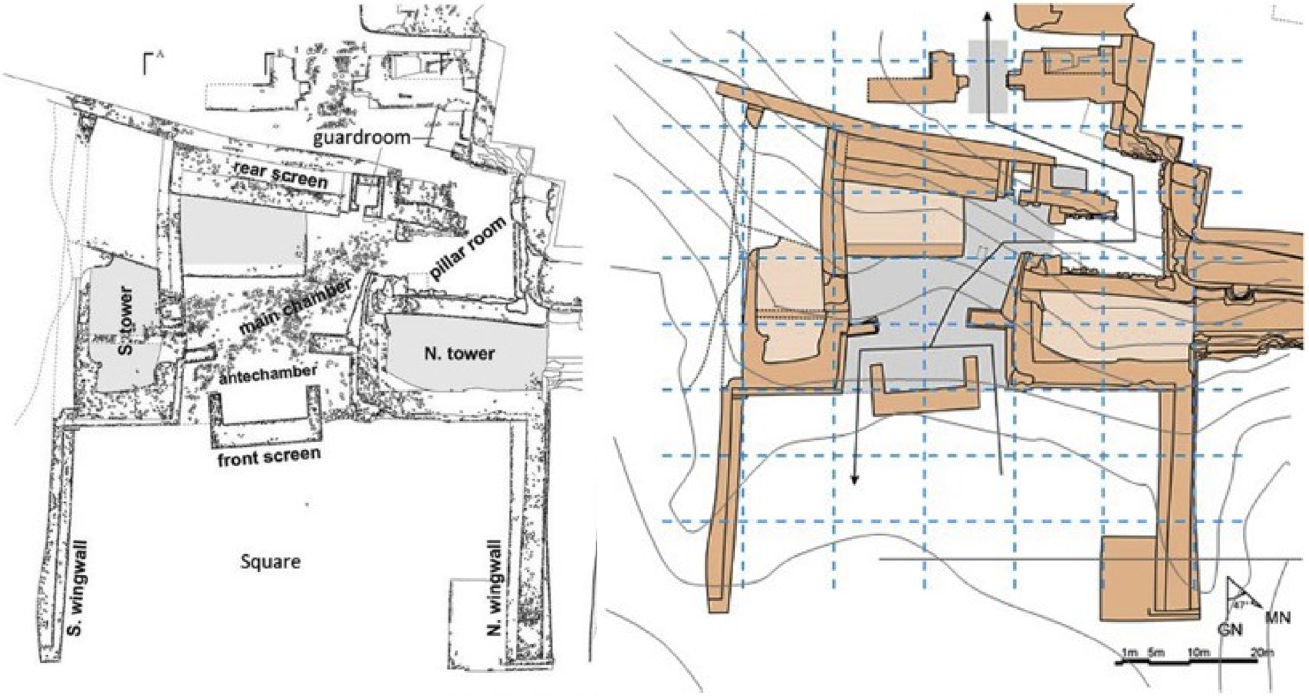


Figure 2.11. Plan of citadel gate at Huangchengtai, Shimao that shows the names of structures (left) and passing route across the gate (right). Figures from Guo et al. (2020: 3–4).

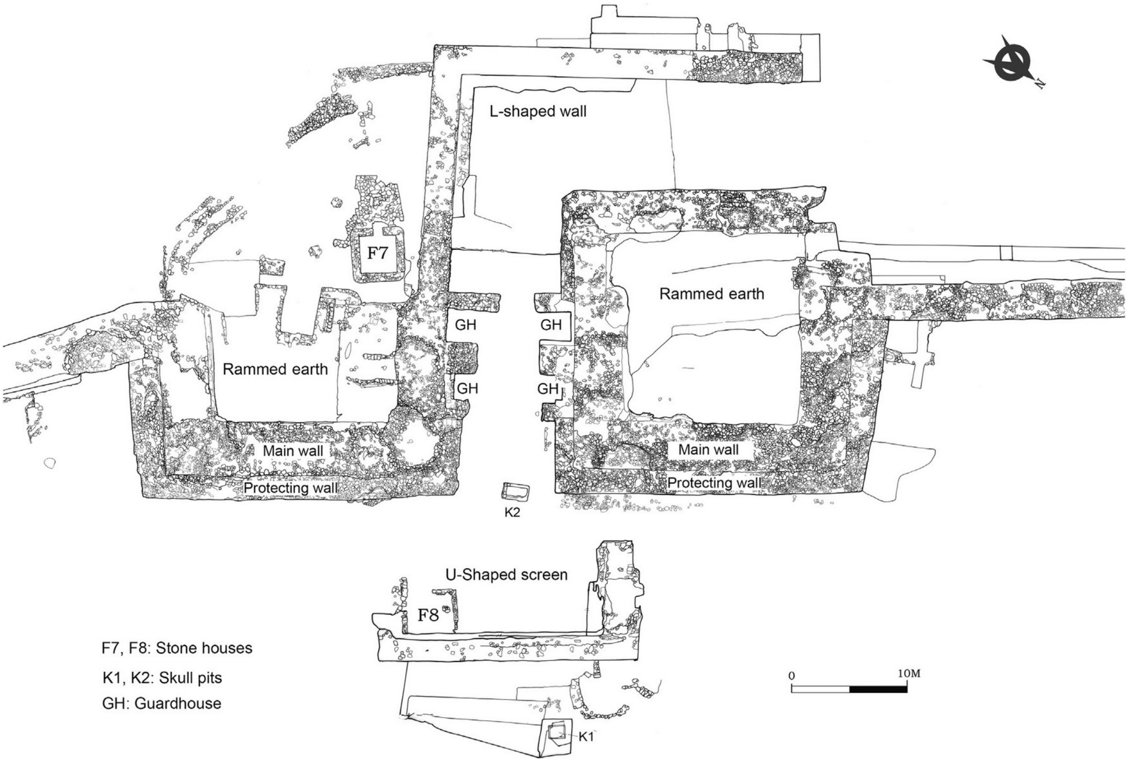


Figure 2.12. Plan of east gate located at the outer enclosure of Shimao. Figure from Sun et al. (2018: 39).

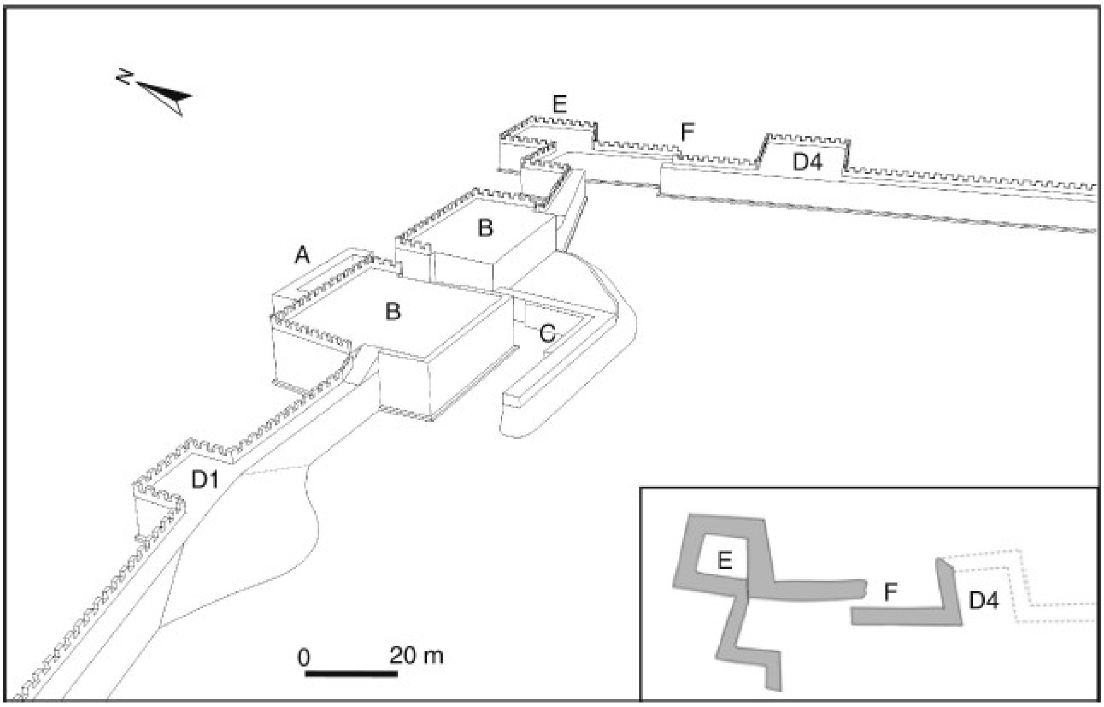


Figure 2.13. Drawing of the auxiliary structures at the outer enclosure of Shimao. A: U-shaped screen, B: gate tower, C: L-shaped wall, D1/D4: bastions, E: corner tower, F: small gate. Figure and information from Sun et al. (2018: 40).

Stone walling is also a common feature across the entire Shimao region. The walled structures vary between areas and can be generally grouped into four types (Table 2.3). The first type was built surrounding the tablelands, utilising the natural environment of steep slopes, usually in irregular shapes (Figure 2.14). This type is concentrated in the south of the Daqing Mountain area, such as at Ashan III (Baotou, 1984; Neimenggu & Baotou, 1984; Sun, 2000). The second was built with one or double layers of straight wall, which also utilise the steep slopes (Figure 2.15). This type is more common in the Qingshui River valley area, such as at Baicaota, Zhaizita and Xiaoshawan (Neimenggu, 1994: 183–204, 225–234, 1997; Wei & Cao, 1999). The third type utilises the alluvial slopes, usually in sector or circular shapes (Figure 2.16 and 2.17). This is common in the Daihai Lake area, such as at Laohushan, Bancheng and Xibaiyu (Yang, 2000), and the Qingshui River valley area, such as at Houchengzui and Zhaizishang (Neimenggu, 1994: 174-182, 1997). The fourth type is built with an inner and an outer layer, and are more common in the Yulin area, such as at Baiyagou and Shiluoluoshan (Figure 2.18) (Shaanxi, 2016b; Shanxi., 2017), but can also be found at Xiata in the Qingshui River valley (Li, 2007). A few sites—Baiyagou, Bicun and Shimao—are even built with a stone platform within the inner wall (Figure 2.6) (Shanxi & Xingxian, 2016; Shaanxi et al., 2017; Sun et al., 2018).

Period (BC)	Site	Size (ha)	Wall structure	Building material	Auxiliary structure	Number, size (m^2) and shape of stone 'altar'
2800–2500	Ashan III	5	Double tablelands	Stone, cobbles, earth	-	16: 1.767 (circular) 1: 60.821 (circular) 1: 0.96 (circular)
	Shamujia	0.048	Double tablelands	-	-	1: 54.76 (回-shaped) 1: 11.4 (squared) 1: 2.4 (circular)
	Heimaban	2	Double tablelands	-	-	1: 1301 (回-shaped) 1: 10.24 (squared)
	Xiyuan	2	Double tablelands	-	-	-
	Weijun	4	Triple tablelands	Stone	-	1: 81 (回-shaped) 1: 25 (回-shaped) 1: 113.098 (circular) 1: 4.47 (rectangular)
	Xiaoshawan	0.4	Double straight walls	Cobbles, earth	-	-
	Zhaizita	5	Double straight walls	Cobbles, earth	Watchtower	-
	Zhaizigadan	5	Single wall	Cobbles, earth	Corner tower-like structure	-
	Baicaota I-II	?	Single straight wall	Cobbles, earth	-	-
	Shilouloushan I	15	Inner and outer walls	Stone, cobbles, earth	Moat	-

Period (BC)	Site	Size (ha)	Wall structure	Building material	Auxiliary structure	Number, size (m^2) and shape of stone 'altar'
2500–2300	Laohushan	13	Sector/circular wall	Stone, earth	Platform-like structure (160m^2)	2: 4.71 (circular) 1: 9.42 (circular)
	Bancheng (group I)	10	Sector/circular wall	Stone, earth	-	1: 30.32 (squared) 1: 26.5 (squared) 1: 25.65 (squared) 1: 25 (sqaured) 1: 29.15 (squared)
	Xibaiyu	9	Sector/circular wall	Stone, earth	Stone-built steps	-
	Baicaota III	?	Single straight wall	Cobbles, earth	-	-
	Zhaizisheng II	3	Single wall	Stone	-	-
	Zhaizita II	5	Double straight walls	Cobbles, earth	Watchtower	-
	Xiata	28	Inner and outer walls	-	Moat, bastions, battlements	-
	Zhaishan	2	-	-	-	-
	Baiyagou	120	Inner and outer walls	Stone	Platform with retaining wall (unknown area)	-
	Shilouloushan II	15	Inner and outer walls	Stone, cobbles, earth	Moat	-
2300–1800	Bancheng (group II)	10	Sector/circular wall	Stone, earth	-	1: 30.32 (squared) 1: 26.5 (squared) 1: 25.65 (squared) 1: 25 (sqaured) 1: 29.15 (squared)
	Zhaizita III	5	Double straight walls	Cobbles, earth	Watchtower	-
	Houchengzui III	138	Single wall	Stone	-	-
	Shilouloushan III	15	Inner and outer walls	Stone, cobbles, earth	Moat	-
	Bicun	75	Single wall	Stone	Platform-like structure (unknown area)	-
	Zhaimao II	17	Single straight wall	-	-	-
	Zhaimaoliang	3	Single wall	Stone	-	-
	Shimao	400	Inner and outer walls	Stone, wood beams	Platform with retaining wall (80,000 m^2) and stone-built steps	1: 155 (circular)
1800–1500	Houchengzui IV	138	Single wall	Stone	-	-
	Zhaizita IV	5	Double straight walls	Cobbles, earth	Watchtower	-

Table 2.3. Wall structures, building materials, auxiliary structures and the number, site size and shape of stone ‘altars’ identified at the studied walled sites.

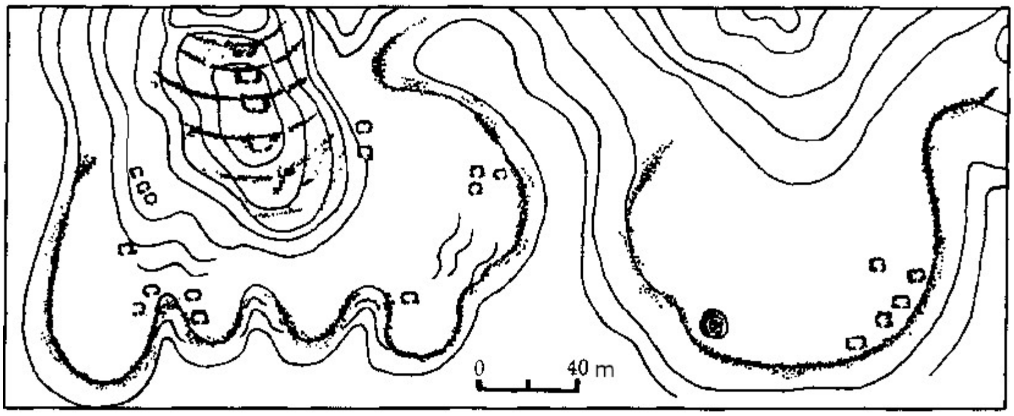


Figure 2.14. Plan of the wall structure at Weijun that shows the irregular walls surrounding tablelands. Modified from the figure from Wei (2003: 67).

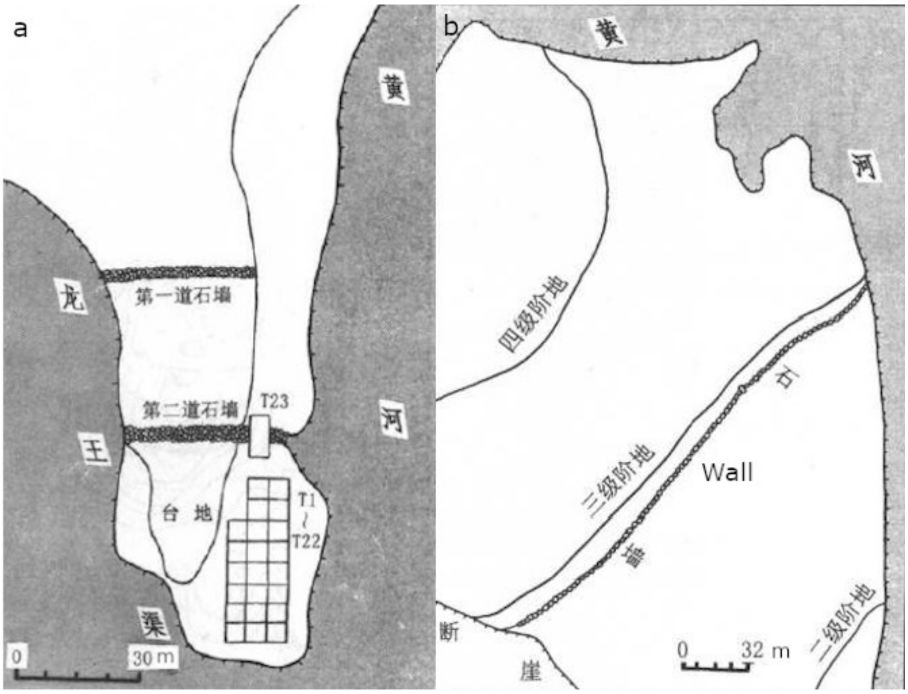


Figure 2.15. Plan of the wall structures with straight wall at a) Baicaota that shows the single layer of straight wall and b) Xiaoshawan that shows the double layers of straight walls. Modified from the figures from Wei (2003: 68).

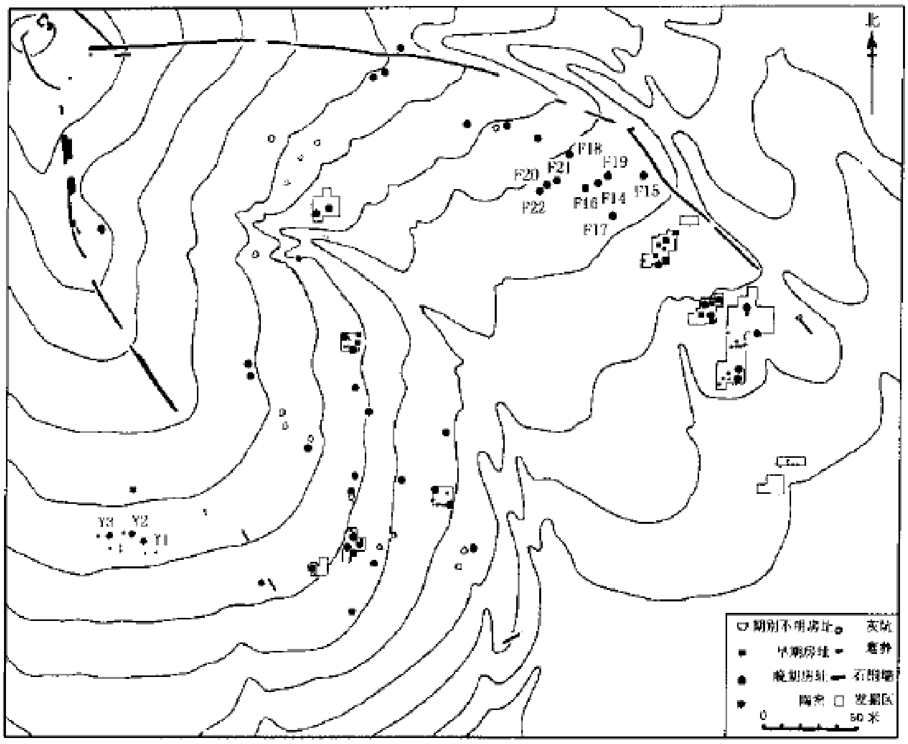


Figure 2.16. Plan of the wall structures at Laohushan that shows the sector-shaped wall. Figure from Wei (2003: 71).

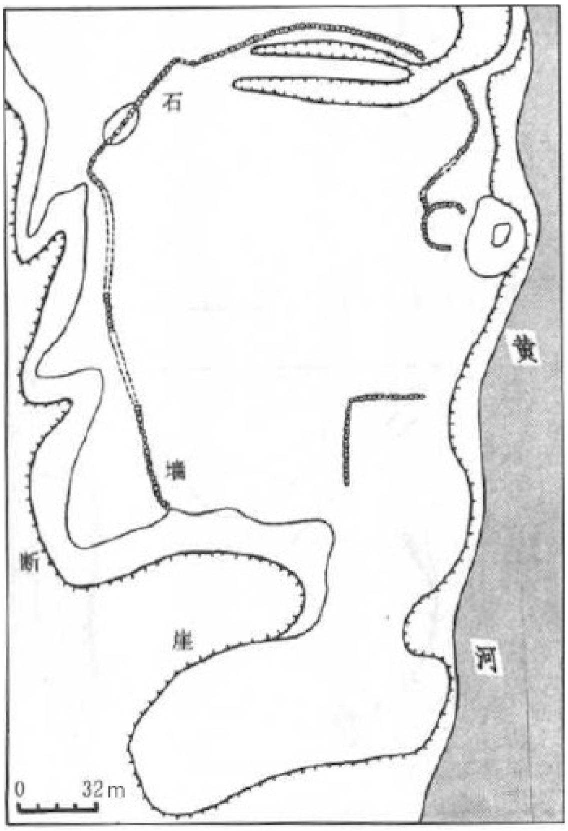


Figure 2.17. Plan of the wall structure at Zhaizishang that shows the round-shaped wall. Modified form the figure from Wei (2003: 68).

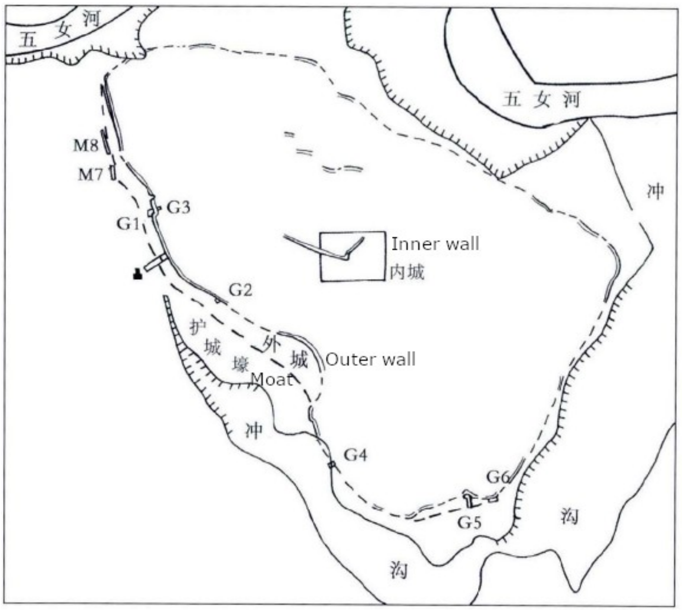


Figure 2.18. Plan of the wall structure at Shiluoluoshan that shows the inner and outer walls. Modified from the figure from Shaanxi (2016: 4).

The defensive features are incorporated as auxiliary structures of the walls at certain sites (Table 2.3). The defensive-like auxiliary structures can be observed at Zhaizita, Zhaizigadan and Zhaizishang in the Qingshui River valley area: Zhaizita consists of a watchtower at the wall entrance (Wei & Cao, 1999), Zhaizigedan was built with a structure that looks like a corner tower (Wang & Yang, 1999), Zhaizishang has a structure that looks like a gate tower (Neimenggu, 1994: 174–182). The Xiata site, also located in this area, has more complete structures of bastions and battlements (Li, 2007; Zhang & Ding, 2016). Both the walled and non-walled settlements utilised the natural environment, such as cliffs and alluvial slopes as natural barriers. The construction of a moat can also be seen in either walled or non-walled settlements, but it is not as common as walling. Houses were discovered at Shimao and all the sites shown in Figure 2.5, but the findings are incomplete and random at most of these sites. Another feature is the construction of the stone circles or piles, which have been referred to as ‘altars’, built either within or near the fortifications. These ‘altars’ were usually built with cobbles in a ring- or square-shaped on small artificial mounds (Figure 2.19). They were common in the south of the Daqing Mountain and Daihai Lake areas (Table 2.3) (Baotou, 1984; Liu, 1988).

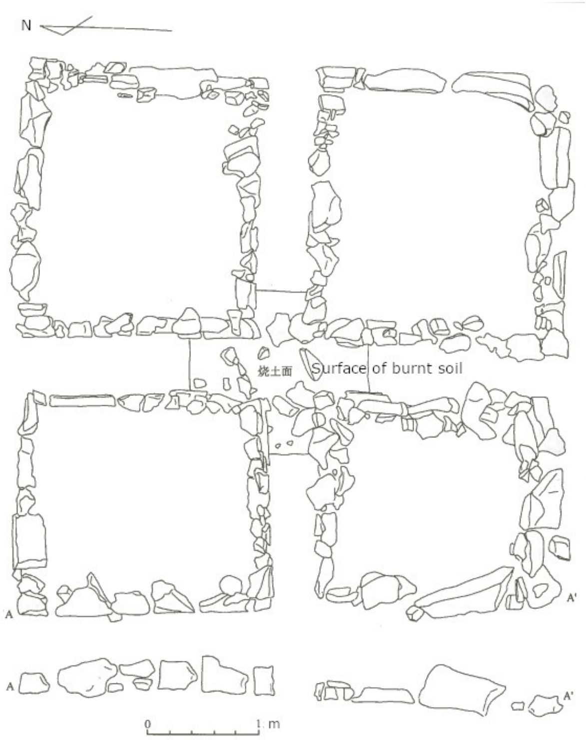


Figure 2.19. Plan of the ‘altars’ structure at Bancheng. Figure from Yang (2000: 212).

The building materials used to build the gates at Shimao were field sandstone, timber beams and loess soil (Guo & Sun, 2018; Guo et al., 2020). These materials may well have been extracted locally since sandstones are present around the site (Guo et al., 2016). The building technique involved earth ramming and placing stone blocks layer by layer, with the space between the blocks filled with clay mixed with straw (Guo et al., 2016). The rammed-earth (or hangtu) technique, in which soil is compacted to form a foundation for construction, was a traditional method seen in the Central Plains (Zhang & Ding, 2016). The surface of the stone blocks was polished (Guo et al., 2016; Shaanxi et al., 2017), and they were carefully placed and dressed during the construction (Figure 2.20) (Jaang et al., 2018). The timber beams were placed horizontally every 1 to 2 m; with the excavators judging that these timber beams were each 4 m long (Guo et al., 2020).

Figure 2.20. Photo of the wall construction at Huangchengtai, Shimao that shows the worked and carefully placed stone blocks. Figure from Jaang et al. (2018: 1018).

Other distinctive discoveries at Shimao include polychrome mural fragments discovered along the gateway at the east gate (Figure 2.21) (Sun et al., 2018). Six pits with decapitated human skulls from young females have been found at east gate (Figure 2.21) (Chen et al., 2016). Since there is no apparent trace of warfare or violence, these skull pits might have been used for sacrificial purpose (Sun et al., 2018). In addition, jade, bronze knives and bracelets have also been discovered, while bronze knives and a mould that may has been used to produce these objects have been discovered at the Huangchengtai platform (Figure 2.10 and 2.22) (Sun & Shao, 2017; Sun et al., 2018). Meanwhile, copper/bronze bracelets were collected from outside the excavation site but have been said to have originated from the Hanjiagedan cemetery in the inner enclosure (Figure 2.6 and 2.22) (Shaanxi et al., 2016b; Sun et al., 2018). These objects included a set of six metal arm bracelets accompanying two jade bracelets, which were probably grave goods (Sun et al., 2018).

Figure 2.21. Photo of skull pits (left) and polychrome mural fragments (right) discovered along the gateway of east gate at the outer enclosure of Shimao. Figures from Sun & Shao (2016: 52) and Shaanxi (2016:109), respectively.

Figure 2.22. Photos of the bronze bracelets from Hanjiageda burials at Shimao. 1: flat ring-shaped; 3,4: wide armbands; 2,7–9: dentate shaped; 5,6: ring shaped. Figure and information from Sun et al. (2018: 41).

The jade and bronze artefacts are distinctive in the Shimao region. The discovery of jade artefacts is concentrated in the Yulin areaat Shimao Bicun and Xinhua, but jade has also been discovered in the Qingshui River valley and Ordos city areas, such as at Xicha and Zhukaigou, albeit in lower numbers. The major types of jade artefacts found at these sites including *yazhang* sceptres, *bi* disks, *yue* axes and *huang* pendants (Wang & Guo, 2016). Other unique types, such as shapes of human heads, tigers and eagles have also been discovered at Shimao (Wang & Sun, 2011). These objects were mainly discovered from burials and ritual structures, but in the case of Shimao they were also discovered in the gaps between the stone blocks of the stone-platform wall (Sun et al., 2018).

Bronze artefacts have been discovered in the Shimao region but only at a few sites—Shimao, Erliban, Huoshiliang and Zhukaigou. The types of these objects are mostly bracelets and small knifes, typical steppe objects, and usually discovered in burials or randomly collected (Neimenggu & Ordos, 2000; Sun & Shao, 2017; Sun et al., 2018). Even though the discovered items are few and not as common as jades, they are the earliest known bronze objects discovered in the Shimao region of the period 2300–1800 BC. Since the discoveries of the jade and bronze objects are few, and most of them are randomly collected from the sites, their occasional presence is not considered further in this thesis. The distribution of these objects, nevertheless, are recorded in Table 1.1, and will be discussed together with the findings of this thesis in Chapter 7.

2.3.4 The demographic and socio-economic evidence

2.3.4.1 Chronology

The currently accepted chronology for the Shimao region is mainly based on the ceramic topology, with the consideration of radiocarbon dates from major sites (CASS, 2010; Han, 2003, 2008; Sun, 2000, 2016; Tian & Guo, 2004; Wei & Cao, 1999). The typo-chronology for different areas of the Shimao region has been put forward by different scholars, as summarised in Table 2.2. The cultural sequences built upon the typo-chronology suggest that there were four cultural periods in the Shimao region during the period 2800–1500 BC. The conventional periods that are commonly used in Chinese archaeology are also listed in Table 2.2, for convenience, as they are often used to referred to the cultural periods different parts of China including the Shimao region. These conventional periods will only be used in this thesis when referring to time, but not associated with cultural identity. Sequences derived from typo-chronology assume that cultural groups who shared similar ceramic types and forms occupied in the same period with the same duration, but it is noted that this may not always be the case. For this reason, although the sequences derived from ceramic typology are indicative for relative dating, considering radiocarbon dates can help further refine the typo-chronological sequences.

<table>
<tr><th>Wei & Cao (1999)</th><th>Sun (2016)</th><th>CASS 2010</th><th>Tian & Guo (2004)</th><th colspan="2">Han (2003; 2008)</th><th>Cultural period in Central Plains</th></tr>
<tr><td>Before 3000 BC
Haishengbulang</td><td>3000–2800 BC
Haishengbulang</td><td>3300–2800 BC
Haishengbulang</td><td>3500–3000 BC
Haishengbulang</td><td colspan="2">3500–2500 BC
Haishengbulang</td><td>Late Yangshao</td></tr>
<tr><td>After 2700 BC
Ashan III</td><td>2800–2500 BC
Ashan III</td><td>2800–2500 BC
Ashan III</td><td>Around 2800 BC
Ashan III/Laohushan</td><td colspan="2">3000–2500 BC
Ashan III</td><td>Yangshao/Longshan transition</td></tr>
<tr><td>Around 2500 BC
Laohushan</td><td>2500–2300 BC
Laohushan</td><td>2500–2300 BC
Laohushan</td><td>2500–2300 BC
Laohushan</td><td rowspan="2">2500–1900 BC
Laohushan</td><td rowspan="2">2500–1900 BC
Dakou</td><td>Early Longshan</td></tr>
<tr><td></td><td>2300–1800 BC
Shimao</td><td>Around 2000 BC
Dakou I/Zhukaigou</td><td>Around 2000 BC
Dakou II</td><td>Late Longshan</td></tr>
<tr><td></td><td></td><td></td><td>Around 1800 BC
Zhukaigou</td><td>1900–1500 BC
Zhukaigou</td><td></td><td>Erlitou</td></tr>
</table>

Table 2.2. Summary of the assignation of cultural periods in the Shimao region, according to the ceramic typology suggested by CASS (2010), Han (2003; 2008), Sun (2000; 2016); Tian & Guo (2004) and Wei & Cai (1999).

Currently, the radiocarbon dates that have been correlated to the typo-chronological sequences are subjected to the issues in relate to sampling, application and interpretation. This is due to variable practices in radiocarbon dating, ranging from the matrices used for dating to uncertainty in even the half-life calculations and infrequent application of standard calibration practices and application of Bayesian modelling. Since no recalibration of the dates and review of the chronology was undertaken, when more radiocarbon dates from the sites in the south of the region were released recently, it is uncertain whether the currently accepted chronology is reliable, and thus whether it can be used to provide the context on demographic and socio-economic changes over space and time. For these reasons, all available dates from the Shimao region will be recalibrated using Bayesian modelling within OxCal 4.4, to see whether the date ranges of the current chronology need to be refined. The reaffirmation of the chronological sequence can ensure that interpretations and suggestions are underpinned by a reliable chronological framework, which serves to provide the context for shifts in occupation and settlement size over time. The date ranges listed in Table 1.2, therefore, may be refined after the recalibration analysis done in Chapter 3.

2.3.4.2 Settlements and stone-wall fortifications

The settlement sites in different areas exhibit a range of sizes and structures. The settlements at the north sector of the region, in the south of the Daqing Mountain (Dai, 2016a), the Daihai Lake (Dai, 2016a; Wei & Cao, 1999), and the Qingshui River valley areas (Wei & Cao, 1999) tend to be smaller, being all below 13 hectares. The sites in the south around at Shimao and the surrounding sites in the Yulin area, exhibit a broader range of dimensions, varying between 1 and 30 hectares from 2800–2500 BC, before increasing to between 1 and 80 hectares from 2500–2300 BC, with the number of sites larger than 50 hectares increasing explicitly (Sun, 2016). The largest 400-hectare Shimao site (the only site above 100 hectares) in this area then developed during 2300–1800 BC (Sun, 2016). The above figures show a trend for site size to become larger over time. In addition to this, the province-wide regional survey conducted in the 1980s, combining with the third nationwide survey on number of sites and site size that was conducted from 2007–2011,[8] suggests that sites increased in number and larger stone fortifications increasingly built in the Yulin area from around 2300 BC onwards (Sun, 2016; Zhang, 2017), presumably linked to population growth around 2500 BC. This suggestion, however, solely based on the record of number and size of sites, which is subjected to certain issues.

First, the sites covered in the above surveys either belong to a long period within the late Neolithic or are labelled by the conventional periods (i.e. Longshan and Erlitou periods), where the date ranges are unclear. The implication is that suggestions are based on the evidence only that the number of sites increased during the entire Longshan period or even from the preceding late Yangshao period onwards, which extends from 3000–1800 BC. This prevents us from identifying the time in which large stone fortifications were built and population size might have increased. Second, large stone fortifications are assumed to have increased in the Yulin area during the late Longshan period, simply because the earlier survey suggested that the majority of sites are dated to the Longshan period (Sun et al. 2018). Similarly, population is assumed to have grown in this area just because the sites seemed to be densely distributed there, along with the emergence of Shimao itself (Sun & Shao, 2015). The appearance of the largest site at Shimao during the late Longshan period also may have misled us to believe that larger stone fortifications are concentrated during this period. Third, the observation alone also cannot be directly linked to population growth, and other evidence should be considered. Due to these limitations, we currently do not know whether the overall

[8]The third nationwide survey is not currently given open access to the public. The information from this survey thus far has only been mentioned in Sun & Shao (2015) and Zhang (2017).

site size expanded, or whether larger sites were increasingly built at the time when Shimao emerged.

As a result, further analyses are needed to explore whether the population might have shifted southwards across the Shimao region, whether larger stone fortifications might have increased, and even whether the population may have grown and/or become concentrated in the south. These questions are related to the studies and sub-topics of distribution of human occupation, population movement, settlement size and distribution shape, and population size and concentration. Currently, no detailed analyses have been done on these subjects for the Shimao region. Labour input estimations have been attempted from wall volume has been done for two individual sites, Shiluoluoshan (Zhang & Ding, 2016) and Shimao (Sun et al., 2018) to reflect their scale. Estimation of population size based upon site size has also been suggested for Laohushan (Wei & Cao, 1999; Wei, 2003). This thesis will consider the changes of settlement size and distribution over time and space, in order to provide new information on demographic changes from a different perspective.

2.3.4.3 Subsistence

Up to 2800 BC, the subsistence economy seemed to be dominated by millet cultivation. This is evident with the isotopic dietary analysis, which suggests that millet (C_4 plants) probably remained a major food source in human and animals' diet at Dakou, Muzhuzhuliang, Shimao, Shengedaliang, Xinhua and Zhukaigou (Atahan et al., 2014; Chen et al., 2015b, 2017a, 2017b). Macrofossil flotation analysis also suggests that broomcorn and foxtail millets were the major crop plants consumed at Zhaimaoliang, Muzhuzhuliang, and Shengedaliang, comprising respectively 43.89%, 67.39% and 72.7% of the total plant seeds at these sites (Gao et al., 2016; Guo, 2017), as well at Shimao and other nearby sites (Sheng et al., 2021). Aside from that, wild-game hunting still formed part of the economy, when wild animals were more prominent over pigs and dogs, as indicated by zooarchaeological evidence from Dagujie, Wuzhuangguoliang and Yangjiesha (Hu & Sun, 2005; Hu et al., 2012, 2013). Current evidence, therefore, shows that, from 2300 BC onwards, the inhabitants in the Shimao region practised a mixed subsistence economy mainly comprised of millet cultivation, pig husbandry and herding of sheep/goat and cattle, and small-scale wild-game hunting. The subsistence economy has thus been suggested to have transitioned from agriculture-based economy to a mixed economy from 2300 BC onwards, when Shimao emerged (Chen et al., 2017a; Guo, 2017; Wang et al., 2014b).

Discoveries of both wild and domesticated herd animals in the Shimao region are little prior to 2300 BC. Domesticated herd animals only increasingly appeared at more locations and in greater number in the region after 2300 BC, at Xicha and Zhukaigou in the Qingshui River valley and Ordos city areas (Huang, 1996; Yang, 2007), and Huoshiliang, Shimao, Muzhuzhuliang, Xinhua and Zhaimaoliang in the Yulin area (Hu et al., 2008a, 2016; Huang, 1996; Owlett et al., 2018a; Xue et al., 2005; Yang, 2007; Yang et al., 2017). This observation shows that herd animals seemed to have become prevalent at Shimao and the other sites in the south of the Shimao region, but we do not understand whether all the preferences for domesticated mammal species and the ways of consumptions for herd animals differed between these sites. This thesis will analyse the faunal evidence with taxonomic abundances and mortality profile analyses to approach these questions.

2.3.4.4 Material culture: ceramic tripods

It has been generally suggested that ceramic tripods were widely adopted in the Shimao region from 2500 BC onwards (Tian & Guo, 2004), replacing the flat-based pottery, and remaining prevalent when Shimao and the surrounding sites were occupied (Sun, 2016). The transformation of specific pottery forms seems to have proceeded such that, first, the base of *gang/weng* was replaced by the three-legged form (Sun, 2016). Second, *jia* was transformed to *jia-li* and then *li* (Chen, 1996: 84–101; Han, 2015b; Shao, 2019). Third, the bottom or leg area of three-legged vessels, especially *li* and *weng*, became even wider and more bulged (Wang & Zhang, 2016). Before the discoveries of the evidence from the Yulin area, the Laohushan cultural sites in Daihai Lake area were assumed to be the area where ceramic tripods were invented, and where the transformation from *jia* to *li* took place, with that later spreading southwards. However, this suggestion now needs to be reconsidered since more evidence now suggests that *jia* vessels already existed in the south contemporaneous to, or even preceding, those in Dahai Lake area (Shaanxi & Yulin, 2000; Shao, 2019). Meanwhile, although the transformation of ceramic typology in the Shimao region is well established, the genesis and transformation sequences in time and space are currently poorly understood. It is therefore uncertain whether adoption and/or modification of ceramic tripods became the most intensive in the south of the region when Shimao and other sites emerged, along with other demographic and economic developments. To address these questions, the prevalence of different shapes of base and forms of ceramic especially tripods and their geographic distribution across the Shimao region will be considered.

Chapter 3

Re-examining the chronological framework and distribution of human occupation

3.1 Introduction

The chronology of the Shimao region is considered first since it provides the context for investigating the spatiotemporal patterns in the latter analyses. The currently accepted chronological framework, outlined in Chapter 2, is mainly built upon ceramic typology, with a limited, associated consideration of radiocarbon (^{14}C) dates. This framework suggests four cultural periods in the Shimao region during the period 2800–1500 BC (Table 1.2 and 2.2), and material cultural sequences are assumed as suggesting that the settlements developed one after another. This sequence indicates that human occupation was concentrated initially in the north and then proceeded to shift southwards around 2300 BC. Radiocarbon dates have so far been used mainly as an adjunct to, or in support of, the material culture-based sequence. Many of the dates were obtained over several decades, under different circumstances and laboratories. They have rarely been subjected to critical quality analysis as is standard in contemporary radiocarbon dating. The calibration methods and half-lives applied to these dates also differed, and recalibration and Bayesian modelling have not yet been attempted for all the published radiocarbon dates. The Shimao region has not yet been subjected to the same procedures. More ^{14}C dates from the sites in the south of the Shimao region have been published in recent years, so these dates should now be considered together with those published previously. Since many of the latter were carried out some time ago, they require added scrutiny.

In this chapter, the existing dates culled from the literature are re-examined, by carrying out first a strict quality control exercise (for suitable materials, error margins). They are then recalibrated using the current half-life and the calibration curve for the northern hemisphere, and finally these dates are subjected to Bayesian modelling using IntCal20 within OxCal v 4.4 (Reimer et al., 2020). While only dates from part of the sites in the Shimao region are considered, this analysis serves as a first attempt to recalibrate existing dates and to compare them again with the existing typo-chronological sequence for the region.

3.2 Aim and objectives

This chapter therefore aims to test the reliability of the date ranges applied in the existing chronological framework, and from this, to identify the distribution and shifting trend of human occupation across the Shimao region. This is done by observing the dates in different ways using Bayesian modelling in OxCal v 4.4. The objectives of this chapter are therefore to:

1) collect the ^{14}C dates from the literature and standardise these dates with the half-life 5568;

2) assign these dates to the four periods set out in Table 1.2;

3) analyse the data via Oxcal v 4.4;

a) to generate a kernel density estimation (KDE) model,

b) to recalibrate the existing ^{14}C dates,

c) to generate a phase contiguous model with general charcoal outlier models,[9]

[9] There are three types of inherent phase models available in OxCal v 4.4: contiguous (one phase starts as the previous one ends), sequential (one phase starts after the previous one has ended with a possible gap), or overlapping (one phase might start before the previous one has ended). See https://c14.arch.ox.ac.uk/oxcalhelp/hlp_input.html. There are two types of outlier model in OxCal v 4.4: a general outlier model and a charcoal outlier model. For more details about these models, see Bronk Ramsey (2009).

d) to plot the analysed dates on a map in time-gradient fashion.

The KDE model estimates a group of dates randomly to reveal the grouping of the analysed dates and within which date ranges they fall, which can be seen as a tool to summarise all the dates.[10] The calibration of dates is unmodelled, which does not apply with the presumed typo-chronological sequence. The phase contiguous model helps to test whether the current periodisation and date ranges of this framework can be established, and thus assess whether these need to be refined. The general outlier model is applied to detect potential outliers and remove or adjust these. The map done in objective 3d illustrates the geographic distribution of dates with no modelling constraint but coloured by phase, to show the extent to which the accepted chronological framework can be verified, as well as to visualise the shifting patterns in human occupation. In the following, the materials and methods used in the analysis will be provided, followed by the results, which will be presented in four parts: the KDE model, calibration of dates, phase contiguous model and geographic distribution of dates on a map. Finally, a discussion of the reliability of the current chronological framework and the pattern of human occupation inferred by the results will be given, before the conclusion.

3.3 Currently accepted typo-chronology

The typo-chronological sequence was summarised in Chapter 2 and is shown in Table 1.2 and 2.2. This sequence has been used to suggest that the loci of settlement groups and/or population shifted southwards across the Shimao region from 2800 BC onwards (Tian & Guo, 2004, Wei & Cao, 1999), from the south of the Daqing Mountain area to the Daihai lake, Qingshui River valley and Ordos city areas (Figure 2.4). After the rediscovery of the Shimao site in the Yulin area, Dai (2016a) includes the sites in the Yulin area and suggests that the population in the south of the Daqing Mountain area and the Daihai Lake area might

[10] For more details about the usage of the KDE model, see Bronk Ramsey (2017).

have moved southwards to the Yulin area, along with the significantly increased number of sites in northern Shaanxi during the late Neolithic. This is however problematic because changes in number of sites alone cannot directly reflect population movement. This only indicates that population density might have shifted southwards. The interpretation itself which mainly based on the currently accepted typo-chronological sequence also suffers significant drawbacks.

3.4 Issue in the application of radiocarbon dates in the Shimao region

Although ^{14}C dates have been used to support the current chronological framework, there are issues in the methodology for deriving these dates, as well as in their application and interpretation. The chronological sequences are therefore still heavily based on ceramic typology, with the assumption that sites with a similar cultural context are contemporary. The ^{14}C dates have up to now only been used when they appear to fit the cultural sequence and have often been discarded when they seem not to. For example, the ^{14}C dates which seem to be too early are excluded (e.g. Zhukaigou in Tian & Han 2003: 236 and Miaozigou in Han 2003: 72. This way of using ^{14}C dates in archaeology can be misleading because the use of these dates is selective.

Another methodological issue links to unsystematic sample collection for ^{14}C dating. Samples have been collected randomly rather than stratigraphically for some of the sites in the Shimao region. This does not permit the generation of a complete chronological sequence for a site. In addition to this, early Chinese ^{14}C dating reports done in 1980s and 1990s do not always include detailed information about the cultural context of the layers from which the samples were collected (e.g. CASS, 1992). Even though the rough cultural context or conventional cultural period is sometimes mentioned, these reports have pointed out that the information is simply an estimation. For these reasons, many ^{14}C dates cannot be precisely correlated with a specific cultural layer. If a date is derived randomly from a site with several phases, this data cannot help us to understand the chronology of this site and its relation to other sites.

Furthermore, the information related to these ^{14}C dates in the literature lacks clarity. The calibrated dates used in the Chinese literature have been related to archaeological sites without indicating which half-life was used for calculating the ^{14}C age (e.g. Tian & Guo, 2004: 68–69, Tian & Han, 2003: 236,). This introduces uncertainty and potential errors. The calculations of ^{14}C age from half-lives 5730 and 5568 (the former has been proven as a more accurate half-life calculation for ^{14}C dating) can result in an offset of 100 years or above to the calibrated dates (Godwin, 1962). Failure to indicate the half-life used renders the accuracy of the ^{14}C dates in the Chinese literature uncertain. The interpretation using dates with a half-life 5568 should then be reconsidered. Apart from that, ^{14}C dates are sometimes mentioned without quoting the original source and reference (e.g. Sun, 2000: 50; Wei & Cao, 1999: 59), or the lab code and material used for dating is missing in the original source (e.g. CASS 2010: 824). These omissions again render the archaeological interpretations from these dates questionable.

Additionally, ^{14}C dates from a site are often shared with other sites where their typologies (pottery and house styles) are assumed to be similar, even if these sites are distant from each other. For example, Tian & Guo (2004: 69) use the ^{14}C dates from the Taosi and Miaodigou II sites in Central China to correlate with those in southern and central Inner Mongolia. This practice is problematic and circular because sites in different areas do not necessarily date to the same period just because their typology is similar. This approach also precludes us from asking questions about the nature and origins of such changes. This practice has also been applied to the dating in the Shimao region. However, the pace of development does not seem to be synchronous in these two regions, even though the developmental trajectory of pottery in northern China followed the Central Plains. The similar types that appeared in northern China may well in fact be later than in the Central Plains, if one considers the cultural sequences and contexts in the Shimao region (Table 1.2 and 2.2) and the Central Plains indicated in CASS (2003, 2010).

3.5 Materials and methods

This section covers the materials used in the analysis, and the protocols for assuring quality control of the data, followed by the details of the application of Bayesian chronological modelling using OxCal v 4.4. After this, the analysis process and the limitations are discussed.

3.5.1 Calibration in Bayesian modelling and OxCal v 4.4

The Bayesian chronological models were generated by the programme OxCal v 4.4. The reasons for choosing Bayesian modelling via OxCal v 4.4 are that the analysed dates can be readily calibrated by inputting such dates to the programme, and that different types of Bayesian models (e.g. phase models and outlier models) can then be applied to these dates for further analysis. This programme is user-friendly and can be used online or downloaded for use offline. There is also an OxCal manual open for assess online,[11] which covers all the information and functions of this programme as well as all the literature in relate to the use of the programme.

This programme is written in C++ and uses Bayesian statistics and Gibbs sampling to calculate probability distribution for ^{14}C dates in sequences and phases (Bronk Ramsey, 1995, 2001, 2009). ^{14}C dates are calculated and analysed automatically once the dates are input using the Chronology Query Language in the programme (Bronk Ramsey, 1997). This

[11] See https://c14.arch.ox.ac.uk/oxcalhelp/hlp_contents.html.

programme has two major functions that are useful for the analyses in this chapter. The first one is that it can interrogate uncalibrated ^{14}C ages and convert them into calibrated dates. This is done automatically in the programme through a plotting process from the latest IntCal20 calibration curve (Reimer et al., 2020) that generates possible date ranges from the analysed dates (Bronk Ramsey, 1995, 2001). The second is that it can generate a KDE model and three types of phase models for a group of ^{14}C dates. The KDE model provides an alternative way of estimating the probability distribution of dates. The running of this model does not involve any prior information, and thus can be considered as a way of summarising all the dates without any cultural constraint introduced by the presumed cultural sequence (Bronk Ramsey, 2017). The phase models help us to evaluate whether the dates in the typo-chronological sequence can be verified, by considering the agreement with dates analysed. This can be observed by agreement indices (A) for individual dates to see how well any posterior distribution agrees with the prior distribution; likelihood indices (A_{model}), to see if a probability distribution is likely to combine well with the group of other distributions; and overall indices ($A_{overall}$) for the overall consistency (Bronk Ramsey, 1995, 2009).[12] These indices usually have values of around 100%; if A is lower than 60%, this may reflect that the samples are problematic, or the applied model is unreliable and may require further checking and adjustment (Bronk Ramsey, 1995). This programme also allows additional models to be built on top of the phase models. This includes a general outlier model, which is useful in this analysis. The outlier model is an alternative to check the consistency between the data and the model. It is able to detect possible outliers, assume some dates to be outliers, and also incorporate treatment of the outliers into the model (Bronk Ramsey, 2009).

[12] See also https://c14.arch.ox.ac.uk/oxcalhelp/hlp_analysis_detail.html. For calculations and formulas, see https://c14.arch.ox.ac.uk/oxcal3/math_ag.htm#overall.

3.5.2 Materials, data collection and quality control

The data were collected from Chinese radiocarbon dating reports (CASS, 1992, 1993), annual dating reports (Anonymous, 1996; Yuan, 1994) and other journal papers that cover the data from the studied sites (Atahan et al., 2014; Chen et al., 2015b, 2017b; Shaani & Yulin, 2005; Sun et al., 2018). The information of all the ^{14}C dates is listed in detail in Table 3.1 and Appendix I. Of these, 37 ^{14}C uncalibrated ages from 14 settlement sites that are associated to the Ashan III, Laohushan, Shimao and Zhukaigou periods are analysed here. OxCal v 4.4 automatically corrects dates calculated by the previously accepted half-life of 5568 years to the true half-life of 5730 years during the calibration process; most of the inputted dates obtained from the literature here all use the half-life 5568 years.[13] In smaller number of cases where the ^{14}C age was only available in the half-life of 5730, they were divided by 1.029 for conversion (Godwin, 1962).

[13] The half-life of carbon-14 was first determined as 5568 years by Willard Libby and has later been redetermined as 5730 by Harry Godwin. See Godwin (1962). The original half-life remained in use in calculations and reported in publication in order to maintain consistency.

Period	Correlated Period (BC)	Site	Area	Code	^{14}C age BP (5568 half-life)	Sigma	Materials	Cultural layer	Reference
4	1800–1500	Shengedaliang	Yulin	Shengedaliang1	3090	30	Collagen (human bone)	M7	Chen et al., 2017a
		Zhukaigou	Ordos city	Zhukaigou5	3192	85	Charcoal (wood)	I(3)H1055	CASS 1992: 59-60
		Zhukaigou	Ordos city	Zhukaigou4	3222	70	Charcoal (wood)	I(3) H1071, 1073	CASS 1992: 59–60
		Zhukaigou	Ordos city	Zhukaigou6	3324	70	Charcoal (wood)	V(2)H5018	CASS 1992: 59–60
		Yangchanggou	Daihai Lake	Yangchanggou1	3362	70	Charcoal (wood)	88楊F2:100	Yuan et al., 1994
3	2300–1800	Zhukaigou	Ordos city	Zhukaigou3	3416	70	Charcoal (wood)	I(4)H1058	CASS 1992: 59–60
		Shimao	Yulin	Shimao7	3411	30	Collagen (human bone)	HJGD001	Sun et al., 2018: 38
		Shimao	Yulin	Shimao6	3416	50	Collagen (human bone)	unknown	Atahan et al., 2014
		Shimao	Yulin	Shimao5	3440	45	Collagen (human bone)	unknown	Atahan et al., 2014
		Shimao	Yulin	Shimao4	3445	30	Lime floor	F6:1	Sun et al., 2018: 38
		Muzhuzhuliang	Yulin	Muzhuzhuliang1	3450	30	Collagen (human bone)	T1201M7	Chen et al., 2015b: 112–117
		Xinhua	Yulin	Xinhua2	3455	35	Collagen (human bone)	unknown	Atahan et al., 2014
		Shimao	Yulin	Shimao3	3455	45	Collagen (human bone)	unknown	Atahan et al., 2014
		Shimao	Yulin	Shimao2	3469	50	Collagen (human bone)	unknown	Atahan et al., 2014
		Xinhua	Yulin	Xinhua3	3518	120	Collagen (human bone)	96H14	Shaanxi & Yulin 2005: 375
		Xinhua	Yulin	Xinhua1	3557	120	Collagen (human bone)	96H50	Shaanxi & Yulin 2005: 374
		Shimao	Yulin	Shimao1	3625	25	Charcoal (wood)	F1:1	Sun et al., 2018: 38
		Erliban	Qingshui River valley	Erliban1	3703	65	Charcoal (wood) and charred soil	T2(6)下H10	CASS 1992: 62
		Zhukaigou	Ordos city	Zhukaigou2	4325	90	Charcoal (wood)	III T23(5)	CASS 1992: 59–60
		Zhukaigou	Ordos city	Zhukaigou1	4679	80	Charcoal (wood)	II T228(4)	CASS 1992: 59–60

Period	Correlated Period (BC)	Site	Area	Code	^{14}C age BP (5568 half-life)	Sigma	Materials	Cultural layer	Reference
2	2500–2300	Laohushan	Daihai Lake	Laohushan1	3761	70	Charcoal (wood)	Kiln Y3	CASS 1992: 59
		Yuanzigou	Daihai Lake	Yuanzigou5	4004	70	Charcoal (wood)	F3041	Yang, 2000
		Yuanzigou	Daihai Lake	Yuanzigou4	4062	100	Charcoal (wood)	Y3005	Yang, 2000
		Zhaizita	Qingshui River valley	Zhaizita1	4174	60	Charcoal (wood)	T4(2) H48	CASS 1992: 63
		Yuanzigou	Daihai Lake	Yuanzigou3	4259	90	Charcoal (wood)	F3045	Yang, 2000
		Yuanzigou	Daihai Lake	Yuanzigou2	4496	90	Charcoal (wood)	F3043	Yang, 2000
		Yuanzigou	Daihai Lake	Yuanzigou1	4772	100	Charcoal (wood)	F3042	Yang, 2000
1	2800–2500	Bainiyaozi	Qingshui River valley	Bainiyaozi1	4110	107	Charcoal (wood)	BD: F3	CASS 1993
		Ashan	South of Daqing Mountain	Ashan4	4121	80	Charcoal (wood)	H14	CASS 1992: 60–61
		Ashan	South of Daqing Mountain	Ashan3	4208	80	Charcoal (wood)	H8	CASS 1992: 60
		Ashan	South of Daqing Mountain	Ashan2	4218	70	Charcoal (wood)	I(3)H39	CASS 1992: 60–61
		Zhengzemao	Yulin	Zhengzemao1	4349	60	Charcoal (wood)	丙區T51 F4	Anonymous 1996
		Ashan	South of Daqing Mountain	Ashan1	4655	70	Charcoal (wood)	II(3)H5	CASS 1992: 60–61

Table 3.1. The sources and details of the radiocarbon dates studied in Chapter 3.

There were constraints to these radiocarbon data collected from the published sources. A quality control assessment was therefore applied to the collected ^{14}C dates, as follows: a) if the laboratory in which the ^{14}C age was generated or the relevant lab code was unavailable or unknown, those dates were omitted from further analyses, b) the materials used to generate these ^{14}C ages include only charcoal from wood and bone collagen, and in one case, a lime floor layer. In the case of charcoal, there is a possibility of 'inbuilt age' for 'old wood' (Dee & Ramsey, 2014), where the age of wood or charcoal precedes the desired date. Since palaeoenvironment record shows that forest existed during the Palaeolithic in the Shimao region, the dates from this region may be subjected to the 'inbuilt age' issue (Yang, 2000). A charcoal outlier model was therefore applied on top of the phase contiguous model in order to deal with this potential issue.

Purified bone collagen is also a standard material for dating archaeological sites, but there are also inherent problems. One common issue is the purity of the collagen (Brock et al., 2012), but this is addressed by following the conventional protocols of ensuring standard collagen yields and C/N ratios, which indicate the state of preservation and absence of impurities such as humic acids from soils. The ^{14}C dates derived from collagen samples are selected only if their C/N ratio falls between 2.9 and 3.5, which is deemed acceptable for ^{14}C dating (van Klinken, 1999). One single case of a date derived from a lime floor layer was included, but it is noted that lime is subjected to exchange with external carbon atoms (Pesce, 2012). These dates were subjected to testing by means of the general outlier model, in order to exclude or adjust statistical outliers in the OxCal programme where necessary.

For the analysis of the phase contiguous model, the collected dates were assigned to one or more of the four cultural periods set out in Table 1.2. This assignation listing in Table 3.1 is referred to the information of sample derived layers recorded in dating reports and also the information of the correlation between those layers and the four cultural periods recorded in excavation reports. For the date measurements missing the above information, the assignation was made according to what we already known at best about the cultural period of a site.

To deal with the difficulties of correlating samples to the stratigraphy, the sensitivity of the outcome was compared between a scenario including both dates where the cultural context is known and dates where the cultural context is unknown, and a scenario including only dates where the cultural context is known. This pre-analysis test showed that there were no significant differences between results from models with samples of unknown cultural context and results from models without such samples. In order words, it is acceptable to include dates with unknown cultural context in the phase contiguous model. Accordingly, ^{14}C ages derived from uncertain cultural contexts are considered in the model, as indicated in Table 3.1. The exception are two dates from Zhukaigou (Zhukaigou7 and Zhukaigou8) and two dates from Dakou (Dakou1 and Dakou2), as shown in Appendix I. It is because these dates cannot be assigned to any phase groups in the phase contiguous model where such information is required.

3.5.3 Analytical process

The analysis consists of three parts: the KDE model, calibration of dates, the phase contiguous model and regional distribution of dates. The KDE model was carried out by inputting all of the dates following the quality controls mentioned in Section 3.3.2 into the programme without any prior information and constraints. A result plot shows the distribution of these dates and where the date ranges are likely to fall. The calibration of dates was done by inputting all analysed dates without grouping them in a predefined order. These dates are analysed individually as well as grouped by site. For the latter, if a site only contains one or two measurements they were omitted because these dates produced a large error distribution in the model. Two graphs were generated from this part: one shows the distribution of date ranges of each measurement, another shows it by site with the start and end dates.

The phase contiguous model was done by inputting dates that were assigned to four phase groups, based on the presumed cultural periods set out in Table 1.2. The graph generated from this model was grouped in four phases, corelating to these four periods. Since the 'phase' is the default term to define grouping in the phase modelling, this term is only used when it refers to the modelling results. The term 'period' is only used when it refers to the cultural periods set out in the currently accepted chronological framework. This model was then applied with the general outlier model to identify potential outliers. This outlier analysis requires us to provide a prior probability, usually 0.05, for the likelihood that any individual measurement will be wrong (Bronk Ramsey, 2009). The result showed that three individual dates (Ashan1, Zhukaigou1 and Zhukaigou2) failed the model as their agreement was below 60%. These dates are kept in the model but considered as outliers. They were automatically adjusted by the phase model and are indicated on the graph in Section 3.4.3.

The geographic distribution of dates plotted on the map was also generated via the OxCal v 4.4, by inputting the studied dates, with additional information of the coordinates of sites from which the dates were derived. The dates were grouped by phase based on the cultural period set out in Table 1.2. No constraints were applied to frame these groupings, that is, the date ranges were not refined by the programme, but they are grouped by colour for identification.

3.5.4 Limitations

One of the major limitations of the analysis is that it considered published data only. Some sites in the Shimao region have no associated ^{14}C dates, or at least none in the public domain.

This problem is especially conspicuous for the Yulin area located in the south of the region because the analysed dates are all concentrated at a small number of sites, mainly from Shimao and Xinhua. For the dates from Shimao, they are all concentrated at the later phase. According to Shao (2016), the occupation period for Shimao can be divided in to three phases—the Huangchengtai platform and the inner wall are the earliest, began around 2300 BC; the outer was built and used together with other construction in the second phase, which is dated to around 2100 BC; all the above structures remained in use until the third phase, dated to no later than 1800 BC. A recent lecture about the new discoveries from Shimao by Professor Sun Zhouyong, has shown four new dates from the upper part of the Huangchengtai platform and the possible earliest date is 2100 cal. BC (UCLA, 2021).[14] Dr Wu Xiaohong is currently working on the sequence of dating for Shimao, and the results will hopefully be published in the future, but at present there is no news as to when we can expect this publication. The dates for Shimao considered in this analysis are all from the later phase and therefore the results will show a later date range; it is noted that if we consider the dates from the early phase of this site, the upper limit of the possible occupation period should be earlier.

In the wider region, apart from the date from the Zhengzemao site used in the analysis, recent discoveries indicate that there are sites that were already developed in this area in the early periods before or around 2500 BC, such as Zhaishan, Zhaimao I, Jiadamao, Miaoliang, Wuzhuangguoliang (Shaanxi, 2002; Shaanxi, 2011; Shaanxi & Yulin, 2009; Shaanxi et al., 2019; Shao, 2019), judging by their material culture. Despite the gaps, the analysis can reflect an overview with concentrations of dates indicating human occupation. The recalibration of available dates can also provide us with an idea of how accurate the current date ranges in the typo-chronological framework are. Possible adjustment therefore will only be made to the

[14] This is a lecture from the Sammy Yukuan Lee Lecture Series, organised by UCLA Center for Chinese Studies.

current framework for the purpose of this thesis, which is to emphasize the temporal and spatial transition of major occupation for the Shimao region.

Another limitation related to the uncertainty of the layer context, which meant that where dates were not collected systematically, it will not be possible to derive the exact start and end dates of occupation for the sites. Despite this, the analysis of the geographic distribution of dates intended to help identify human occupation is still meaningful because the focus is to identify the general north-south difference in time scale. It can still tell us the general occupation date of the sites in the north and in the south and whether they concentrated at different time periods, even if not the complete occupation date of individual sites. The relatively more complete collection of dates from other sites, such as Yuanzigou and Zhukaigou, and sites with a single date, but where the layer context is known, can help determine a rough occupation order across the region. Given the available dates, this is the best option to outline the occupation pattern in space and time.

3.6 Results

The results are presented in four parts: the KDE model, calibration of dates, phase contiguous model and the geographic distribution of dates on the map.

3.6.1 KDE model

The KDE model with no constraint by the cultural sequence is shown in Figure 3.1. This illustrates that there is one small peak and two major peaks in the number of dates. The first peak is between 3600 and 3200 BC. The second peak is between 3000 and 2400 BC, and the third between 2100 and 1200 BC.

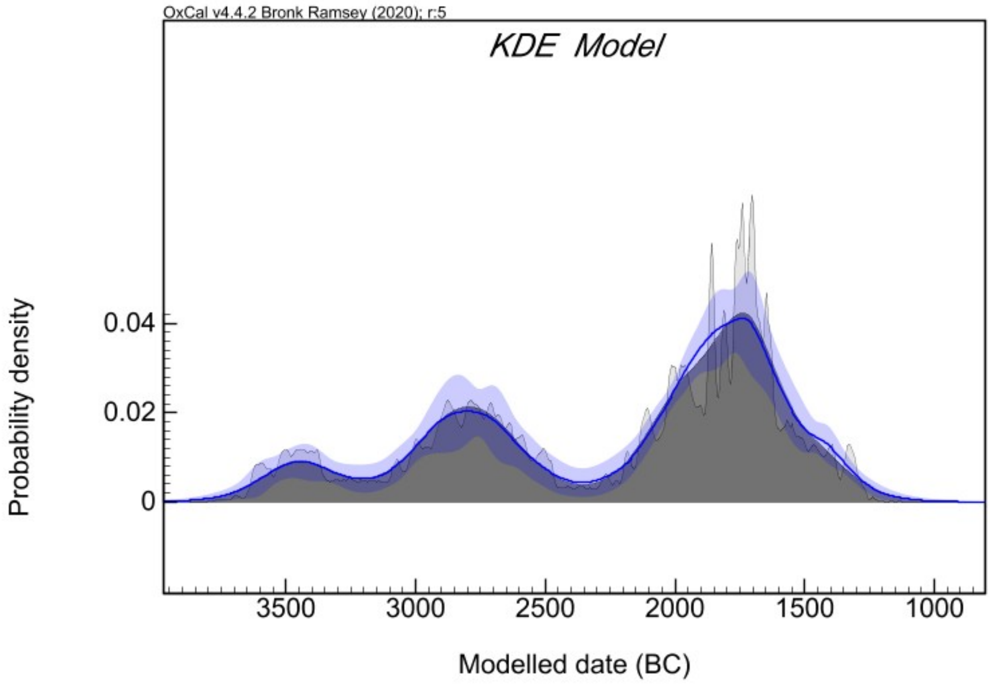
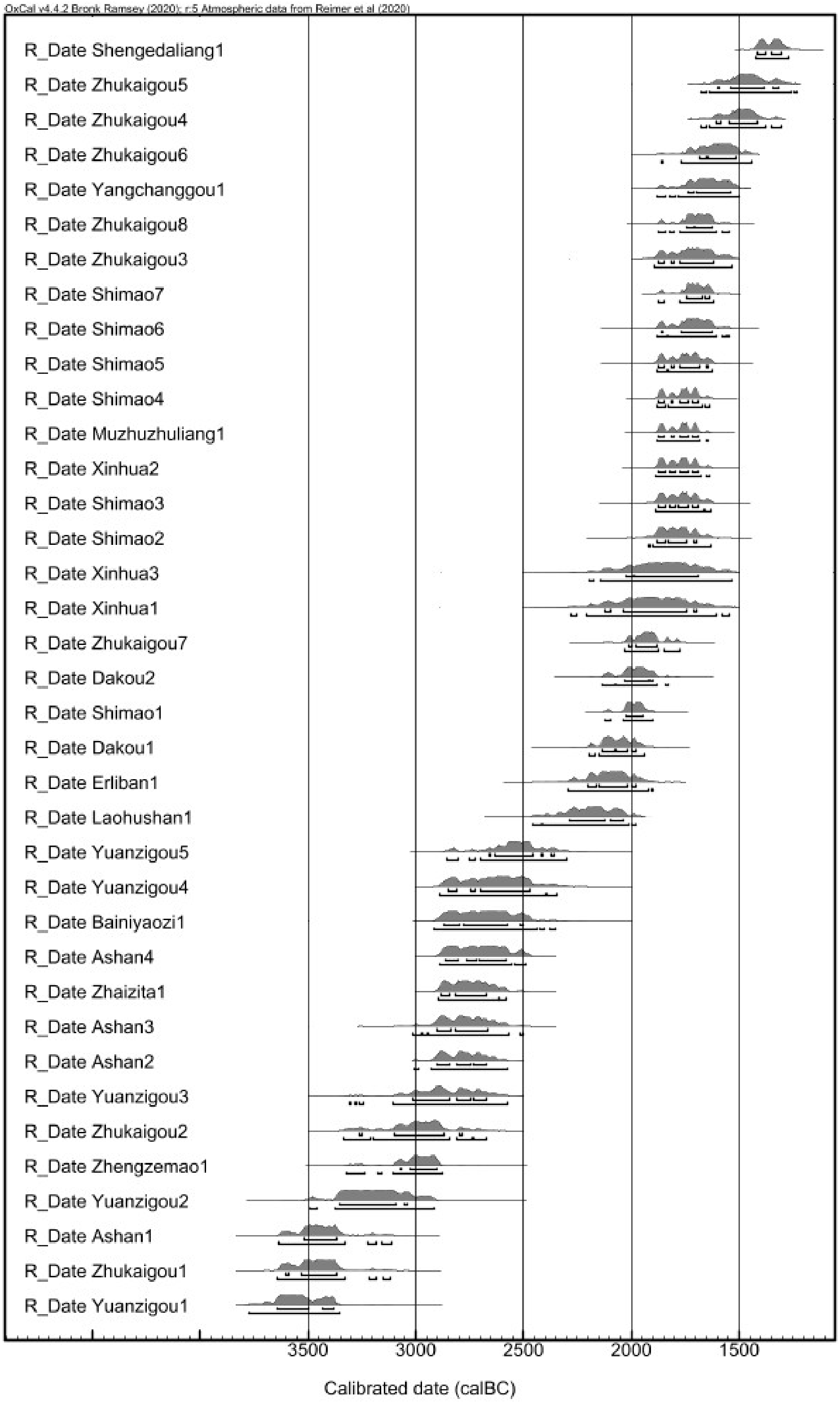


Figure 3.1. KDE model covering all the analysed dates that shows the distribution of all the dates with no constraint from presumed typo-chronological sequence. Higher peaks indicate a higher probability density that the dates concentrate. The dark grey distribution represents the sampled KDE estimated distribution. The blue line and the lighter blue band overlying it show the mean of one standard deviation for snapshots of the KDE distribution generated during the Markov chain Monte-Carlo (MCMC) process, and gives an indication of the significance of any features. The light grey distribution behind this overlay is the Sum distribution (alternative method for date summary in OxCal v 4.4) that has not been smoothen by the KDE method.

3.6.2 Calibration of dates

The calibration of dates is shown in Figure 3.2 and Table 3.2. This illustrates that those dates from the south of Daqing Mountain, Daihai Lake and Ordos areas concentrate between 3000 and 2500 BC, with a few dates falling between 3500 and 3000 BC. Those from the Qingshui River valley, Ordos and Yulin areas fall between 2200 and 1300 BC, but only a few dates, mostly from Zhukaigou, concentrate between 1500 and 1300 BC.



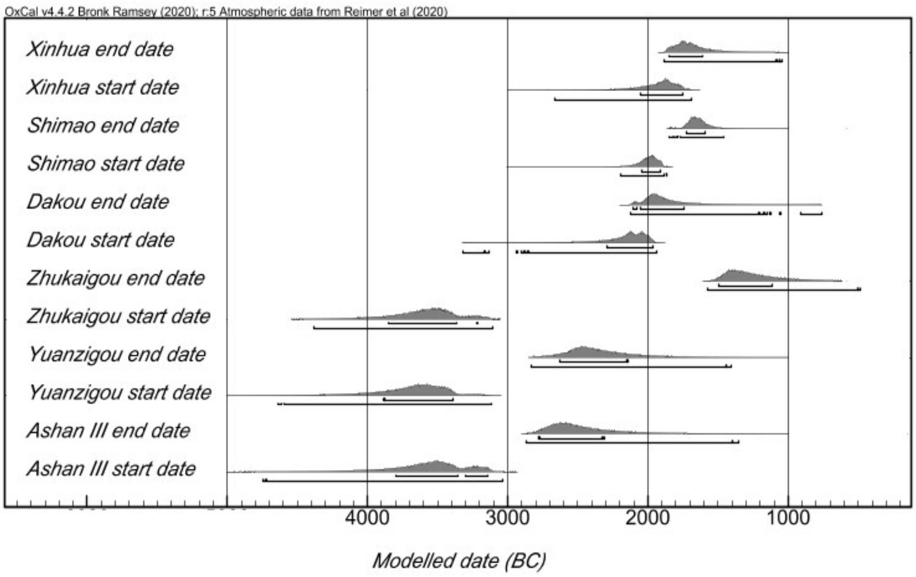
OxCal v4.4.2 Bronk Ramsey (2020); r:5 IntCal20 atmospheric curve (Reimer et al 2020) Amodel=90.5; Aoverall=90.6

Figure 3.2. The unmodelled probability distribution of date ranges of individual dates from the Shimao region. Dates shown in cal. BC with probability at 68.2% (upper bracket) and 95.4% (lower bracket) under the date ranges, corresponding to Table 3.3.

Code	^{14}C age BP (5568 half-life)	Sigma	Calibrated date range 95% (BC)	Calibrated date range 68% (BC)
Ashan1	4655	70	3635–3112	3520–3364
Ashan2	4218	70	3008–2577	2905–2675
Ashan3	4208	80	3011–2502	2902–2669
Ashan4	4121	80	2888–2488	2866–2580
Yuanzigou1	4772	100	3493–2915	3354–3037
Yuanzigou2	4496	90	3337–2675	3354–3037
Yuanzigou3	4259	90	3307–2574	3011–2675
Yuanzigou4	4062	100	2889–2344	2852–2472
Yuanzigou5	4004	70	2857–2297	2662–2356
Yangchanggou1	3362	70	1878–1499	1739–1540
Laohushan1	3761	70	2454–1976	2288–2040
Zhaizita1	4174	60	2895–2581	2881–2671
Bainiyaozi1	4110	107	2916–2349	2871–2504
Dakou1	3673	40	2197–1941	2136–1979
Dakou2	3615	45	2136–1827	2031–1901
Erliban1	3703	65	2290–1901	2199–1981
Zhukaigou1	4679	80	3642–3121	3605–3367
Zhukaigou2	4325	90	3337–2675	3262–2783
Zhukaigou3	3416	70	1892–1533	1873–1619
Zhukaigou4	3222	70	1678–1304	1602–1417
Zhukaigou5	3192	85	1676–1231	1599–1315
Zhukaigou6	3324	70	1864–1445	1684–1511
Zhukaigou7	3576	40	2033–1773	2014–1883
Zhukaigou8	3401	40	1874–1544	1742–1626
Shengedaliang1	3090	30	1425–1270	1413-1302
Zhengzemao1	4349	60	3323–2879	3076–2900
Shimao1	3625	25	2120–1898	2027–1949
Shimao2	3469	50	1919–1630	1879–1697
Xinhua1	3557	120	2279–1545	2120–1700
Xinhua2	3455	35	1885–1641	1875–1693
Xinhua3	3518	120	2195–1535	2025–1688
Muzhuzhuliang1	3450	30	1881–1642	1873–1693
Shimao3	3455	45	1886–1631	1877–1691
Shimao4	3445	30	1880–1640	1872–1691
Shimao5	3440	45	1881–1625	1874–1645
Shimao6	3416	50	1881–1546	1862–1626
Shimao7	3411	30	1871–1619	1744–1636

Table 3.2. Calibration of individual dates (95% and 68% ranges) from the Shimao region.

The start and end dates of each site are shown in Figure 3.3 and Table 3.3. This shows that all of the sites have fairly broad age ranges. The dates from Ashan III in the south of Daqing Mountain area and Yuanzigou in the Daihai Lake area start at an earlier time period, 3800–3000 BC, whereas the dates from Dakou in the Qingshui River valley area, and Shimao and Xinhua in the Yulin area start at a later time period, 2000–1800 BC. Dates from Ashan III and Yuanzigou end earlier, as late as between 2300 and 2100 BC, followed by Dakou around 1900 BC, and then Shimao and Xinhua between 1700 and 1600 BC. The end date for Zhukaigou, at 1200 BC, is the most recent. Zhukaigou seems to have been occupied across the entire period overlapping with all the sites.



OxCal v4.4 Bronk Ramsey (2020); r:5 IntCal20 atmospheric curve (Reimer et al 2020) A_{model}=104.5; $A_{overall}$=104.6

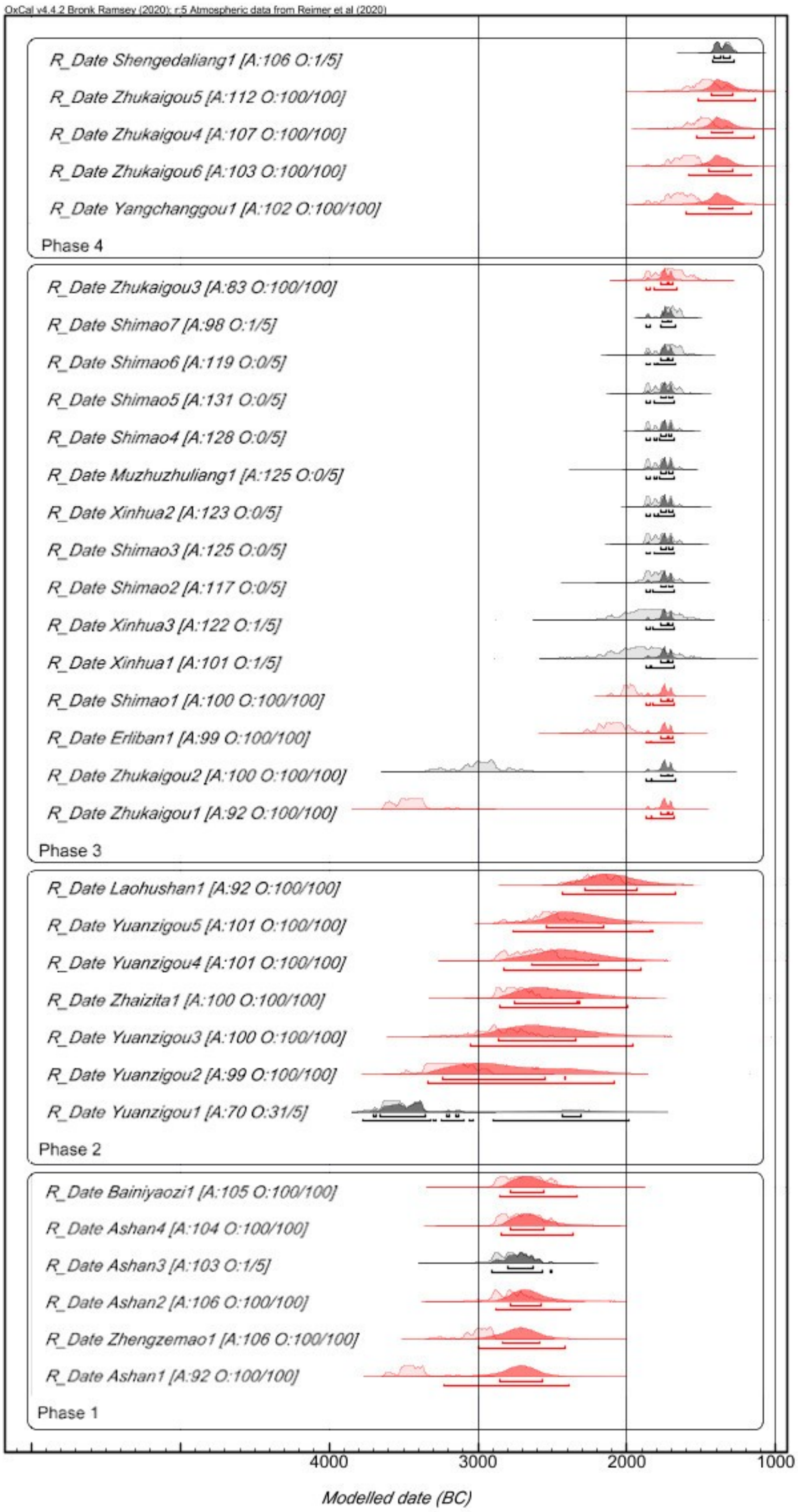
Figure 3.3. The unmodelled probability distribution of start and end dates from individual sites, corresponding to Table 3.4.

Site	Calibrated date range 95% (BC)		Calibrated date range 68% (BC)	
	Start boundary	End boundary	Start boundary	End boundary
Xinhua	2051–1755	1885–1042	2662–1687	1854–1611
Shimao	2191–1864	1853–1458	2041–1911	1722–1592
Dakou	3319–1941	2126–764	2290–1968	2105–1739
Zhukaigou	4379–3111	1575–482	3854–3210	1492–1116
Yangzigou	4639–3117	2829–1411	3888–3391	2628–2141
Ashan III	4750–3035	2866–1355	3795–3139	2782–2307

Table 3.3. The start and end dates of individual sites (95% and 68% ranges).

3.6.3 Phase contiguous model

Figure 3.4 and Table 3.4 show the distribution of dates generated from the phase contiguous model with general and charcoal outlier models. This shows that the dates for phases 1 and 2 overlap between 2900 and 2700 BC, while phase 2 possibly extends from 3400–2200 BC. The dates for phases 3 fall between 1900 and 1700. The dates for phase 4 fall between 1600 and 1300 BC. A summary of the start and end dates for each phase is shown in Figure 3.5 and Table 3.5. This shows that phase 1 fits within the timespan of phase 2. Both phase 3 and 4 are more recent, with a possible gap after phase 2. Phase 4 appears to be the last appearance.

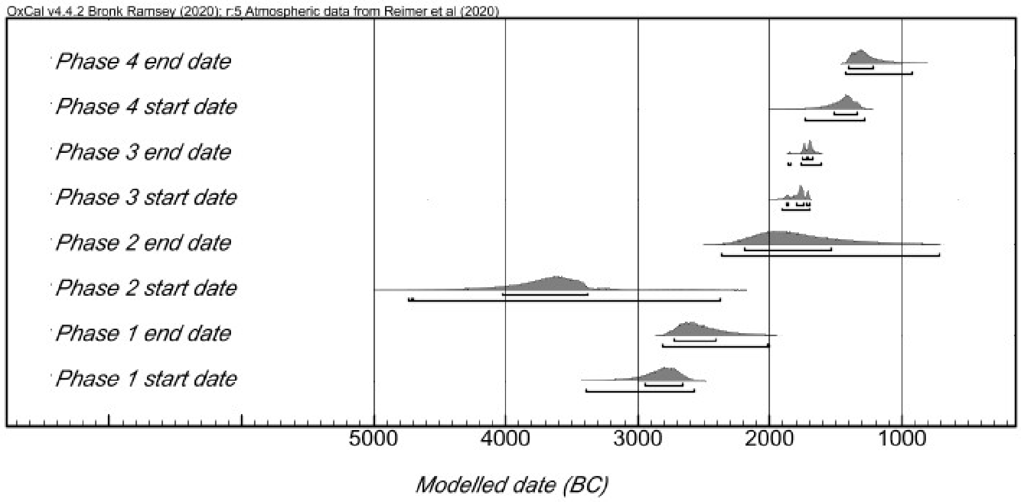


OxCal v4.4.2 Bronk Ramsey (2020); r:5 IntCal20 atmospheric curve (Reimer et al 2020)

Figure 3.4. The probability distribution of individual dates in contiguous phase model with general and charcoal outlier models, corresponding to Table 3.5. The transparent distribution shows the calibrated dates before modelling. A denotes agreement indices A for individual dates; O denotes the probability for the measurement being an outlier, the posterior probability that is higher than the prior probability 5% are considered as outliers.

Phase	Correlated Period (BC)	Code	^{14}C age BP (5568 half-life)	Sigma	Unmodelled calibrated date range 95% (BC)	Unmodelled calibrated date range 68% (BC)	Modelled calibrated date range 95% (BC)	Modelled calibrated date range 68% (BC)
4	1800–1500	Shengedaliang1	3090	30	1425–1270	1413–1302	1428–1278	1415–1306
		Zhukaigou5	3192	85	1676–1231	1599–1315	1526–1133	1432–1290
		Zhukaigou4	3222	70	1678–1304	1602–1417	1533–1149	1436–1293
		Zhukaigou6	3324	70	1864–1445	1684–1511	1586–1161	1449–1290
		Yangchanggou1	3362	70	1878–1499	1739–1540	1606–1160	1452–1288
3	2300–1800	Zhukaigou3	3416	70	1892–1533	1873–1619	1870–1666	1770–1694
		Shimao7	3411	30	1871–1619	1744–1636	1870–1671	1766–1696
		Shimao6	3416	50	1881–1546	1862–1626	1871–1672	1768–1696
		Shimao5	3440	45	1881–1625	1874–1645	1871–1683	1771–1695
		Shimao4	3445	30	1880–1640	1872–1691	1871–1687	1769–1696
		Muzhuzhuliang1	3450	30	1881–1642	1873–1693	1871–1687	1771–1696
		Xinhua2	3455	35	1885–1641	1875–1693	1871–1687	1771–1696
		Shimao3	3455	45	1886–1631	1877–1691	1871–1686	1772–1695
		Shimao2	3469	50	1919–1630	1879–1697	1871–1687	1773–1695
		Xinhua3	3518	120	2195–1535	2025–1688	1871–1682	1774–1694
		Xinhua1	3557	120	2279–1545	2120–1700	1871–1683	1776–1693
		Shimao1	3625	25	2120–1898	2027–1949	1872–1680	1773–1694
		Erliban1	3703	65	2290–1901	2199–1981	1872–1679	1773–1694
		Zhukaigou2	4325	90	3337–2675	3262–2783	1872–1676	1772–1694
		Zhukaigou1	4679	80	3642–3121	3605–3367	1872–1679	1773–1694
2	2500–2300	Laohushan1	3761	70	2454–1976	2288–2040	2431–1676	2286–1934
		Yuanzigou5	4004	70	2857–2297	2662–2356	2761–1825	2540–2160
		Yuanzigou4	4062	100	2889–2344	2852–2472	2831–1906	2643–2191
		Zhaizita1	4174	60	2895–2581	2881–2671	2856–1996	2757–2321
		Yuanzigou3	4259	90	3307–2574	3011–2675	3047–1963	2866–2341
		Yuanzigou2	4496	90	3493–2915	3354–3037	3336–2082	3237–2413
		Yuanzigou1	4772	100	3774–3356	3643–3380	3773–1989	3699–2306
1	2800–2500	Bainiyaozi1	4110	107	2916–2349	2871–2504	2856–2338	2786–2557
		Ashan4	4121	80	2888–2488	2866–2580	2848–2359	2782–2562
		Ashan3	4208	80	3011–2502	2902–2669	2909–2506	2804–2627
		Ashan2	4218	70	3011–2502	2902–2669	2909–2506	2804–2627
		Zhengzemao1	4349	60	3008–2577	2905–2675	2876–2382	2785–2574
		Ashan1	4655	70	3635–3112	3520–3364	3228–2386	2851–2571

Table 3.4. The probability distribution of individual dates in contiguous phase model with general and charcoal outlier models (unmodelled and modelled calibrated dates in 95% and 68% ranges).



OxCal v4.4.2 Bronk Ramsey (2020); r:5 IntCal20 atmospheric curve (Reimer et al 2020) A_{model}=107.4; $A_{overall}$=104.9

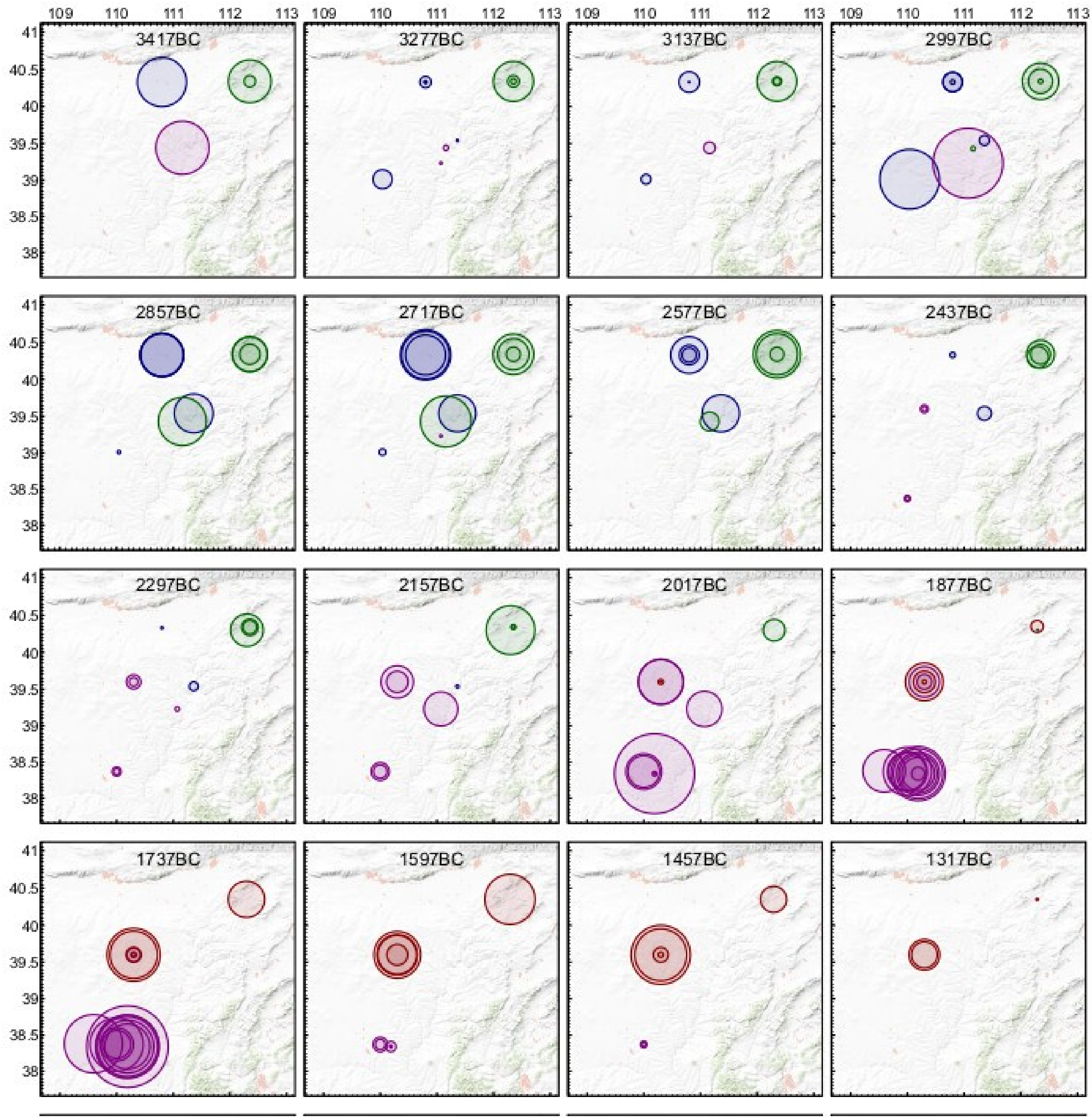
Figure 3.5. Summary of start and end dates of phase 1–4 in contiguous phase model with general and charcoal outlier models based on the result shown in Figure 3.4, corresponding to Table 3.5.

Phase	Calibrated date range 95% (BC)		Calibrated date range 68% (BC)	
	Start boundary	End boundary	Start boundary	End boundary
1	3434–2576	2804–1976	2947–2649	2726–2406
2	4592–2195	2413–836	4070–2425	2225–1588
3	1895–1697	1863–1626	1872–1701	1755–1679
4	1767–1284	1428–886	1526–1336	1401–1216

Table 3.5. The summary of start and end dates of phase 1–4 (95% and 68% ranges) based on contiguous phase model with general and charcoal outlier models.

3.6.4 The geographic distribution of dates

The geographic distribution of analysed dates coloured by phase is shown in Figure 3.6. The earlier dates for Phases 1 and 2 are concentrated in the south of Daqing Mountain, Daihai Lake and the Qingshui River valley areas. Phase 2 extends until 2000 BC and overlaps slightly with earliest dates for Phase 3 concentrated in the Ordos and Yulin areas. The dates assigned to phase 4 fall between 3850 and 1300 BC, but dates become concentrated only in the Ordos area from 1500–1300 BC.



OxCal v4.4.2 Bronk Ramsey (2020); r:5 IntCal20 atmospheric curve (Reimer et al 2020).

Figure 3.6. The plotting of calibrated dates on a map that shows the probability distribution of each measurement in time-gradient fashion across the Shimao region. These dates are unmodelled but grouped by colour reflecting the grouping of dates based upon the typo-chronological sequence. Period 1 in blue; period 2 in green; period 3 in purple; period 4 in red. Larger circle indicates higher probability that the date distributes at a certain point of time. The coordinates area shown on the side of the map.

3.7 Discussion: the reliability of the chronological framework and the shifting trend of human occupation

The results do not fully fit with the current chronological framework, which suggests that there are four cultural periods during the period 2800–1500 BC, and that the sites from the south of Daqing Mountain, Daihai Lake, Yulin and Qingshui River valley, and Ordos city areas developed one after the other in this order. Results from the KDE model instead imply that the dates are distributed in two major date ranges, one between 3000 and 2400 BC and another between 2100 and 1200 BC (Figure 3.1). Although there is a small group of dates centred on 3500 BC, this is much earlier than the first period of the accepted cultural sequence (2800–2500 BC). Therefore, it is uncertain whether these dates form a single event or are even relevant to the study period. The results from the calibration of dates show that the dates from the sites in the Shimao region are concentrated in two major groups, which are close to the date ranges implied by the KDE model (Figure 3.2 and 3.3). Nevertheless, the results from the phase contiguous model and the geographic distribution of dates on the map show that there might be three contiguous phases. While phases 1 and 2 are likely overlapped, phases 3 and 4 are more likely to be contiguous (Figure 3.4–6).

Although the four cultural periods cannot be fully separated according to time periods, the clusters of dates from the sites in the north sector of the Shimao region are in a general sense earlier than those in the south. This result therefore partly matches the proposal based on the typo-chronological sequence (CASS, 2010; Han, 2003, 2008; Sun, 2000, 2016; Tian & Guo, 2004; Wei & Cao, 1999), which suggests that human settlement density shifted southwards across the Shimao region over time. The results based on plotting of individual dates lends further support to this idea. As shown in Figure 3.6, human occupation concentrated in the north sector of the region during 3000–2000 BC but then became concentrated in the Daihai

Lake area between 2400 and 2000 BC. By 2100 and 2000 BC the concentration of dates had shifted southwards, to the Ordos city and Yulin areas that developed between 2100 and 1600 BC, and again mostly in the Ordos city area between 1600 and 1300 BC. However, the start and end dates of the occupation of the sites in the south as at Shimao and Xinhua cannot be identified, due to the unsystematic collection of dates. As discussed in Section 3.5.4, the analysed dates from Shimao only cover the dates from the later phase of the site. The possible earliest date for Shimao as shown here is around 2100 BC and the possible latest date is 1600 BC (Table 3.2); but the start date could happen anywhere between 2190 and 1860 BC (Table 3.3). The date for the upper limit here matches with the possible earliest date shown in Sun (2021). The time period suggested here, however, is different from the period 2300–1800 BC suggested in Shao (2016) and elsewhere (e.g. Sun et al., 2018, 2021; Womack et al., 2021). A more accurate possible occupation period for Shimao should be confirmed once more complete dates from this site are analysed and published.

Due to the fact that typo-chronological sequence is still important for periodisation, and the radiocarbon dates can only help to refine this sequence, the best option for now is to follow the four-period framework for the purpose of this research. It does not however mean that the chronology of this region should be modified. Nevertheless, the date ranges for these periods need to be refined, with the consideration of the timing when the concentration of major settlements shifted, as suggested in Table 3.2 and Figure 3.6. The refined date ranges for the four periods are listed in Table 3.6. The first period is adjusted to 2800–2400 BC, when settlements concentrate in the south of Daqing Mountain, Daihai Lake and Qingshui River valley areas. The second period is adjusted to 2400–2000 BC, when settlements concentrate only in the Daihai Lake area. The third period is adjusted to 2000–1600 BC, when settlements concentrate in the Ordos and Yulin areas. The fourth period is adjusted to 1600–1300 BC, when settlements concentrate only in the Ordos area. The advantage of this adjustment is to eliminate the concept of cultural period, which is solely defined by typo-chronology. For this reason, the assignation of the period for the Shimao and nearby sites here (2000–1600 BC), is different from the assignation for the so-called Shimao culture by Sun et al. (2021) (2300–1800 BC). The difference is mainly due to the latter considers the dates from Bicun and Zhaimaoliang, which they think are part of the Shimao culture, whereas my assignation considers a general time period when Shimao and other nearby sites developed to the utmost. Although the map and the other results show that there are some early dates fall between 3500 and 2900 BC, these dates are not considered because the number of these early dates are few. We are also unable to find out whether the samples for these dates are reliable or whether they are subjected to other issues such as the in-built age problem, unless new samples can be collected and analysed.

Date (BC)	Cultrual period in the Shimao region	Cultural period in Central Plains
2800–2400	Ashan III	Transition period from Yangshao to Longshan
2400–2000	Laohushan	Early Longshan
2000–1600	Dakou I/Shimao	Late Longshan
1600–1300	Early to middle Zhukaigou	Erlitou

Table 3.6. Refined date ranges for the four periods in Table 1.1 based on the results from Chapter 3, Figure 3.6.

As mentioned in Section 3.5.4, some sites in Yulin area were established as early as 3000 BC and coexisted with some sites in other areas (Sun, 2016). Since there is one date (Zhengzemao) from the Yulin area that can be assigned to period 1, it is noted that some sites were likely already developed in the south before the implied transition. Nevertheless, this does not conflict with the patterns of human occupation discussed above because the number of sites in the south is small and does not dispute the suggestion that human occupation shifted southwards because we know that major settlements were gone during the Shimao period. Some portions of the population may have shifted southwards and integrated with the pre-existing communities in the Yulin area or to other locations.

While this analysis has only shown the dates of some sites in the Shimao region, all other sites without radiocarbon dates therefore have to be assigned to the refined periods by considering the typo-chronology. For the purpose of this thesis, this is for now the best we can do to assign those sites without dating into different periods. The assignation of these sites and information of their sources are listed in Table 1.3; and they are plotted on a map shown in Figure 3.7. This assignation and the refined framework shown in Table 3.6 will be used to underpin and provide contexts for changes over time and space throughout the thesis hereafter.

Figure 3.7. Map of the assignation of studied walled and non-walled settlement sites to the refined four periods from 2800–1300 BC based upon typo-chronology. Information comes from Table 1.2 and Appendix I.

3.8 Conclusion

This chapter has used Bayesian chronological modelling to analyse existing ^{14}C dates in the Shimao region. The major finding is that the dates from sites in the north sector of the region tend to be earlier than those from the south. This partially supports the proposal of a southwards shifting for occupation across the Shimao region, which likely took place over a short period, between 2100 and 2000 BC (Figure 3.6). The map that considers all sites, including those without ^{14}C dates, also illustrates a similar pattern (Figure 3.7). For this reason. the typo-chronological framework has been preserved here with adjustments (Table 3.6). This framework will be used to underpin the analyses in the following chapters. While this chapter suggests that human occupation likely shifted southwards and potentially involved population movement, the next chapter will continue to explore the demographic boundary to see whether the settlement size expanded, and thus whether the population became concentrated in the south after the suggested southwards shifting of occupation.

Chapter 4

Settlement size and distribution

4.1 Introduction

On the basis of clusters of radiocarbon dates, some evidence for a southward demographic shift across the Shimao region, most notable at cal. 2100–2000 BC, was identified in Chapter 3, (Figure 3.6–7). Currently, evidence in relation to population growth is limited to the surveys of the number of sites. Surveys suggest that sites particularly larger fortifications might have increased in number, and thus that the population might have grown in the south of the region between 2000 and 1600 BC at the time in which Shimao emerged. However, these surveys alone have only limited value in terms of suggesting changes of population size over time due to the indeterminate occupation time of the sites included. This suggestion of population growth therefore needs to be explored further from another angle. The currently incomplete evidence about, and poor understanding of, the demographic changes in the region has led to the questions of whether the overall settlement size expanded, whether larger walled sites increased, and from this, whether the population became more concentrated along with the emergence of Shimao.

In this chapter, settlement size and their distributions are considered to explore this demographic transition process further. Analysing settlement size and density is a challenging exercise, because there are many uncertainties, for examples, different methods are adopted for the estimation of site sizes in archaeological surveys, and the sites that can be considered are limited to those recorded in such surveys. Nevertheless, the approach adopted here, of analysing the area covered by sites, are meaningful in terms of observing a general changing pattern for settlement size in time and space. The distribution of site size is analysed through boxplot and is considered along with the geographic distribution of settlements in order to show changes in space and time. Site size represents one of the few readily available means for assessing population size or concentration across the region. For the purposes of this exercise, larger sites above 100 hectares are assumed to have accommodated more people compared to smaller sites. From that, the analysis allows not only to identify whether settlement size increase during the Shimao period, but also gives a clue on where the population may have concentrated at.

4.2 Aim and objectives

The aim of this chapter is to identify diachronic changes in settlement size and distribution across the Shimao region over the period 2800–1300 BC. This is accomplished by comparing settlement sizes through time, while considering geographic distributions. The data are analysed using IBM SPSS Statistics 27 and expressed as boxplots. The results are then tested statistically using the same programme. The spatiotemporal distribution of sites over the four periods are expressed on maps to provide a presentation of the results in regional context.

The objectives of this chapter are to: 1) collect numeric data from published sources about the area covered by sites; 2) collate the numeric data about the area covered by sites into the four periods as set out in Chapter 3, and divide them into walled and non-walled sites; 3) analyse and compare the datasets of the area covered by sites over the four periods in boxplots using IBM SPSS Statistics 27 and test the results with statistical test; 4) plot the walled and non-walled sites separately and show their size on a map over the four periods using ArcMap 10.8. In the rest of the chapter, interpretation of population growth, the problem and approaches to estimating population dynamics will first be provided, followed by materials and methods, and then results. A discussion on the changes in settlement size and distribution shape will be provided before the conclusion.

4.3 Interpretations of population growth

As discussed in Chapter 2, preliminary evidence from the province-wide survey conducted in the 1980s shows that there were five to six times more sites in the Longshan period (equivalent to 2400–1600 BC) in the Yulin area than in the previous period (Sun, 2016; Sun et al., 2018). In addition, the third nation-wide survey, conducted from 2007–2011, shows three and a half times the number of sites during the Longshan period than in the previous period (Chen et al., 2015b). This survey also shows that, out of 4446 Neolithic sites, eleven reach 50–100 hectares but the 400-hectare Shimao site is the only one to extend to over 100 hectares (Sun & Shao, 2015; Zhang, 2017). Although these surveys have often focused on locations where finds were reported by people, or where individual finds were expected to occur, and the majority of these sites remained unexcavated (Jaffe & Hein, 2020), the numbers from these surveys are useful to identify potential occupation trend. There are 70–80 walled sites dating to the Longshan period (assigned to ca. 2400–1600 BC) discovered in northern Shaanxi (Sun, 2016).

Larger walled sites have been assumed to have increased around the time when Shimao emerged (Sun & Shao, 2015). Aside from Shimao, three other sites are currently known to extend above 100 hectares in the Shimao region: the walled 120-hectare Baiyagou site in the Weifen River valley area, the 138-hectare Houchengzui site in the Qingshui River valley area, and the non-walled 120-hectare Xicha site in the Qingshui River valley area (Figure 3.7). Other evidence for site size is reflected by the settlement pattern around Shimao, along the Tuwei River, as shown in Sun et al. (2018). This suggests that there are some small walled sites (below 10 hectares) with two larger walled sites (50–100 hectares) further south

(Figure 4.1). These finds are currently insufficient to reflect changes in settlement size and distribution pattern, since there are as yet no dates. As a result, they cannot tell us much about changes in population densities and locations.

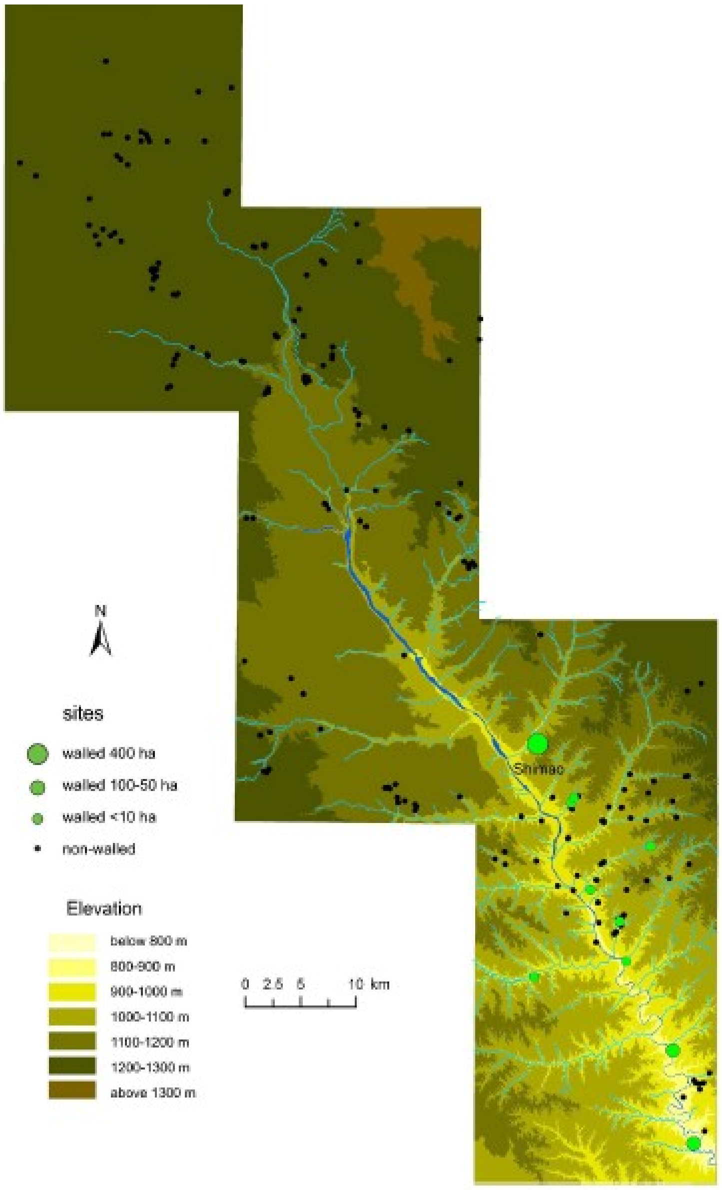


Figure 4.1. Map of the settlement pattern at and around Shimao along the Tuwei River valley. Figure from Sun et al. (2018: 36).

Quoting the third nation-wide survey in the Yulin area, Zhang (2017) suggests that the population in this area increased dramatically during the Longshan period (equivalent to the period 2400–1600 BC as defined in Chapter 3), as it did in the other regions in ancient China at this time. The sites then diminished during the Erlitou period (equivalent to 1600–1300

BC) (Zhang, 2017). In contrast, the situation in central-south Inner Mongolia, which covers the areas of the south of Daqing Mountain, Daihai Lake, Qingshui River valley and Ordos, remained relatively unchanged through these periods, although the number of sites decreased slightly during the Erlitou period (Zhang, 2017). The preliminary evidence from the surveys, in the form of numbers of sites, has been used to suggest that the population in the north sector of the Shimao region shifted southwards and eventually peaked in the south of the region (Dai, 2016a). The increase in the number of sites has been used to suggest that population peaked between the late Yangshao and Longshan periods (equivalent to 2800–1600 BC) in this region (Sun, 2016).

Shimao, with its large stone platform (8 hectares), complex wall layouts and defensive auxiliary structures, is assumed to have served as a political centre during this period (Sun, 2016; Sun et al., 2018). Similarly, the settlement hierarchy in the Tuwei River valley surrounding Shimao has been reconstructed, revealing that there are eleven walled sites, including Shimao, and 193 non-walled sites along the Tuwei River valley during the Longshan period (equivalent to 2400–1600 BC) (Sun et al., 2018). This suggests that Shimao is the only large site and was surrounded by many other smaller sites (all below 30 hectares) (Wang & Guo, 2016). This discovery gives Shimao a central position in terms of the surrounding areas, a major factor in providing evidence of its dominant position.

The spatiotemporal studies of the number of sites across China in the Atlas of Chinese Cultural Relics, which considered all types of sites recorded in different provincial/regional volumes, indicates that site density increased in the Loess Plateau in northern China between 2350 BC and 1750 BC (Hosner et al., 2016; Wagner et al., 2013). However, as discussed in Jaffe et al. (2020), the dates of sites recorded in these Atlases are uncertain when they are assigned to conventional period only. The studies that used these data are therefore not reliable.

Moreover, the above suggestions for population growth remain untested. First, the suggestions for population growth are heavily dependent on observations of changes in number of sites. An increase in numbers of sites, while suggestive of larger numbers of people, cannot by itself necessarily be linked to population expansion. Second, the evidence is constrained because the sites fall in a rather long period from 2800–1600 BC, and there is not enough data to decide which of these sites were contemporaneous. Since it is unlikely that all the sites, or larger sites, were occupied at the same time, we cannot identify the changes in site numbers and size over periods of time from the current evidence. Third, the evidence for appearance of larger sites in Yulin area between 2000–1600 BC comes from an unpublished survey. What is required is to examine the patterning in space and time more rigorously. Fourth, the Shimao site may be over-emphasized in the interpretation of the expansion of walled sites and even population size in the south. Although a very large site reflects a presumably highly concentrated population, the overall settlement size of Shimao remains uncertain.

For these reasons, Dai's (2016a) suggestion that populations moved southwards and peaked in the south should be tested. The evidence in relation to settlement size, shape distribution and population growth is indeed very limited. Given that more data and information related to the area covered by the site, and the locations and occupation periods of sites from the south of the Shimao region are now available, these new data can be considered together with those published previously. This allows a review of the changing patterns in settlement size and distribution shape in relative terms over the four periods covering 2800 to 1500 BC, and thereafter to reevaluate how likely it was that population grew and became concentrated in

Yulin area during the period 2000–1600 BC when Shimao emerged. No such comparative and synthetic analysis has been done for this region before.

4.4 The problem, and approaches to estimating population dynamics

These questions are explored here by considering and comparing the major distribution of settlement size for walled and non-walled sites and the distribution shape of these sites over the period 2800–1300 BC. The published data considered in this chapter include site size from detailed archaeological excavation reports published in books, brief excavation reports for individual sites or for a group of sites, culture relics newspapers and journal papers. The Atlases of Chinese Cultural Relics of the Inner Mongolia region, and Shaanxi and Shanxi provinces have also been considered for initial identification of potential sites to be studied in this thesis. Since the sites considered in these Atlases are presented equally as loci reflecting human activities, regardless of the actual scale and nature of the sites (Jaffe et al., 2020), the potential sites that were identified were then crosschecked with other sources containing information about these sites. Only sites that can be identified as settlements, or potentially served as settlements (e.g. sites in which houses discovered) and sites where size was estimated through investigation and trial and proper excavations were selected in the analysis of this chapter. The analysis in this chapter only considers the sites of which locations, site size and occupation period (based on both the recalibration of radiocarbon dates done in Chapter 3 and the current typo-chronology) can be identified from publications.

As pointed out in Chapter 3, due to the lack of dates it is not possible to identify the exact occupation period for each site. The sites are therefore assumed to be occupied for the maximum possible extent of a cultural period defined by typo-chronology. Despite this limitation, the analysis can provide us with information about the relative changes of site size and general distribution shape over periods. The analysis of this chapter also only considers sites whose locations, size and occupation period can be identified from the published literature in order to deal with the above issue. It is therefore noted that the sites recorded in unpublished sources, such as the third nation-wide survey, cannot be considered here. Nevertheless, once the data from the recent survey are available, or when data can be assessed in other ways, future studies can be done with the new data to supplement the analysis done here.

The analysis of settlement size is conducted by synthesising the figures for the areas covered for all the sites as well as further separating the results into walled versus non-walled sites in each of the four periods set out in Chapter 3 (Table 3.6). Boxplots were chosen for the analysis here because they make it possible to show the range, major distribution, skewness, outliers and spreading of individual sites in each period, which is suitable for the purpose of this research to identify the overall changes in settlement size over time. The statistical test was carried out because this tells us whether the changes shown in the boxplots are statistically significant. The one-way Anova test was applied here because this specific test allows comparison of variances between more than two groups for categorical and numerical data together. ArcMap 10.8 was used to reflect the results from the boxplots, the transition patterns of settlement size and the distribution shape of the settlements over space and time, thereby visualizing the full picture of settlement distribution on a single map. The assignation of sites followed the distribution on the map in Figure 3.7 and it is also listed in Table 1.2 in text. It is noted that the assignation of sites to these periods does not always reflect that these sites occupied the entire individual period or more than one periods. The best that can be done for now is to identify the phases of each of the studied sites and correlate them to each of the periods indicated in Table 1.2, where applicable.

Since data about wall length and width are available for some sites in the region, wall height is uncertain almost at all these sites, which does not allow even a simple calculation for the scale of the walled settlements. The data for wall width is also difficult to use for comparison because the building materials and structures vary across different sites, as indicated in Table 2.3. In particular, in the Qingshui River valley area, most of the walls were built with a great amount of earth mixed with cobbles inside the stone surface (Figure 4.2). This can bias the results since the analysis for wall scale focuses on the input of stone materials. Overall, therefore, wall scale is rejected as a viable analysis in this chapter.

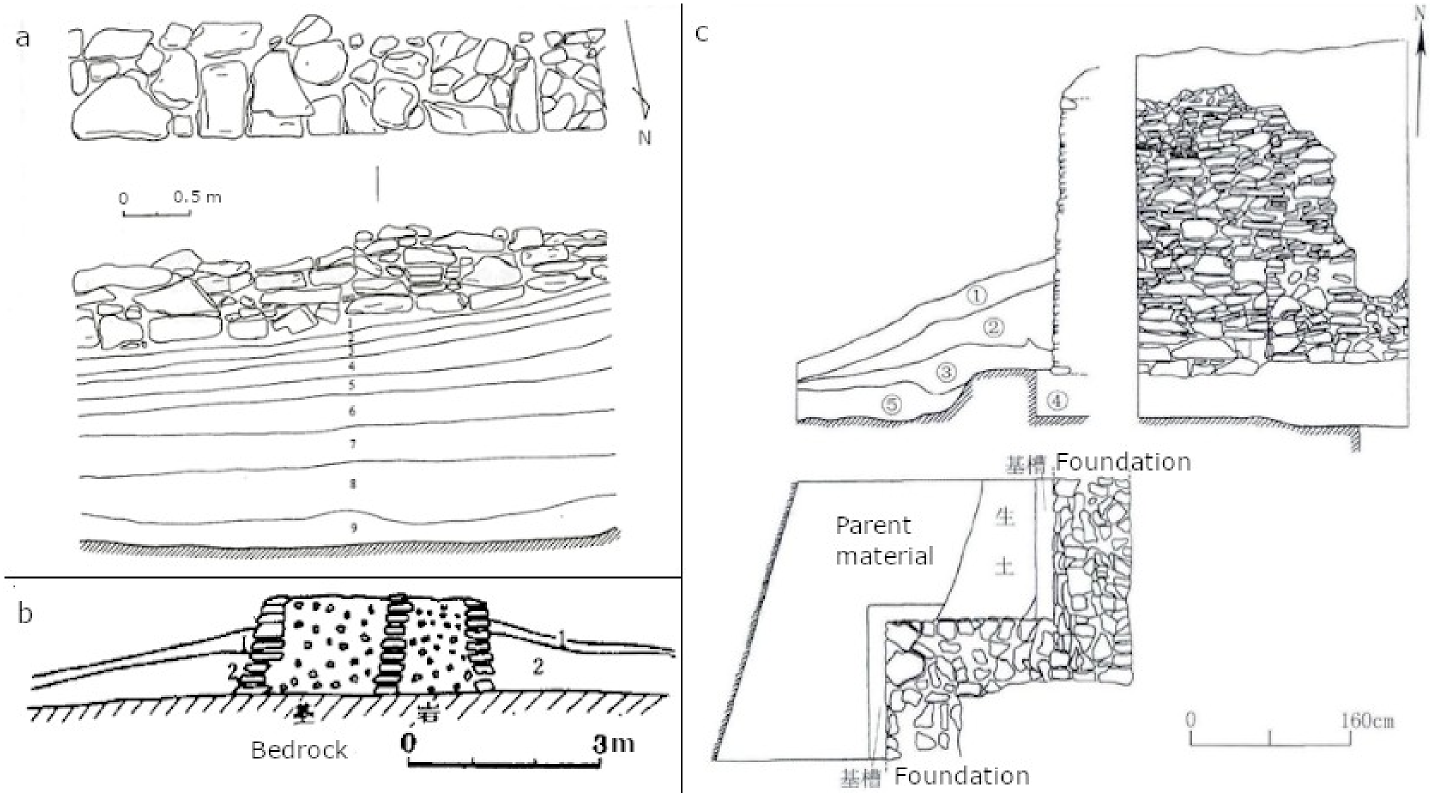


Figure 4.2. Drawings of the wall cross sections that show different use of building materials at a) Laohushan (stone and earth), modified from the figure from Yang (2000: 208); b) Xiaoshawan (cobbles and earth), modified from the figure from Neimenggu (1994: 226); c) Shiluoluoshan (stone), modified from the figure from Shaanxi (2016: 8).

4.5 Materials and methods

4.5.1 Materials and data collection

The information was collected from archaeological reports in books (e.g. Neimenggu, 1994; 1997; Yang, 2000), both brief and detailed excavation reports for individual sites (e.g. Shaanxi, 2002; Neimenggu & Ordos, 2000; Shaanxi & Yulin, 2005; Tian, 1986; Wang & Guo, 2015), journal papers that provide the relevant information for certain sites (e.g. Baotou, 1984; Fu, 1989; Sun, 2000; Wei & Cai, 1999; Wei & Wang, 1990), the culture relics newspaper *Zhongguo Wenwubao* (e.g. Jia, 2015), and the articles available on the official website of the Institute of Archaeology, Chinese Academy of Social Sciences.[15] The Atlas of Chinese Cultural Relics of Inner Mongolia, Shaanxi and Shanxi provinces (Guojia wenwuju, 1998, 2003, 2006) was also consulted. The sites identified from the Atlases were crosschecked with the above-mentioned data sources for confirmation. These materials are accessible from university libraries, through the inter-library loan service, and online databases of Chinese literature, such as CNKI. These data are mostly published in Chinese and mainly come from the national journals such as *Kaogu, Kaogu yu wenwu* and *Wenwu*. Another major source is the edited volumes published by the provincial archaeological institutes such as that of Inner Mongolia and Shaanxi.

These data were obtained from 37 sites, 23 of which are walled, as listed in Table 4.1, along with their sources of information. The datasets were derived and arranged in chronological order over the four periods, following the refined framework derived in the Chapter 3, listed in Table 3.6, and is indicated in Table 4.1. The dataset of site size was arranged based on the total period of occupation of the sites, which means sites that were occupied in more than one period appear repeatedly.

[15] http://kaogu.cssn.cn.

Period	Site	Area	Size (ha)	Reference
1	Ashan III	South of Daqing Mountain	5	Baotou, 1984; Neimenggu & Baotou, 1984; Sun, 2000; Wei, 2003
	Shamujia	South of Daqing Mountain	0.048	Baotou, 1984; Sun, 2000
	Heimaban	South of Daqing Mountain	2	Baotou, 1984; Sun, 2000, Wei, 2003
	Xishata	South of Daqing Mountain	2.1	Baotou, 198; Sun, 2000
	Weijun	South of Daqing Mountain	4	Liu, 1988; Wei, 2003
	Zhukaigou II (zone VII)	Ordos city	3	Tian, 1988
	Baicaota II	Qingshui River valley	?	Neimenggu 1994: 183–204
	Xiaoshawan	Qingshui River valley	0.4	Neimenggu 1994: 225–234, Wei & Cao, 1999
	Zhaizigedan	Qingshui River valley	5	Wang & Yang, 1999
	Zhaizita I	Qingshui River valley	5	Neimenggu, 1997: 280–326; Wei & Cao, 1999
	Houchengzui II	Qingshui River valley	138	Neimenggu, 1997: 151–164; Cui, 2003
	Zhuangwoping II	Qingshui River valley	3	Neimenggu, 1997: 165–178
	Bainiyaozi III	Qingshui River valley	?	Cui, 2014
	Wuzhuangguoliang	Yulin	30	Shaanxi & Shaanxi, 2011: 37–41; Shaanxi, 2011
	Zhaishan	Yulin	2	Shao, 2019; Sun, 2016; Shaanxi & Yulin, 2009
	Zhaimao I	Yulin	17	Lu, 2002; Sun, 2016
	Shiluoluoshan I	Yulin	6	Shaanxi, 2016b; Zhang & Ding, 2016
	Zhengzemao I	Yulin	?	Shaanxi & Yulin, 2000; Sun, 2016
	Houzhaizimao I	Yulin	21	Shaanxi & Shaanxi, 2011: 42–46; Sun, 2016

Period (BC)	Site	Area	Size (ha)	Reference
2400–2000	Laohushan	Daihai Lake	13	Yang, 2000; Tian, 1986; Wei & Cao, 1999
	Yuanzigou	Daihai Lake	20	Yang, 2000
	Bancheng	Daihai Lake	10	Fu, 1989; Yang, 2000; Wei & Cao, 1999
	Xibaiyu	Daihai Lake	9	Yang, 2000; Wei & Cao, 1999
	Damiaopo	Daihai Lake	25	Fu, 1989; Yang, 2000
	Mianpo	Daihai Lake	7	Yang, 2000
	Zhukaigou I	Ordos city	50	Yang, 2000; Tian and Han, 2003
	Baicaota III	Qingshui River valley	?	Neimenggu, 1994: 183–204
	Erliban	Qingshui River valley	6	Neimenggu, 1991: 161–164; Neimenggu, 1994: 246–260
	Xicha I	Qingshui River valley	120	Neimenggu & Qingshuihe, 2001; Tang et al., 2004
	Zhuangwoping III	Qingshui River valley	3	Neimenggu, 1997: 165–178
	Yongxingdian	Qingshui River valley	?	Neimenggu, 1997: 235–245
	Xiata	Qingshui River valley	28	Li, 2007; Zhang & Ding, 2016
	Zhaizita II	Qingshui River valley	5	Neimenggu, 1997: 280–326; Wei & Cao, 1999
	Houchengzui III	Qingshui River valley	138	Neimenggu, 1997: 151–164; Cui, 2003
	Zhaizishang II	Qingshui River valley	3	Neimenggu, 1994: 174–182
	Guandi IV	Qingshui River valley	2	Neimenggu, 1997: 85–119
	Zhaimao II	Yulin	17	Shaanxi, 2002; Sun, 2016
	Shiluoluoshan II	Yulin	6	Shaanxi, 2016b; Zhang & Ding, 2016
	Houzhaizimao II	Yulin	21	Shaanxi & Shaanxi, 2011: 42–46; Sun, 2016
	Baiyagou	Weifen River valley	120	Shanxi, 2017

Period	Site	Area	Size (ha)	Reference
2000–1600	Zhukaigou II	Ordos city	50	Yang, 2000; Tian & Han, 2003
	Huoshiliang	Qingshui River valley	10	Hu et al., 2008
	Dakou I	Qingshui River valley	3	Ji & Ma, 1979
	Bainiyaozi IV	Qingshui River valley	?	Cui, 2014
	Shimao	Yulin	400	Shaanxi et al., 2013; Shaanxi, 2016a; Shao, 2016; Sun, 2016
	Xinhua	Yulin	3	Shaanxi & Yulin, 2005; Sun, 2016
	Zhaimaoliang I–II	Yulin	3	Shaanxi et al., 2018; Sun et al., 2018; Wei et al., 2018
	Muzhuzhuliang	Yulin	4	Sun, 2016; Wang & Guo, 2015
	Shengedaliang	Yulin	4	Shaanxi et al., 2016
	Shiluoluoshan III	Yulin	6	Shaanxi & Shaanxi, 2011: 37–41; Zhang & Ding, 2016
	Zhengzemao II	Yulin	?	Shaanxi & Yulin, 2000; Sun, 2016
	Bicun	Weifen River valley	75	Shanxi & Xingxian, 2016; Shanxi et al., 2017
1600–1300	Yangchanggou	Daihai Lake	?	Neimenggu & Beijing, 1991
	Sandaogou	Daihai Lake	?	Neimenggu & Beijing, 2004
	Dakou II	Qingshui River valley	3	Ji & Ma, 1979
	Gaojiaping	Qingshui River valley	5	Neimenggu, 1994: 261–271
	Guandi V	Qingshui River valley	2	Neimenggu, 1997: 85–119
	Nanhao	Qingshui River valley	2.5	Neimenggu, 1994: 205–224
	early Xiaomiao	Qingshui River valley	0.7	Neimenggu, 1994: 272–277
	Qingcaota	Qingshui River valley	5	Neimenggu & Yikezhao, 1990
	Houchengzui IV	Qingshui River valley	138	Neimenggu, 1997: 151–164; Cui, 2003
	ZhaizitaIV	Qingshui River valley	5	Neimenggu, 1997: 280–326; Wei & Cao, 1999
	Zhukaigou III-IV	Qingshui River valley	50	Neimenggu & Ordos, 2000; Tian & Han, 2003
	Xicha II	Qingshui River valley	120	Neimenggu & Qingshuihe, 2001; Tang et al., 2004
	Bainiyaozi V	Qingshui River valley	?	Cui, 2014
	Zhuangwoping IV	Qingshui River valley	3	Neimenggu, 1997: 165–178

Table 4.1. The sources and site size of settlements studied in Chapter 4.

4.5.2 Analysis process

The data for site size was analysed in boxplots using IBM SPSS Statistics 27. Boxplots show the major distribution of values for these measurements, which is useful for showing the trend of temporal changes, because the box shows the major 50% distribution which is then separated by a line denoting the median value, thus dividing the box into an upper and lower 25% within the major distribution. The identification of outliers is also useful to highlight the sites with extremely high values. Points with values that lie more than one and a half and three times away from the major distribution are considered as outliers and marked by circles and stars, respectively. The results were grouped by period, presenting the major distribution in each of the four periods. The results were further separated into walled and non-walled sites for comparison. Two versions of graphs were generated: one covers all the data, and another excludes the data from Shimao. The reason for doing this was to show the results without the high value from this exceptional site, which can stretch the upper range of the major distribution and median values. The statistical tests were done for the results from these two versions of graphs to test whether changes in sizes over time are statistically significant. A map was generated to reflect the measurements of settlement size across the region over the four periods.

4.5.3 Assumptions and limitations

The major limitation of the analysis is that the selection of sites is limited by the information that is currently available. The criteria for site selected, which has been mentioned in Section 4.4, allows a more accurate analysis for temporal and regional changes but at the same time this means that many of the settlement sites have to be neglected in the analysis. It is therefore important to note that this approach can show only the changes of distribution of major sites across the region, but this does not reflect the complete settlement pattern of the region. Due to this limitation, we should keep in mind that there are much more sites distributed around the sites analysed here. It is therefore important to also include other studies of settlement pattern for the region in the discussion. The second limitation is that the occupation period cannot be identified for each individual site due to the lack of calibrated dates. The best that could be done was to separate sites into phases where applicable based on typo-chronology. The sites were assumed to be contemporaneous and to have occupied the maximum possible extent of each of the periods. Another limitation is that the changes in the area covered by these sites over phases is unknown and the size of these sites can only be assumed to be constant. This may produce biased results, especially since the data from the sites in early periods could be much smaller than what is visible today. These sites could have been expanded gradually over time and became larger in later periods. Although these sites can be assigned to different periods of time, the changes of in site size are not specified over the periods. These cases may be shown as outliers in boxplots, and potential cases will also be discussed in Section 4.7 for an objective interpretation.

4.6 Results

4.6.1 Quantitative and statistical analysis

The quantitative analysis of the area covered by the sites based on the occupation period of the sites is shown in Figure 4.3. This illustrates that the median value of the size of walled sites increases over time, if including Shimao (Figure 4.3a). The upper value of the walled sites during 2000–1600 BC is much higher than the outliers in all other periods. If Shimao is excluded, the median values during 2000–1600 BC are much lower (Figure 4.3b). The median value of the site size is the highest during the period 1600–1300 BC, but only two sites are considered in this period, which stretches the median value to a higher level. The median value of the walled sites during the period 2400–2000 BC is higher than the previous and the next periods, with two outliers at a similar level to the upper range of the distribution during the period 1600–1300 BC.

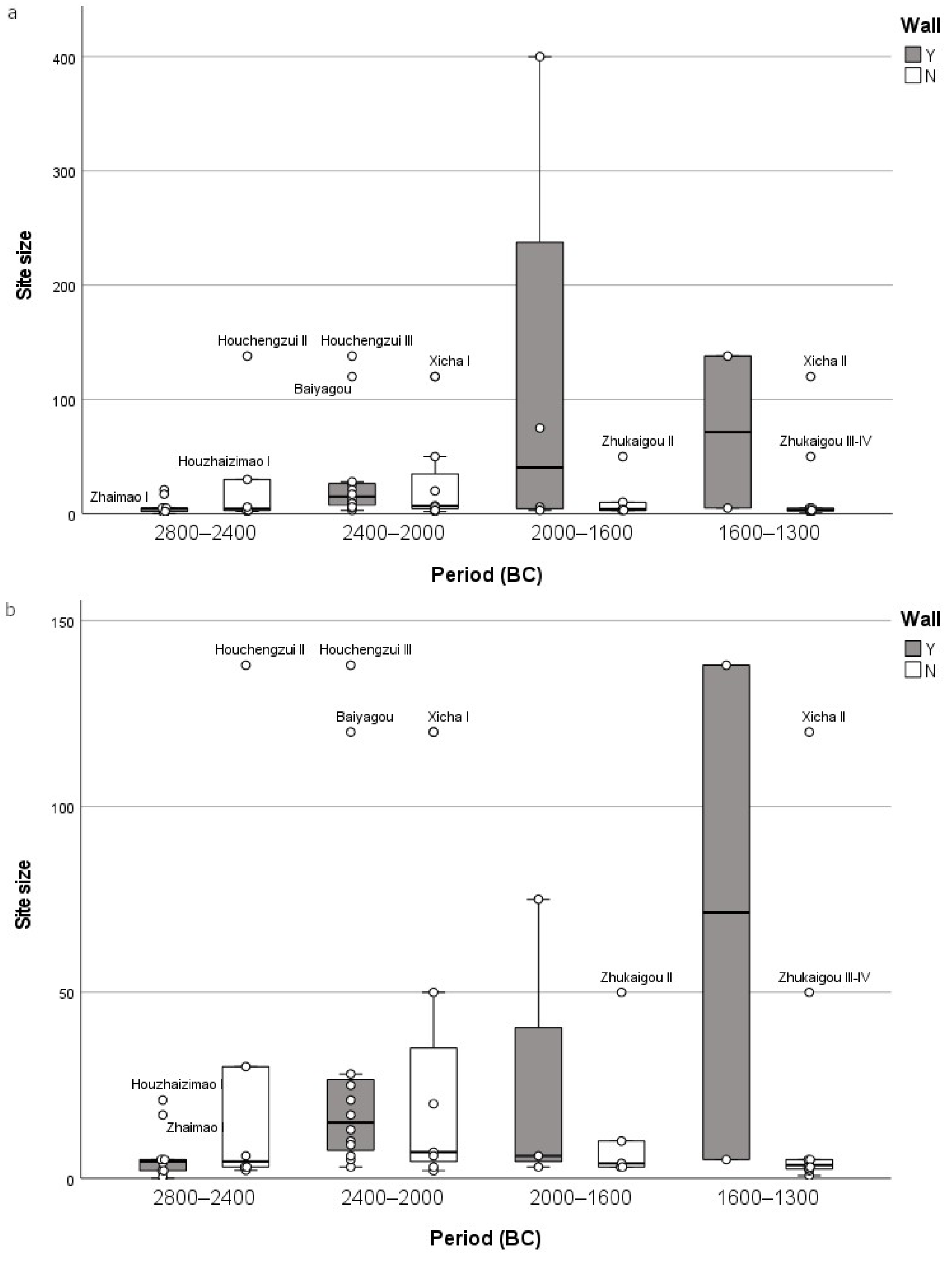


Figure 4.3. Boxplots of the quantitative distribution of site size (walled versus non-walled) over the four periods from 2800–1300 BC. 4.2a covers 23 walled sites and 14 non-walled sites; 4.2b excludes the walled Shimao site assigned to the period 2000–1600 BC. 2800–2400 BC: walled (N=7), non-walled (N=5); 2400–2000 BC: walled (N=12), non-walled (N=7); 2000–1600 BC: walled (N=4), non-walled (N=4); 1600–1300 BC: walled (N=2), non-walled (N=8). The points on the boxplots denote the distribution of size of individual sites. Information comes from Table 4.1.

The area covered by the non-walled sites is the highest during the period 2400–2000 BC, but either the range of the major distribution or the median value are similar between periods. The median value of the walled sites becomes higher than non-walled sites during the period 2400–2000 BC. This is also the case during the period 2000–1600 BC, if the Shimao site is included (Figure 4.3a), but the median values between them are similar if the Shimao site is excluded (Figure 4.3b). During the period 1600–1300 BC, the median value of the walled sites is much higher than that of the non-walled ones. Again, the median value is distorted by the fact that only two sites are covered in this period.

The distribution of individual walled sites is also shown in Figure 4.3, and the frequencies of site size in each period are shown in Table 4.2a–d. These illustrate that the size of walled sites is more concentrated at a lower level of between 2 and 5 hectares during the period 2800–2400 BC and between 3 and 6 hectares during the period 2000–1600 BC (Table 4.2a and c), although a few sites are larger or outliers (Table 4.3). In contrast, the site size is evenly distributed between 3 and 28 hectares during the period 2000–1600 BC (Table 4.2b), with a couple of outliers (Table 4.3). The two sites in the period 1600–1300 BC are distributed at 5 and 138 hectares (Table 4.2d). The one-way Anova test shows that the differences in the distribution of site size for walled sites between periods are statistically insignificant, both when including Shimao [$F(3, 24) = 2.31$, $p = 0.102$], and when excluding Shimao [$F(3, 24) = 1.86$, $p = 0.102$].

Walled sites 2800–2400 BC

Covered area (ha)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.048	1	10.0	10.0	10.0
	.4	1	10.0	10.0	20.0
	2	2	20.0	20.0	40.0
	4	1	10.0	10.0	50.0
	5	3	30.0	30.0	80.0
	17	1	10.0	10.0	90.0
	21	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

a

Walled sites 2400–2000 BC

Covered area (ha)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	1	8.3	8.3	8.3
	5	1	8.3	8.3	16.7
	6	1	8.3	8.3	25.0
	9	1	8.3	8.3	33.3
	10	1	8.3	8.3	41.7
	13	1	8.3	8.3	50.0
	17	1	8.3	8.3	58.3
	21	1	8.3	8.3	66.7
	25	1	8.3	8.3	75.0
	28	1	8.3	8.3	83.3
	120	1	8.3	8.3	91.7
	138	1	8.3	8.3	100.0
	Total	12	100.0	100.0	

b

Walled sites 2000–1600 BC

Covered area (ha)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	1	25.0	25.0	25.0
	6	1	25.0	25.0	50.0
	75	1	25.0	25.0	75.0
	400	1	25.0	25.0	100.0
	Total	4	100.0	100.0	

c

Walled sites 1600–1300 BC

Covered area (ha)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	5	1	50.0	50.0	50.0
	138	1	50.0	50.0	100.0
	Total	2	100.0	100.0	

d

Table 4.2a–d. Frequency of site size for walled settlements during the four periods between 2800–1300 BC.

Extreme values for walled sites[a]

Period			Site	Size (ha)
1	Highest	1	Houzhaizimao I	21
		2	Zhaimao I	17
		3	Ashan III	5
		4	Zhaizigedan	5
		5	Zhaizita I	5
	Lowest	1	Shamujia	0
		2	Xiaoshaowan	0
		3	Zhaishan	2
		4	Heimaban	2
		5	Weijun	4
2	Highest	1	Houchengzui III	138
		2	Baiyagou	120
		3	Xiata	28
		4	Damiaopo	25
		5	Houzhaizimao II	21
	Lowest	1	Zhaizishang II	3
		2	Zhaizita II	5
		3	Shilouloushan II	6
		4	Xibaiyu	9
		5	Bancheng	10
3	Highest	1	Shimao	400
		2	Bicun	75
	Lowest	1	Zhaimaoliang	3
		2	Shilouloushan II	6
4	Highest	1	Houchengzui IV	138
	Lowest	1	Zhaizita IV	5

a. The requested number of extreme values exceeds the number of data points. A smaller number of extremes is displayed.

Table 4.3. Extreme values (outliers) for walled sites in the four periods between 2800–1300 BC.

For non-walled sites, the distribution of size concentrates at a low level in all periods. During the period 2800–2400 BC, the size site concentrates between 2 and 6 hectares (Table 4.4a), with a couple of outliers (Table 4.5). During the period 2600–2400 BC, the size site concentrates between 2 and 7 hectares, with a greater value of 20 hectares (Table 4.4b), with one outlier (Table 4.5). In the next period, 2400–2000 BC, the size concentrates around 3 and 4 hectares with a one larger site at 10 hectares (Table 4.4c), and one outlier (Table 4.5). The size in the last period 1600–1300 BC concentrates between 1 and 5 hectares (Table 4.4d), with one outlier (Table 4.5). The one-way Anova test shows that the differences between the periods in the size distribution for the non-walled sites are statistically insignificant [$F(3, 24) = 0.66$, $p = 0.583$].

Non-walled sites (2800–2400 BC)

Covered area (ha)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	1	16.7	16.7	16.7
	3	2	33.3	33.3	50.0
	6	1	16.7	16.7	66.7
	30	1	16.7	16.7	83.3
	138	1	16.7	16.7	100.0
	Total	6	100.0	100.0	

Non-walled sites (2400–2000 BC)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	1	14.3	14.3	14.3
	3	1	14.3	14.3	28.6
	6	1	14.3	14.3	42.9
	7	1	14.3	14.3	57.1
	20	1	14.3	14.3	71.4
	50	1	14.3	14.3	85.7
	120	1	14.3	14.3	100.0
	Total	7	100.0	100.0	

b

Non-walled sites (2000–1600 BC)

Covered area (ha)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	2	40.0	40.0	40.0
	4	1	20.0	20.0	60.0
	10	1	20.0	20.0	80.0
	50	1	20.0	20.0	100.0
	Total	5	100.0	100.0	

c

Non-walled sites (1600–1300 BC)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	1	10.0	10.0	10.0
	2	1	10.0	10.0	20.0
	3	1	10.0	10.0	30.0
	3	2	20.0	20.0	50.0
	4	1	10.0	10.0	60.0
	5	2	20.0	20.0	80.0
	50	1	10.0	10.0	90.0
	120	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

d

Table 4.4a–d. Frequency of site size for non-walled settlements during the four periods between 2800–1300 BC.

Extreme Values for non-walled sites[a]

Period			Site	Siza (ha)
1	Highest	1	Houchengzui II	138
		2	Wuzhuangguoliang	30
		3	Shilouloushan I	6
	Lowest	1	Xishata	2
		2	Zhukaigou (zone VII) II	3
		3	Zhuangwoping II	3
2	Highest	1	Xicha I	120
		2	Zhukaigou I	50
		3	Yuanzigou	20
	Lowest	1	Guandi IV	2
		2	Zhuangwoping III	3
		3	Erliban	6
3	Highest	1	Zhukaigou II	50
		2	Huoshiliang	10
	Lowest	1	Xinhua	3
		2	Dakoul	3
4	Highest	1	Xicha II	120
		2	Zhukaigou III-IV	50
		3	Gaojiaping	5
		4	Qingchaotai	5
		5	Shengedaliang	4
	Lowest	1	early Xiaomiao	1
		2	Guandi V	2
		3	Nanhao	3
		4	Zhuangwoping IV	3
		5	Dakou II	3

a. The requested number of extreme values exceeds the number of data points. A smaller number of extremes is displayed.

Table 4.5. Extreme values (outliers) for non-walled sites in each of the periods between 2800–1300 BC.

4.6.2 Spatiotemporal distribution of settlements

The spatiotemporal distribution of the walled and non-walled sites in terms of the area covered is shown in Figure 4.4. This shows that the walled sites concentrated in the south of the Daqing Mountain and Qingshui River valley areas during 2800–2400 BC tend to have smaller sizes. When the walled sites disappear in the south of the Daqing Mountain area, they start to appear in the Daihai Lake area and expand into the Qingshui River valley and Yulin areas during 2400–2000 BC. Walled sites greater than 100 hectares also appear during this period. The walled sites then concentrate in the Yulin area only during 2000–1600 BC, when the Shimao site appears. The sites then concentrate in the Qingshui River valley area only during 1600–1300 BC. Most of the walled sites are not occupied during this period, with only Houchengzui IV and Zhaizita IV, built in the earlier periods, still occupied.

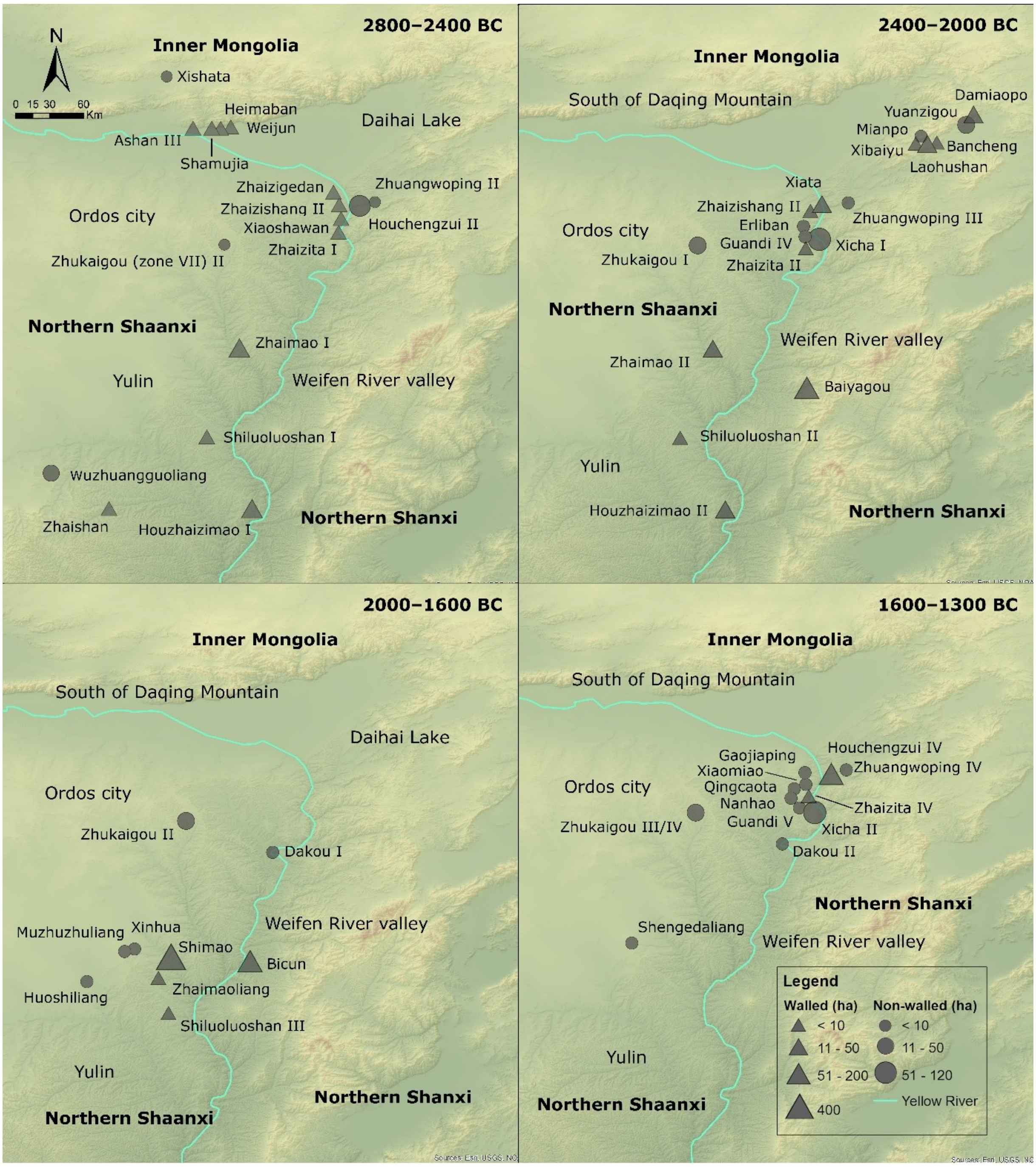


Figure 4.4. Map of the distribution of walled and non-walled settlement sites with the measurement of site size over the four period from 2800–1300 BC, corresponding to the results shown in Figure 4.3. Information comes from Table 4.1.

4.7 Discussion: transitions in settlement size and distribution

The quantitative analysis shows that the overall occupied area of walled sites was larger during the period 2400–2000 BC compared other periods, if the Shimao site, assigned to 2000–1600 BC, is excluded (Figure 4.3a). Even though the results show that the walled sites have larger sizes during 1600–1300 BC than other periods, the distribution is distorted to a higher level due to there being only two walled sites, including the large 138-hectare Houchengzui site (Figure 4.3). Figure 4.3 also shows that walled sites greater than 100 hectares started to appear from 2400–2000 BC onwards. It is worth noting that the size of walled sites is evenly distributed during this period, whereas those in other periods concentrates at low levels (Figure 4.3, Table 4.2b). Even though the one-way Anova test shows that the differences in size distribution between periods for the walled sites are not statistically significant, whether or not Shimao is included, it is evident that there is a trend of sites becoming bigger during the period 2400–2000 BC, with two large sites that reach 120 and 138 hectares (Figure 4.3b and Table 4.3). During the next period 2000–1600 BC, the size of most of the walled sites concentrates to a low level again, with only the extremely large Shimao site breaking that rule (Figure 4.2a and Table 4.2c). Except Shimao, large sites above 100 hectares, however, do not exist during this period. This means the inhabitants were distributed at larger sites, especially at those larger than 100 hectares and later they were highly concentrated at Shimao only.

Observing this transition over space and time, the sites concentrated in the Daihai Lake and Qingshui River valley areas during the period 2400–2000 BC (Figure 4.4). The loci of sites then shifted to the Yulin area during 2000–1600 BC, when the largest walled site, Shimao, emerged. As the sites concentrate in the Qingshui River valley area during the period 1600–1300 BC, the walled sites almost disappear, with Houchengzui IV and Zhaizita IV being the only ones remaining (Figure 4.4). Even though Houchengzui is an outlier among the non-walled sites during the period 2800–2400 BC (Figure 4.3), whether this site has already reached 138 hectares when it was still unwalled is uncertain because this figure is the measurement for the walled structure built in the next period 2400–2000 BC (Wang & Zhang, 2016).

The results do not show significant changes in site size over the period 2800–1300 BC, but the transition from 2400–2000 BC to 2000–1600 BC shows a sign of population concentration in the Yulin area, after the suggested population shift southwards took place across the region. During the period 2000–1600 BC, the walled sites concentrated in the Yulin area, when the Shimao site appeared, which was surrounded by a few smaller sites (both walled and non-walled) (Figure 4.4). This potentially reflects population growth from a demographic movement. Even if the population did not grow, the inhabitants were presumably more concentrated in the Yulin area, especially at Shimao (Figure 4.4). Eventually, the walled sites almost disappeared during 1600–1300 BC when the sites concentrated in the Qingshui River valley area only. The large walled site at Houchengzui was still occupied, however, and could have served as a centre by this period, being surrounded by smaller sites (mostly non-walled) (Figure 4.4).

As mentioned in Section 4.5.3, the limited number sites analysed here may affect the outcome of the results. As far as we known, the Yulin area has a distribution of more non-walled sites, several small walled sites (below 10 hectares) and two larger walled sites (50–100 hectares) further south during the Longshan period (Figure 4.1). Even though this cannot reflect changes of settlement pattern over time and space, this shows a great number of sites in varied sizes, especially the walled ones, distributed close to Shimao. Taking the settlement pattern into consideration does not affect the argument that population become more concentrated at a few large sites (above 100 hectares) over time and later peaked at the largest site of Shimao; since the difference of site size is still very extreme as between Shimao and other sites, it indicates that population was highly concentrated at Shimao alone and much lesser at other smaller sites. It is noted that when it comes to the changes of population density in the broader region, further studies as in comparing the more complete settlement patterns between areas and periods are needed.

The transformation reflected by the stone structures and stone ‘altars’ over the four periods also suggests the organisation of a more concentrated population (Figure 2.19). The stone ‘altars’ that were common in 2800–2400 BC seemed to change (Baotou, 1984; Liu, 1988) during 2400–2000 BC to become a combination of a platform-like structure with a stone ‘altar’ built inside, as at the Laohushan site (Figure 2.16) (Yang, 2000). This seemed to be an integration of stone ‘altar’ and platform building. The large platform structure had already appeared during the same period at Baiyagou, before the greatest one appeared at Shimao during the next period 2000–1600 BC (Figure 2.8). The platforms at Baiyagou and Shimao were built at a central or inner location and surrounded by the inner and outer walls (Figure 2.6). Since both the stone ‘altars’ and the platform structures are considered as communal areas that could be used for ritual or public activities (Baotou, 1984; Sun et al., 2018, 2021), this change implies that a larger space was required to accommodate more people and holding ceremonies and public activities at Shimao, drawing people from the broader region to attend such activities.

4.8 Conclusion

One of the major findings is that the current evidence does not suggest that the overall settlement size, either walled or non-walled, expanded across the periods. The trend of changes, nevertheless, shows that the site sizes became more diverse, with the appearance of large sites above 100 hectares during the period 2400–2000 BC, and settlements and people subsequently joined up to form the largest site at Shimao during the period 2000–1600 BC. These changes suggest that first there was some general population growth, and while people moved to Shimao, this enabled its expansion. At the same time, the growth of the platform and the concurrent use of a stone 'altar' imply a growth in the ritual role of Shimao.

A second finding is that the distribution shape of settlements became more concentrated in the Yulin area during the period 2000–1600 BC. The larger walled sites, that is greater than 100 hectares, began to appear from 2400–2000 BC onwards. The settlements in the Yulin area then became closer to one another during the period 2000–1600 BC when Shimao emerged, compared to the previous periods (Figure 4.4). While the Shimao site is surrounded by a few smaller sites, both walled and non-walled, inhabitants were presumably highly concentrated at this largest walled site, regardless of whether the population had grown overall or not.

In summary, these findings of this chapter, from the perspective of settlement size, do not give clear evidence that support the current interpretations that the population grew over the Longshan period from 2400–1600 BC. Despite this, the findings do show that difference of settlement size becomes extreme during this period, and population becomes concentrated at large sites above 100 hectares during the period 2400–2000 BC and then highly concentrated at Shimao during the period 2000–1600 BC. The development of these large sites and most especially of Shimao, suggesting greatly increased activity, possibly with highly concentrated population, presents us with the single most basic feature of the development of a city. The phenomenon of population becomes more concentrated over time may be associated to the major loci of settlements moving southwards around 2100–2000 BC, as suggested in Chapter 3; this may have boosted population during the time when Shimao was developing. A possible southward population movement and expansion in the south may be due to the relatively warmer and more humid climate before 1800 BC in the Yulin area (Cui et al., 2019). The more favourable micro-climate in this area would also help to sustain the subsistence activities for a large size of population here than in other areas. The choice of Shimao as a major ritual centre within the large platform at Shimao may have been an added stimulus for growth. The next chapter will explore the evidence from faunal remains to identity whether management of herd animals and their consumption are different at Shimao and surrounding sites.

Chapter 5

The prevalence and consumption of herd animals

5.1 Introduction

The last two chapters suggested that there is a visible trend with sites becoming larger during the period 2400–2000 BC, some with fortifications larger than 100 hectares appeared in the north sector of the region. The human occupation and population likely shifted southwards across the Shimao region around 2100–2000 BC. From 2000–1600 BC, the population concentrated at Shimao, and it may draw more people to the site from other smaller sites. If the shifting of settlement loci or population movement did take place and facilitated the emergence of Shimao and surrounding sites, the rise of the south should be visible in the organisation of the local economies at that time. There are several notable changes in the local economies during the time when Shimao and other sites emerged. One of the most visible is that domesticated herd animals (sheep, goat and cattle) appear at more sites and in greater numbers.[16] We can see that herd animals had become prevalent in the south during the period 2000–1600 BC, but we do not understand how prevalent different species of herd animals were and how they were treated. Furthermore, it is uncertain whether all the sites had similar preferences for domesticated mammals as well as ways of consumptions for herd animals.

For this reason, a comparative study was conducted into the taxonomic abundances and mortality patterns across all available sites, so as to provide an overview on the prevalence

[16] Sheep and goat are normally considered together because they are difficult to separate from the bones alone when they are being similar in size, shape and tooth profiles.

and consumption of herd animals at Shimao and surrounding sites. Although the data for these estimations are available, existing studies tend to consider individual sites only or at most comparison of two sites, which does not allow a proper comparison between sites. Moreover, the methods and considered data are inconsistent, making it difficult to compare findings between sites and thus gain an overview of the situation of the entire region. Overall, the incomplete and disjointed information means that the questions of whether the preferences and consumptions of herd animals between Shimao and surrounding sites differed remain unanswered. Determination of taxonomic abundances in sites' bone residues shows us which species dominated human consumption, subject to the nature of deposition, excavation and recovery. Mortality profiles indicate age-at-death, provide clues on whether animals might have been consumed for primary (e.g. meat) and secondary (e.g. milk and wool) products or primarily traction power.

5.2 Aims and objectives

This chapter aims to assemble all the information possible for faunal abundances at the sites discovered with herd animals—Huoshiliang, Shimao, Muzhuzhuliang, Xinhua, Zhukaigou and Zhaimaoliang, and to examine comparatively their taxonomic abundance and mortality profiles for major species of domesticated mammals. Given that the analysed sites are mostly assigned to the period 2000–1600 BC (Zhukaigou is the only site extending to the period 1600–1300 BC), the timing of the transition and changes over time cannot be observed and thus is not covered in the analysis.

The objectives of this chapter are to: 1) collect and synthesise the published data from the faunal reports quantifying wild and domesticated mammal species and age-at-death of pigs, sheep, goat and cattle; 2) standardise the data and generate two datasets for the former and four datasets for the latter; 3) convert these data to percentages; 4) identify the relative proportions of wild versus domesticated mammal species; 5) identify the relative proportions of domesticated herd animals (sheep, goat and cattle) versus non-herd animals (pigs and dogs); 6) compare the mortality patterns for pigs, sheep, goat and cattle separately by age group, and test the results with Chi-square test and Fisher's exact test.

5.3 Evidence of domesticated herd remains in the Shimao region

Domesticated herd animals are rare in earlier periods prior to ca. 2000 BC. Thereafter, they occurred at several sites: Xicha and Zhukaigou in the Qingshui River valley and Ordos city areas, and Huoshiliang, Shimao, Muzhuzhuliang, Xinhua and Zhaimaoliang in the Yulin area (Figure 5.1) (Hu et al., 2008a, 2016; Huang, 1996; Owlett et al., 2018a; Xue et al., 2005; Yang, 2007; Yang et al., 2017). Domesticated forms remined in evidence until the period 1600–1300 BC at Xicha and Zhukaigou. Belonging to an earlier stage, some animals have been identified at the sites of Jiadamao and Miaoliang sites in the Yulin area assigned to the period 2800–2000 BC (Figure 5.1), but publications on these are not yet available (Hu, 2020). Wild sheep and/or goats and cattle are also found before 2000 BC. They include sheep and/or goats at Dagujie and Yangjiesha in the Yulin area (Figure 5.1) (Hu et al., 2012, 2013) during the Haishengbulang cultural period around or before 2800 BC (Table 2.2), and wild cattle at Miaozigou, to the northeast of the Shimao region (Figure 5.1), are also dated to around this time (Huang, 2003).

Figure 5.1. Map that shows the distribution of herd animals (sheep/goat and cattle) across the Shimao region. Early domesticated herd animals refer to the period 2800–2000 BC; late domesticated herd animals refer to the period 2000–1600 BC. Possible domesticated herd animals refer to sites discovered with herd animals but unsure whether they were wild or domesticated.

Currently, there is no concrete or explicit evidence to suggest that domesticated herd animals were present prior to 2000 BC, or at least not in any significant quantities, and herd animals seemed to have become prevalent only after 2000 BC. Although prior to this time wild or feral and minimally managed sheep/goat and cattle have been discovered in the region, there is currently no solid evidence to indicate local domestication. The presence of these animals as domesticated can be inferred from bone morphology, the sex and age profiles of the mortality pattern, taxonomic abundances, genetic analyses, and dietary determinations from isotopic and tooth wear analyses (Yuan, 2008). These analyses have been carried out for the remains of herd animals from several sites in the Shimao region. They suggest that the sheep, goat and cattle discovered at Huoshiliang, Shimao, Muzhuzhuliang, Xicha, Xinhua, Zhaimaoliang and Zhukaigou are indeed domesticated, based largely on bone morphology (Huang, 1996; Owlett, 2018; Xue, et al., 2005; Yang, 2007).

Sheep/goat remains at Huoshiliang, Shimao and Zhukaigou have been identified as domesticated, based on mortality patterns (Hu et al., 2008a, 2016; Huang, 1996) that differ in age and sex profiles from wild animals (Hu et al., 2016). The sheep/goat and cattle from Muzhuzhuliang and Shengedaliang have been interpreted as domesticated by Chen et al. (2017b), Guo (2017) and Yang et al. (2017), but no formal report has yet been published. Sheep/goat and cattle remains from Dakou, Yongxindian and Zhengzemao have been interpreted as domesticated (Figure 5.1) (Chen et al., 2015b, 2017b), but it is uncertain what evidence this is based on. Gaojiaping, Shiluoluoshan and Zhaizita also have traces of herd remains, as indicated in the excavation reports (Neimenggu, 1994: 262–271, 1997: 280–326; Shaanxi, 2016b), but it is uncertain whether they are domesticated or wild.

5.4 Current interpretation and the knowledge gap for herd animals in the Shimao region

The increasing use of herd animals in the Shimao region during the period 2000–1600 BC have been interpreted as a situation in which the subsistence economy transitioned from an agricultural-based economy to a mixed economy with some pastoralism at this time (Chen et al., 2017b; Guo, 2017; Wang et al., 2014b). Meanwhile, agriculture remained important (Sheng et al., 2021), as archaeobotanical studies indicate that millet continued to be the major crop plant used at Shengedaliang, Muzhuzhuliang and Zhaimaoliang (Gao et al., 2016; Guo, 2017). At Dakou, Muzhuzhuliang, Shengedaliang, Shimao, Xinhua and Zhukaigou, isotopic dietary studies suggest that consumption of C_4 millet remained more important than protein (meat) in human and animal diets (Atahan et al., 2014; Chen et al., 2015b, 2017b). These studies suggest that millet will have been more important than animal meats in human diet at these sites. Nevertheless, the appearance of herd animals at more sites and in greater number at those sites suggest a significant change in subsistence strategy, as herding was adopted with millet cultivation and some certain degree of wild-game hunting. Insufficient attention paid to the faunal evidence itself means that existing evidence is limited for indicating whether the choices of animal species and the consumptions of herd animals differed between Shimao and surrounding sites. Taxonomic abundances and mortality profiles are therefore worth conducting, especially given that they have not yet been undertaken with a comparative and synthetic approach.

5.5 Taxonomic abundances and mortality profile analysis

The study of taxonomic abundances reveals the species composition of faunal assemblages. It allows us to examine the relative proportions of different species in the site's faunal assemblage and hence which species dominated, subject to taphonomic factors related to use and discard practices. Quantification of bones remains takes the forms of counting by number of individual specimens (NISP) and minimum number of individuals of the taxon (MNI). NISP considers every single bone fragment that is identifiable, while MNI considers unique identifiable skeletal elements for a species, which means that only a single skeletal element is counted for an individual (Lyman, 2008, Chapter 2). MNI counts are thus always lower than NISP counts.

The analysis of taxonomic abundances has thus far only been conducted for Huoshiliang and Zhukaigou separately, applying different methods and applying different species in these two cases (Hu et al., 2008a; Huang, 1996). The Huoshiliang study only considered meat-yielding mammals and excluded the micro fauna, showing that sheep/goat made up of 60% of the of the assemblage around 2000–1600 BC. The Zhukaigou study, meanwhile, considered wild animals as well as domesticated species of pigs, dogs, sheep and cattle presented by phases. This shows that during phase 1 (equivalent to 2000–1600 BC) pigs made up of 45% followed by sheep and cattle, comprising between 20% and 30% each. During phases 2–4 (equivalent to 1600–1300 BC), pigs made up 30% and 45% in phases 2 and 3, respectively but became less prominent in phase 4, while sheep made up 40% and 30% in phases 2 and 3, respectively, and remained a prominent species in phase 4 with 35%. These results indicate that sheep/goat seemed to have dominated at Huoshiliang, while both sheep (but not goats) and pigs were important at Zhukaigou. Since the coverage of faunal species, the time periods assessed, and the way of presenting the results are all differ in these two analyses, the results cannot be compared between sites. In other cases, at Shimao, Muzhuzhuliang and Xinhua, the information for taxonomic abundances, based on the quantification of skeletal elements of different species, is only recorded and presented as raw data. In order to be able to compare faunal assemblages at these sites in a meaningful way, the data for faunal remains are expressed using standard calculation methods of NISP and MNI and presented in relative proportion.

Mortality profile analysis allows us to estimate how herd animals were consumed and gives us clues as to whether they were used as primary or secondary products, or both. According to Greenfield's (2010) definition, a primary product is a one-off use that includes meat, hide and bone, while secondary products can be repeatedly collected or used from animals, and include milk, wool and traction power. This can be determined from the pattern of age-at-death and age and sex profiles. Age-at-death can be determined by both epiphyseal fusion of bones, and tooth eruption and wear. The former indicates the specific age range of an animal before their maturity around the age of 3.5 (Yang et al., 2017). For animals older than that the specific age range can only be estimated from the eruption and wear evident in mandibular and/or maxillary remains.

Generally, it has been suggested that pigs were slaughtered at around 1–2 years old, or even earlier if they were consumed as meat (Brunson et al., 2016; Hu et al., 2016). Sheep and goat were slaughtered at 1.5–2.5 years old if they were for meat production, while males would be slaughtered at a younger age, with females surviving to an older age if they were used for dairy production. Both males and females that died at or after reaching adulthood age, were mainly used for wool production (Payne, 1973). Similarly, female cattle were kept to an older age if they were used for milk production, while males survived to an older age if they were used for traction (Marciniak, 2011; Sherratt, 1983). If the mortality concentrates at more than one age stage, it means that the animals might be used for more than one of these purposes.

Similarly, the mortality profiles for pigs, sheep/goat and cattle in the region have usually been recorded and presented in raw data, but how these animals were consumed remains unclear and unexplored at most of the sites. Mortality profiles have only been studied at Muzhuzhuliang, Shimao and Zhaimaoliang. At Muzhuzhuliang most of the goats survived to an older age, and so it is suggested that they were kept for wool and milk production (Yang et al., 2017). At Shimao and Zhaimaoliang, some sheep/goats survived to an older age (Owlett et al., 2018a), but this pattern is not interpreted as showing a sign of exploitation of secondary products. Some of the cattle also survived to an older age, but there is no evidence showing they were used for milk production or ploughing (Owlett et al., 2018a). Apart from that, the evidence related to mortality pattern at the other sites mentioned above has not yet been explored. A synthetic and comparative study is therefore also needed for the mortality profile analysis in order to identify the difference between sites. The results from this section will be tested with the Chi-square test and Fisher’s exact test in order to find out whether the patterns are different between sites. These tests are chosen because they allow us to compare categorical variables of sites and age groups. The Fisher’s exact test is a further test applied in cases with low frequency counts.

5.6 Materials and methods

5.6.1 Materials, data collection and standardisation

These data come from the reports of faunal remains from individual sites, as for Huoshiliang, Shimao, and Muzhuzhuliang (Hu et al., 2008a, 2016; Yang et al., 2017), faunal reports included within the detailed excavation reports, as for Zhukaigou and Xinhua (Huang, 1996; Xue et al., 2005), and journal papers that covered relevant raw data, as for Shimao and Zhaimaoliang (Owlett et al., 2018a). In order to ensure that the data considered here are suitable for comparison between sites, sites with fewer than 100 identifiable remains are excluded from this analysis. As a result, the data from Xicha that is available from a master's thesis (Yang, 2007) are not considered because it reports only 14 identifiable remains for 2400–1600 BC and 4 for 1600–1300 BC. The faunal remains from Huoshiliang, Shimao, Muzhuzhuliang, Xinhua and Zhaimaoliang are assigned to the period 2000–1600 BC, based on the recalibration analysis done in Chapter 3 and typo-chronology. Those from Zhukaigou, meanwhile, are assigned to both the period 2000–1600 BC and 1600–1300 BC.

The faunal remains from Huoshiliang were originally collected from an excavation of a 350 square metres area of the site between April and June 2016, with the remains unearthed from stratigraphic units and from pits and houses (Hu et al., 2008a). Those from Muzhuzhuliang were collected from an excavation of a 3600 square metre area in 2011 (Wang & Guo, 2015), with the remains unearthed from pits and houses (Yang et al., 2017). The faunal remains collected from Shimao are separated into two groups. One of them comes from the excavation of the East Gate at the outer wall between 2011 and 2012 (Shaanxi et al., 2013), mostly being unearthed from houses and abutments and some from pits and burials (Hu et al., 2016). Another group comes from a longer excavation (spanning between 2011 and 2016) that unearthed remains from different locations at Hangjiagedan, the East Gate, and the

Huangchengtai platform inside the inner wall (Owlett et al., 2018a). Faunal remains from Xinhua, meanwhile, were collected from two excavations between 1996 and 1999 covering an area of 3362.75 square metres (Shaanxi & Yulin, 2005), with the material being unearthed from pits and houses (Xue et al., 2005). Those from Zhukaigou were collected from four different excavations between 1977–1984 over an area of 4000 square metres, with faunal material unearthed from stratigraphic layers from different phases, and from pits and houses. At Zhaimaoliang, the remains were collected from a rescue excavation conducted between 2014 and 2015 of an area of 3000 square metres (Shaanxi et al., 2018), with faunal material mostly unearthed from household foundations and some from large pits (Owlett et al., 2018a).

Apart from the remains from Zhukaigou, which can be assigned based on the ceramic chronology to five phases (phase 1 to late Longshan period, phases 2–4 to Erlitou period, phase 5 to Shang period), the remains from other sites are dated to the late Longshan period (equivalent to 2000–1600 BC used in this thesis). The data considered in the analysis of taxonomic abundances for wild versus domesticated mammal species is shown in Table 5.1; the more detailed list of the numbers of wild and domestic animal species is included in Appendix II. The data for the different domesticated mammal species, meanwhile, is shown in Table 5.2. The data for mortality analysis for pigs, sheep, goat and cattle are shown in Tables 5.3–5.6, respectively. Data from the Huoshiliang, Muzhuzhuliang and Shimao sites (2012–2013 and 2011–2016 separately), and from the Xinhua, Zhukaigou and Zhaimaoliang sites are considered for the analysis of taxonomic abundances. For mortality analysis, data from Huoshiliang, Shimao and Zhukaigou are considered for pigs; data from Huoshiliang, Muzhuzhuliang, Shimao, Zhukaigou are considered for sheep and goats; and data from Shimao and Zhukaigou are considered for cattle. The data from Shimao (2011–2016) and

Zhaimaoliang are not considered in this section as the raw data are unavailable in the literature and therefore cannot be standardised with the rest of the data presented here. Patterns comparing the mortality of herd animals as between these two sites, as presented in Owlett et al. (2018a), will be discussed in Section 5.8 where applicable.

	2000–1600 BC															
	Huoshiliang (from 2016)				Shimao (from 2012–2013)				Shimao (from 2011–2016)				Xinhua (from 1996–1999)			
	NISP	NISP%	MNI	MNI%	NISP	NISP%	MNI	MNI%	NISP	NISP%	MNI	MNI%	NISP	NISP%	MNI	MNI%
Total domestic species	1056	95.22	87	79.82	1498	98.17	132	91.667	2604	94.11	92	74.19	155	91.72	19	76.00
Total wild species	53.00	4.78	22.00	20.18	28.00	1.83	12.00	8.33	163	5.89	32	25.81	14.00	8.28	6.00	24.00
Total mammal species	1109	100.00	109	100.00	1526	100.00	144	100.00	2767	100.00	124	100.00	169	100.00	25	100.00

	2000–1600 BC								1600–1300 BC			
	Zhaimaoliang (from 2014–2015)				Zhukaigou (from 1977–1984)				Zhukaigou (from 1977–1984)			
	NISP	NISP%	MNI	MNI%	NISP	%	MNI	%	NISP	%	MNI	%
Total domestic species	381	95.97	23	82.14	114	100	15	100	795	91.17	120	86.96
Total wild species	16	4.03	5	17.86	0.00	0.00	0.00	0.00	77.00	8.83	18.00	13.04
Total mammal species	397	100.00	28	100.00	114	100.00	15	100.00	872	100	138	100

Table 5.1. Raw data of the analysis of taxonomic abundances for domestic and wild mammal species and conversion to relative percentages in Chapter 5.

	2000–1600 BC															
	Huoshiliang (from 2016)				**Muzhuzhuliang (from 2011)**				**Shimao (from 2012–2013)**				**Shimao (from 2011–2016)**			
	NISP	NISP%	MNI	MNI%	NISP	NISP%	MNI	MNI%	NISP	NISP%	MNI	MNI%	NISP	NISP%	MNI	MNI%
Dog (*Canis familiaris*)	15	1.42	4	4.60	175	6.23	20	10.15	30	2.00	3	2.27	54	2.07	12	13.04
Pig (*Sus domesticus*)	131	12.41	13	14.94	484	17.22	27	13.71	463	30.91	52	39.39	765	29.38	17	18.48
Sheep/goat (*Ovis aries*/*Capra hircus*)	693	65.63	61	70.11	1606	57.15	122	61.93	651	43.46	57	43.18	1224	47.00	52	56.52
Cattle (*Bos taurus*)	217	20.55	9	10.34	476	16.94	22	11.17	349	23.30	19	14.39	561	21.54	11	11.96
Horse (*Equus Caballus*)	0	0.00	0	0.00	59	2.10	4	2.03	5	0.33	1	0.76	0	0.00	0	0.00
Donkey (Equus asinus)	0	0.00	0	0.00	10	0.36	2	1.02	0.00	0.00	0.00	0.00	0	0.00	0	0.00
Total domestic species	1056	100.00	87	100.00	2810	100.00	197	100.00	1498	100.00	132	100.00	2604	100.00	92	100.00

	2000–1600 BC												**1600–1300 BC**			
	Xinhua (from 1996–1999)				**Zhaimaoliang (from 2014–2015)**				**Zhukaigou (from 1977–1984)**				**Zhukaigou (from 1977–1984)**			
	NISP	NISP%	MNI	MNI%	NISP	NISP%	MNI	MNI%	NISP	NISP%	MNI	MNI%	NISP	NISP%	MNI	MNI%
Dog (*Canis familiaris*)	75	48.39	4	21.05	4	1.05	1	4.35	3	2.63	1	6.67	19	2.39	6	5.00
Pig (*Sus domesticus*)	39	25.16	11	57.89	100	26.25	6	26.09	32	28.07	5	33.33	220	27.67	45	37.50
Sheep/goat (*Ovis aries*/*Capra hircus*)	18	11.61	2	10.53	129	33.86	10	43.48	33	28.95	5	33.33	365	45.91	50	41.67
Cattle (*Bos taurus*)	23	14.84	2	10.53	148	38.85	6	26.09	46	40.35	4	26.67	191	24.03	19	15.83
Total domestic species	155	100.00	19	100.00	381	100.00	23	100.00	114	100.00	15	100.00	795	100.00	120	100.00

Table 5.2. Raw data of the analysis of taxonomic abundances for the domesticated mammal species and conversion to relative percentages in Chapter 5.

	2000–1600 BC						1600–1300 BC		
	Huoshiliang (from 2016)			**Shimao (from 2012–2013)**			**Zhukaigou (from 1977–1984)**		
Age class (Lemoine et al., 2014)	Original age group	MNI	%	Original age group	MNI	%	Original age group	MNI	%
A (<1m)	N/A	0	0.00	0-4m	4	20.00	1-4m	8	19.51
B (3-8m)	4-9m (M1, P1, I3 erupted)	2	18.18	4-6m	8	40.00	4-9m (M1, P1, I3 erupted)	6	14.63
C (8-12m)	N/A	0	0.00	6-12m	2	10.00	9-12m (M2, C erupted)	14	34.15
D (12-16m)	12-18m (M2 erupted, DP4 heavily worn or replaced by P4)	5	45.45	12-18m	5	25.00	12-15m (P4, P3, I1 erupted)	9	21.95
E (18-52m+)	18-24m (M3 completely erupted)	3	27.27	18-24m	1	5.00	16-20m (I2, P1 erupted)	4	9.76
							17-22m (M3 erupted)		
	24m>	1	9.09				>24		
Total		11	100.00		20	100.00		41	100.00

Table 5.3. Raw data of mortality analysis for pigs and conversion to percentages in Chapter 5. Classification of age class based on Lemoine et al. (2014).

	2000–1600 BC									1600–1300 BC		
	Huoshiliang (from 2017)			**Muzhuzhuliang (from 2011)**			**Shimao (from 2012–2013)**			**Zhukaigou (from 1977–1984)**		
Age class (Payne, 1973)	Original age group	MNI	%	Original age group	MNI	%	Original age group	MNI	%	Original age group	MNI	%
A	<6m (M1 not erupted)	0	0.00	N/A	0	0.00	N/A	0	0.00	N/A	0	0.00
B	6-12m (M1 erupted)	1	6.67	2-6m	5	5.81	2-6m	2	14.29	6m (M1 erupted)	2	7.14
C	12-20m (M2 erupted)	1	6.67	6-12m	16	18.60	6-12m	5	35.71	12-20m (M2 erupted)	9	32.14
D	20-30m (M3 and premolars erupted)	10	66.67	12-24m	19	22.09	12-24m	4	28.57	20-30m (M3 and premolars erupted)	13	46.43
E			0.00	24-36m	19	22.09	24-36m	0	0.00			0.00
F	>30m (M3 heavily worn)	3	20.00	36-48m	8	9.30	36-48m	1	7.14	>30m (M3 heavily worn)	4	14.29
G			0.00	48-72m	5	5.81	48-72m	1	7.14			0.00
H			0.00	72-96m	9	10.47	72-96m	0	0.00			0.00
I			0.00	96-120m+	5	5.81	96-120m+	1	7.14			0.00
Total		15	100.00		86	100.00		14	100.00		28	100.00

Table 5.4. Raw data of mortality analysis for sheep and conversion to percentages in Chapter 5. Classification of age class based on Payne (1973).

	2000–1600 BC								
	Huoshiliang (from 2017)			**Muzhuzhuliang (from 2011)**			**Shimao (from 2012–2013)**		
Age class (Payne, 1973)	Original age group	MNI	%	Original age group	MNI	%	Original age group	MNI	%
A	<6m (M1 not erupted)	2	4.44	N/A	0	0.00	N/A	0	0.00
B	6-12m (M1 erupted)	7	15.56	2-6m	0	0.00	2-6m	0	0.00
C	12-20m (M2 erupted)	11	24.44	6-12m	3	13.64	6-12m	4	28.57
D	20-30m (M3 and premolars erupted)	22	48.89	12-24m	1	4.55	12-24m	2	14.29
E			0.00	24-36m	5	22.73	N/A	0	0.00
F	>30m (M3 heavily worn)	3	6.67	36-48m	3	13.64	36-48m	2	14.29
G			0.00	48-72m	2	9.09	48-72m	3	21.43
H			0.00	72-96m	6	27.27	N/A	0	0.00
I			0.00	96-120m+	2	9.09	96-120m+	3	21.43
Total		45	100.00		22	100.00		14	100.00

Table 5.5. Raw data of mortality analysis for goat and conversion to percentages in Chapter 5. Classification of age class based on Payne (1973).

	2000–1600 BC			1600–1300 BC		
	Shimao (from 2012–2013)			**Zhukaigou (from 1977–1984)**		
Age class (O'Connor and Addyman 1988)	Original age group	MNI	%	Original age group	MNI	%
Juvenile	Young (M1 erupted)	1	10	6-14 (M1 erupted)	3	25
Immature	N/A	0	0	14-16 (M2 erupted)	2	17
Subadult	Adult (M3 erupted)	5	50	>26 (M3 and premolars erupted)	7	58
Adult	N/A	0	0	N/A	0	0
Elderly	Old (M3 in wear)	4	40	N/A	0	0
Total		10	100		12	100

Table 5.6. Raw data of mortality analysis for cattle and conversion to percentages in Chapter 5. Classification of age class based on O’Connor and Addyman (1988).

The number of faunal remains in the analysis of the taxonomic abundances were considered in aggregation for each site because, apart from the data for Shimao and Zhaimaoliang in Owlett et al. (2018a), the reports seldom contain detailed information about the excavation context where the bones were unearthed. This means that they cannot be grouped into their precise contexts, i.e. separating remains unearthed from different contexts such as pits and burials. Both NISP and MNI counting methods were used for the analysis of taxonomic abundances. The MNI counting here records the highest frequency of the skeletal element of a species. Both counting methods are used because they both suit the case in this analysis: NISP is appropriate where assemblages have small amounts of bone remains (as at Xinhua), while MNI is a more conservative estimate for a species. It also helps to deal with preservation bias in the case where bones of some species might be more fragmented than others, as well as when the samples size of bones are varied significantly between sites. It is understood that NISP and MNI are always under-estimates because of the nature of deposition, excavation and recovery. Nevertheless, NISP% and MNI% can be fruitfully compared between the analysed sites to show the relative differences. With the exception of Xinhua, the NISP and MNI data were derived directly from the faunal remain reports. In Xinhua, the report (i.e. Xue et al., 2005) did not summarize the number of NISP and MNI for each specimen, and hence the data were derived from the text, which mentioned the number of unearthed skeletal elements for each specimen.

The data for the mortality profile analysis came from either left and right mandibles (mainly for sheep and goat) or both left and right mandibles and maxillaries (mainly for pigs and cattle). The counting method of MNI was used here, which means that only the skeleton element (either left or right and mandible or maxillary) with the highest frequency was counted. Sheep and goat were considered separately in this part of analysis because they were distinguished in the collected data. The data for this part were standardised because the raw data were not recorded and presented in the same way due to the application of different age class models in the reports, and in some cases they are unspecified. The data from tooth eruption and wear stages were standardised to different types of age class models for pigs, sheep/goat and cattle separately because the age stages for each of these species are not compatible. This allowed a comparison of the mortality patterns for each of these species between sites.

For pigs, the age class model used in the excavation reports of Huoshiliang, Shimao and Zhukaigou are different and not specified. Since only the information on the tooth eruption and wear condition and/or absolute age of different stages were given, these were used to correlate with Lemoine et al.'s (2014) model that uses generalised age classes with an approximate age range: stages A (<1 month), B (3–5 months), C (8–12 months), D (12–16 months), E (18–52 months), F (52–96 months) and G (>96 months), as assigned in Table 5.3. For sheep and goat, the age class models used in the excavation reports of Shimao and Muzhuzhuliang are not specified but appear to be consistent with Payne's (1973) model. Those used for Huoshiliang and Zhukaihou are also not specified, but the information on tooth eruption and wear condition, as well as the absolute age ranges, were included. This information was used to correlate with Payne's (1973) model, which uses the generalised age classes with approximate age range: stages A (0–2 months), B (2–6 months), C (6–12 months), D (1–2 years), E (2–3 years), F (3–4 years), G (4–6 years), H (6–8 years) and I (8–10 years or above), as assigned in Tables 5.4 and 5.5. For cattle, the models used in the excavation reports for Shimao and Zhukaigou were not specified, but again, the information on tooth eruption and wear condition were used to correlate with O'Connor and Addyman's (1988) model that uses the generalised age classes: juvenile, immature, subadult, adult and elderly, as assigned in Table 5.6.

5.6.2 Analytical process

The data from the above sites were used to analyse both taxonomic abundances and the mortality profiles where applicable. The data only covers mammal species because the focus of this chapter is herd animals, and therefore only similar mammals are considered to compare with herd animals. The analysis of taxonomic abundances considers the data on the quantification of recorded animal remains and is conducted by presenting the data in stacked column graphs through Microsoft Excel. This shows the relative proportion of wild versus domesticated mammals as well as different species among domesticated mammals between sites. The analysis of mortality profiles considers the data on the quantification of recorded animal remains of pigs and herd animals where their age-at-death has been recorded. This analysis is conducted by presenting the data by combined line and column graphs through Microsoft Excel to show the age profiles and to reflect how these animals might have been consumed. Pigs are also considered here as they are another important mammal species alongside herd animals, thus allowing a comparison of the patterns between them.

In the analysis of taxonomic abundances, the NISP and MNI data for each specimen from different sites were converted to percentages, as shown in Table 5.1 and 5.2. These data were then used to generate stacked column graphs that illustrate the NISP% and MNI% of wild and domesticated mammals between sites as well as domesticated herd and non-herd mammals grouped by site. The latter is categorised by pigs, dogs, sheep/goat and cattle; all other domesticated mammal species are grouped as others. Although sheep and goat bones were distinguished by morphological analysis in some data sources, a large number of bones remained undistinguished and were all classified as Caprinae. For this reason, sheep, goat and Caprinae remains were grouped together as sheep/goat in this part of the analysis.

For the mortality profile analysis, the collated and standardised data were converted to percentages, as shown in Table 5.3–5.6. The information was then used to generate the combined graphs of clustered histograms and lines. Four major graphs were generated to illustrate the mortality and survival rates of pigs, sheep, goat and cattle by age class between sites separately. While the age class grouping of sheep at Huoshiliang and Zhukaigou, as well as of goat at Huoshiliang, can only be generalised to stages A (0–2 months), B (2–6 months), C (6–12 months), D–E (1–3 years) and F–I (3–10 years and above), the grouping at Shimao and Muzhuzhuliang, which could be grouped to stages A–I independently, were converted to the former in order so as to compare the patterns between these four sites. The mortality patterns of sheep and goat at Shimao and Muzhuzhuliang, grouped to stages A–I, were shown in separate graphs to show the more detailed patterns between these two sites. As a result, two versions of the graphs were provided, for sheep and goat separately.

5.6.3 Limitations

The limitation of this analysis is that the data available mainly focuses on the period from 2000–1600 BC, which does not allow an observation of the transition of the prevalence and consumption of herd animals over time, preceding and following this time period. Nevertheless, the data from 1600–1300 BC at Zhukaigou were included in the analysis. This allows a comparison of the data from 1600–1300 BC at Zhukaigou with those from 2000–1600 BC at this site, as well as at other sites in the analysis of taxonomic abundances. For the mortality profile analysis, the data from 1600–1300 BC at Zhukaigou were considered for comparison with those from 2000–1600 BC at other sites. Those from 2000–1600 BC at Zhukaigou were excluded because the figures recorded for this phase alone are too small to form an analysable profile. Despite this limitation, the analysis of the data mainly from 2000–1600 BC is helpful because this is the period when Shimao emerged. Focusing on this period therefore allows a fruitful discussion on how prevalent herd animals were, and how were they consumed when this large site was formed.

5.7 Results

5.7.1 Taxonomic abundances

The results are divided into the proportion of wild versus domesticated animals and the proportion of different species of domesticated animals. Both are presented in NISP% and MNI% separately.

5.7.1.1 Proportion of wild and domesticated animals

Figure 5.2 shows the NISP% and MNI% of wild versus domesticated mammals between Huoshiliang, Shimao (2012–2013 and 2011–2016), and Xinhua, Zhaimaoliang and Zhukaigou (2000–1600 BC and 1600–1300 BC). The figure reveals that both the NISP% and MNI% of domesticated mammals account for a much greater proportion than wild animals at all the sites. The NISP% and MNI% of domesticated mammals are above 90% and 70%, respectively, at all the sites.

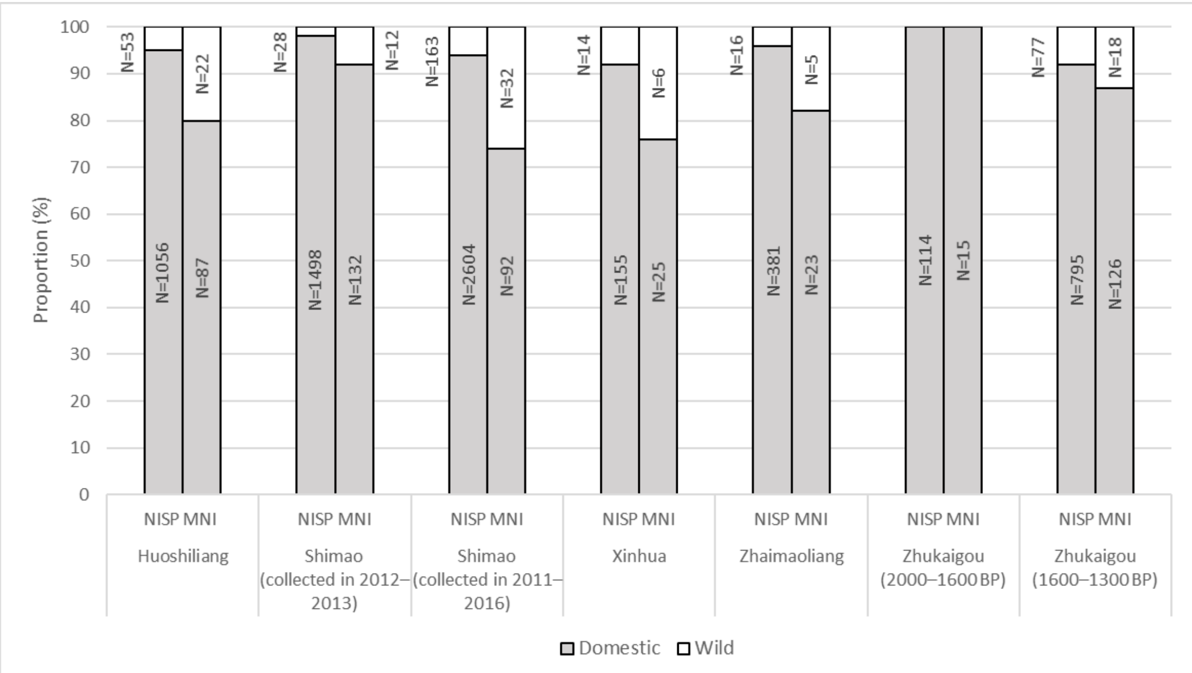


Figure 5.2. NISP% and MNI% of wild versus domesticated mammals between Huoshiliang, Shimao (collected in 2012–2013 and 2011–2016), Xinhua, Zhaimaoliang and Zhukaigou (assigned to 2000–1600 BC and 1600–1300 BC). Information comes from Table 5.1 and Appendix II.

5.7.1.2 Proportion of herd and non-herd mammals

Figure 5.3 shows the NISP% and MNI% of domesticated mammal species between Huoshiliang, Shimao (2012–2013 and 2011–2016), Xinhua, Zhaimaoliang and Zhukaigou (2000–1600 BC and 1600–1300 BC). The NISP% and MNI% are in general similar for different mammal species at all the sites, except that the proportions of pigs and dogs are greater at Xinhua. Both NISP% and MNI% show that sheep/goats make up 60–70% of the domesticated mammal species at Huoshiliang and Muzhuhzuliang. Sheep/goats and pigs have an almost equal proportion of about 35–40% each at Shimao and Zhukaigou, according to the results of MNI%. Different from the other sites, either pig or dog is the major domesticated mammal species used at Xinhua, accounting for about 80% of all domesticated mammal species.

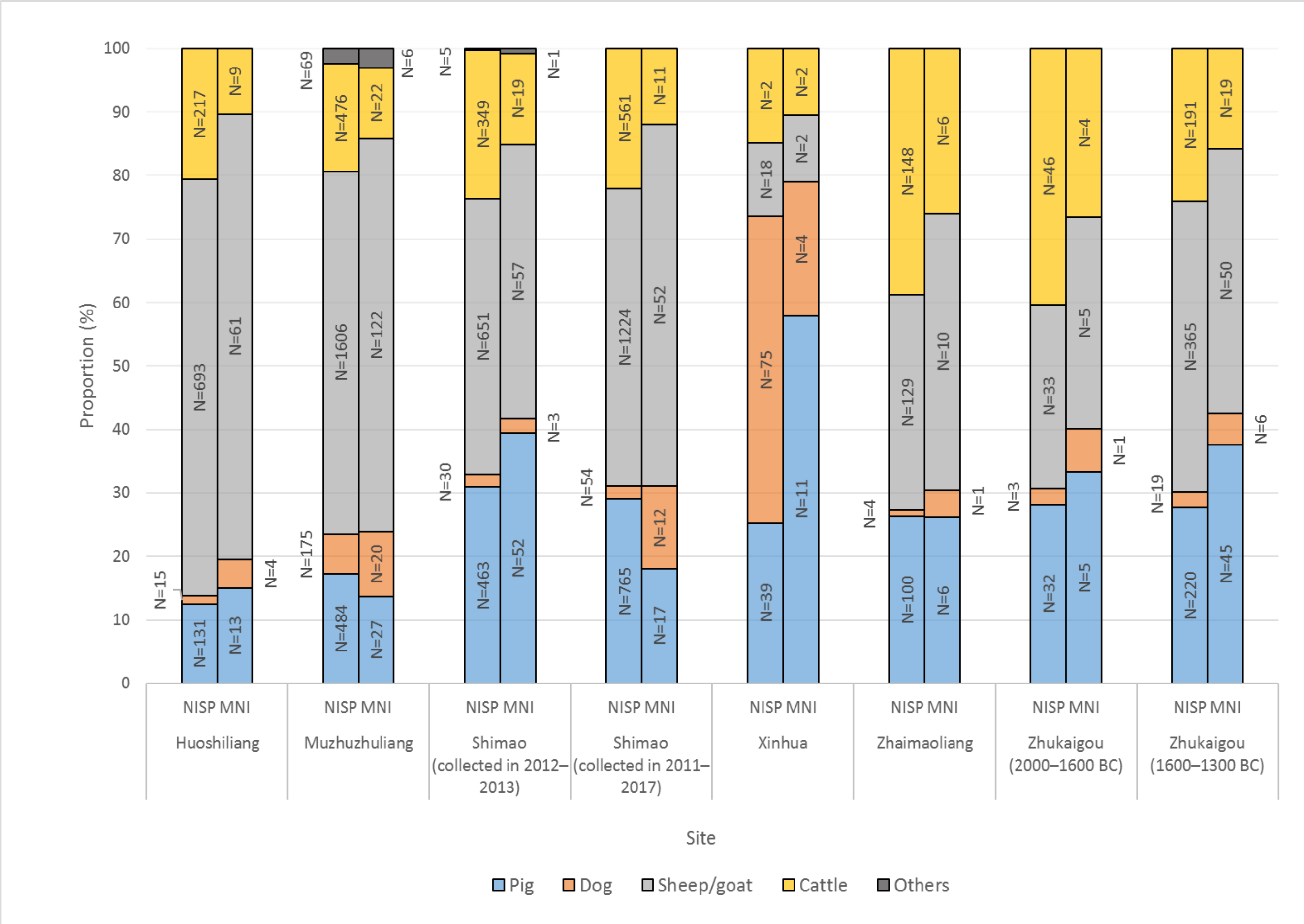


Figure 5.3. NISP% and MNI% of domesticated mammals, categorized by pigs, dog, sheep/goat, cattle and others between the Huoshiliang, Muzhuzhuliang, Shimao (collected in 2012–2013 and 2011–2016), Xinhua, Zhaimaoliang and Zhukaigou (assigned to periods 2000–1600 BC and 1600–1300 BC). Information comes from Table 5.2.

Shimao, Xinhua and Zhukaigou have a relatively higher proportion of pigs compared to Huoshiliang and Muzhuzhuliang. The MNI% shows that Xinhua probably has the highest proportion of pigs, which reaches about 60%. Xinhua also has the highest proportion of dog by both the NISP% and MNI% measures. Huoshiliang and Muzhuzhuliang, meanwhile, have a relatively higher proportion of sheep/goats than Shimao and Zhukaigou, while Xinhua has the lowest. The proportions of cattle at each site are in general equal, but Xinhua has the lowest proportion in terms of both NISP% and MNI%. Muzhuzhuliang and Shimao have very small proportions of other mammal species, including horse (*Equus caballus*) and donkey (*Equus asinus*) (Table 5.2).

5.7.2 Mortality profiles

This section presents the results of the mortality pattern analyses for pigs, sheep, goat and cattle.

5.7.2.1 Pigs

Figure 5.4 shows the mortality pattern of pigs at Huoshiliang, Shimao and Zhukaigou. The figure reveals that the age of death of the pigs at Shimao concentrates at an earlier stage than Huoshiliang, and then Zhukaigou. In contrast, the age of death of pigs at Zhukaigou spreads relatively equally across the age ranges and extends to a later stage than at the other two sites. Almost 60% of the pigs at Shimao died at stage A/B (0–8 months), while about 50% of those at Huoshiliang died at stage D (12–16 months). About 35% of the pigs at Zhukaigou died equally at stages A/B and E separately. The Chi-square test shows that frequency counts at each age stage between these sites are statistically different [$x^2(8)=18.232$, $p=0.02$]. Due to the low frequency counts in each age stage, the Fisher's exact test is also carried out and confirms that distributions are statistically different (Fisher's exact $p=0.019$).

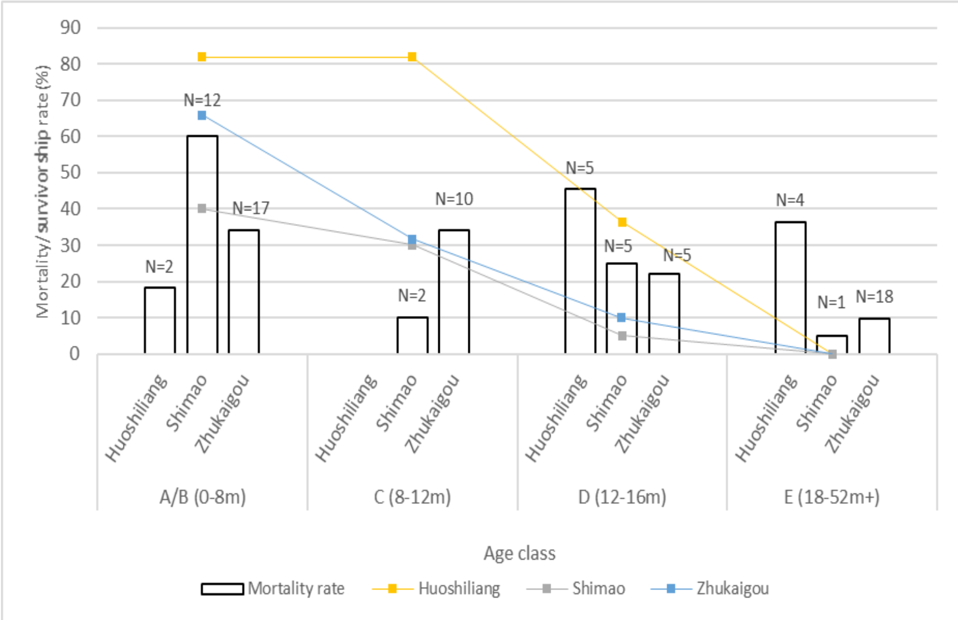


Figure 5.4. Mortality profile of pigs shown by clustered columns and survivorship curves between Huoshiliang (N=11), Shimao (N=20) and Zhukaigou (N=50). Age classes A/B (0–8 months), C (8–12 months), D (12–16 months) and E (18–52 months) follow the Simplified–A system in Lemoine et al. (2014). The lines denote the survivorship rate of pigs from each of these sites. Information comes from Table 5.3.

5.7.2.2 Sheep

Figure 5.5 shows the mortality pattern of sheep at Huoshiliang, Muzhuzhuliang, Shimao and Zhukaigou. The figure reveals that the mortality patterns of sheep are quite similar between sites, with the age of death concentrating at stage D–E (1–3 years) for all the sites. The subtle difference is that the mortality concentrates at earlier stages at Shimao and Zhukaigou than at Huoshiliang and Muzhuzhuliang. At Shimao and Zhukaigou, the mortality concentrates at stages C (6–12 months) and D–E (1–3 years), with about 60–70% of the animals dying in these age ranges. Sheep bones at Huoshiliang, meanwhile, are strongly concentrated at stage D–E (1–3 years), when almost 70% of them were killed. The mortality at Muzhuzhuliang concentrates at stages D–E (1–3 years) and F–I (3–10 years and above), with, respectively, about 45% and 30% of the sheep being killed at those ages. The Chi-square test shows that frequency counts at each age stage between these sites are statistically different [$x^2(9)=15.466$, $p=0.077$]. Due to the low frequency counts in each age stage, the Fisher's exact test is also carried out and confirms that distributions are statistically different (Fisher's exact p=0.054). The mortality pattern of sheep at Muzhuzhuliang and Shimao is shown in Figure 5.6. This graph, which shows the age classes A–I separately, illustrates that the age of death of sheep at Muzhuzhuliang also is more concentrated at stages C (6–12 months), D (1–2 years) and E (2–3 years) than it is at stages F (3–4 years) and H (6–8 years).

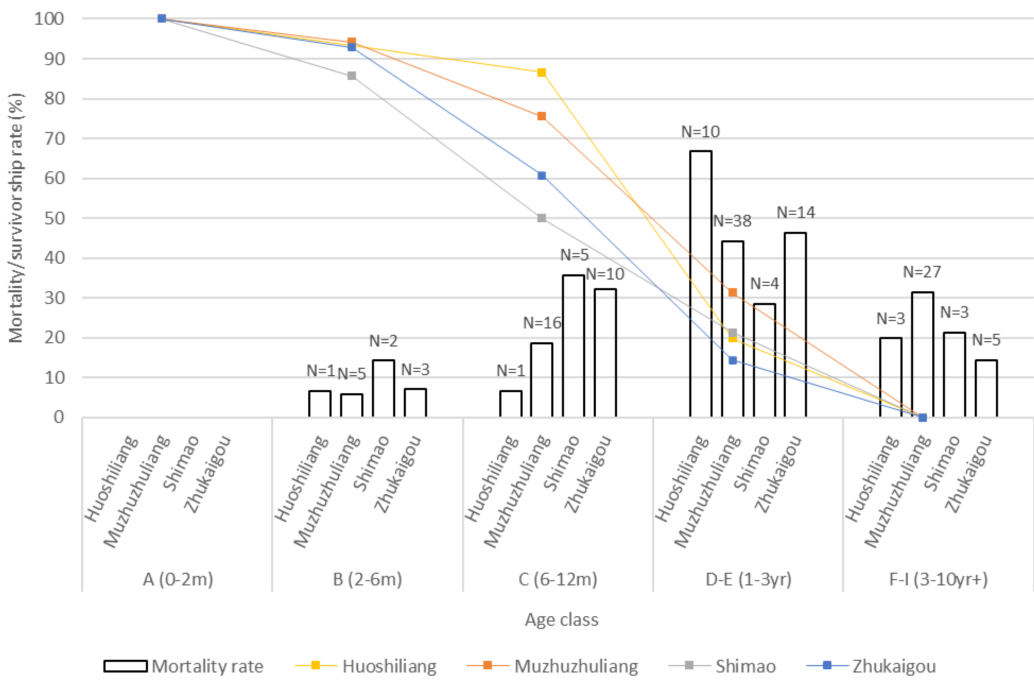


Figure 5.5. Mortality profile of sheep shown by clustered columns and survivorship curve between Huoshiliang (N=15), Muzhuzhuliang (N=86), Shimao (N= 14) and Zhukaigou (N=32). Age classes A (0–2 months), B (2–6 months), C (6–12 months), D–E (1–3 years), F–I (3–10 years and above) follow Payne's (1973) system. The lines denote the survivorship rate of sheep from each of these sites. Information comes from Table 5.4.

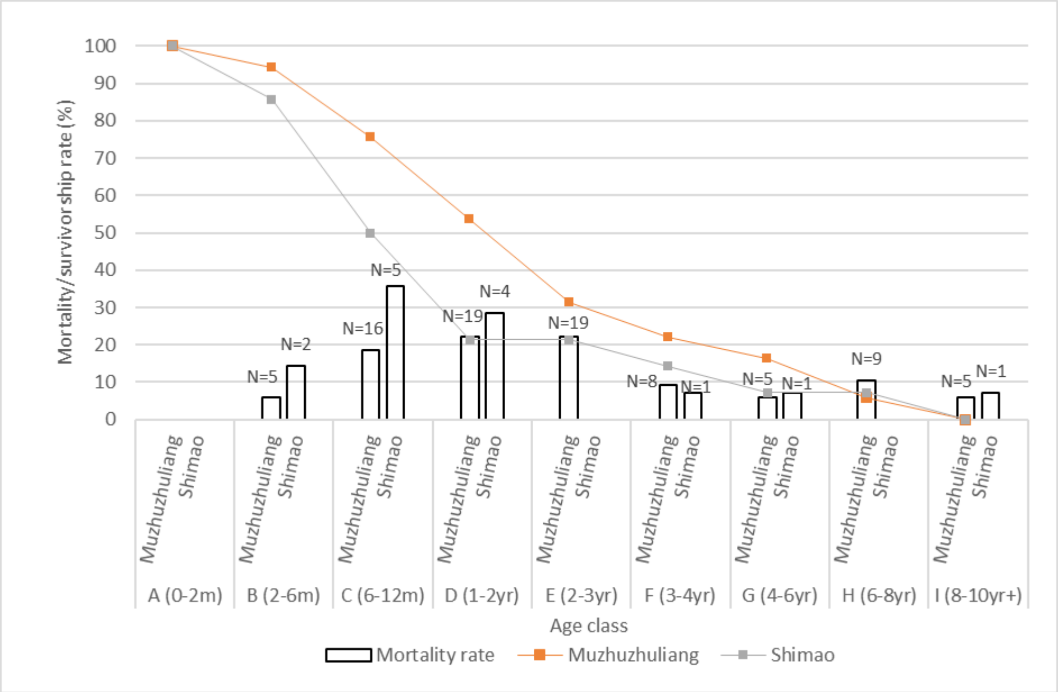


Figure 5.6. Mortality profile of sheep shown by clustered columns and survivorship curve between Muzhuzhuliang (N=86) and Shimao (N=14). Age classes A (0–2 months), B (2–6 months), C (6–12 months), D (1–2 years), E (2–3 years), F (3–4 years), G (4–6 years), H (6–8 years) and I (8–10 years and above) follow Payne's (1973) system. The lines denote the survivorship rate of sheep from each of these sites. Information comes from Table 5.4.

5.7.2.3 Goat

Figure 5.7 shows the mortality pattern of goats at Huoshiliang, Muzhuzhuliang and Shimao. The figure reveals that the mortality concentrates earlier at Huoshiliang than at Muzhuzhuliang and Shimao. Specifically, the mortality of goats at Huoshiliang concentrates at stages A to C (0–12 months), but mostly at stages D–E (1–3 years), which constitute 50% of the total. In respect to goat at both Muzhuzhuliang and Shimao, meanwhile, a small proportion of mortality concentrates at stages C (6–12 months) and D–E (1–3 years), but about 60% concentrates at stages F–I (3–10 years and above). The Chi-square test shows that frequency counts at each age stage between these sites are statistically different [$x^2(8)=30.543$, $p<0.0001$]. Due to the low frequency counts in each age stage, the Fisher's exact test is also carried out and confirms that distributions are statistically different (Fisher's exact $p<0.0001$). The mortality pattern of goat between Muzhuzhuliang and Shimao is shown in Figure 5.8. This graph, which shows the age classes A–I separately, illustrates that the age at death of goat at Muzhuzhuliang concentrates at stages E (2–3 years) and H (6–8 years), while at Shimao it concentrates at C (6–12 months), G (4–6 years) and I (8–10 years and above).

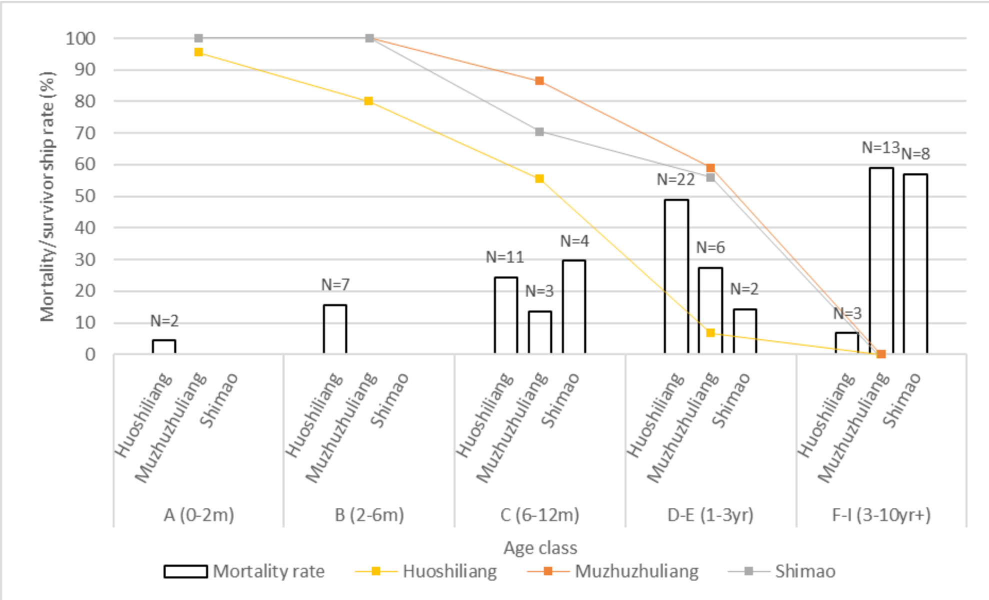


Figure 5.7. Mortality profile of goat shown by clustered columns and survivorship curve between Huoshiliang (N=45), Muzhuzhuliang (N=22) and Shimao (N=14). Age classes A (0–2 months), B (2–6 months), C (6–12 months), D–E (1–3 years), F–I (3–10 years and above) follow Payne's (1973) system. The lines denote the survivorship rate of goat from each of these sites. Information comes from Table 5.5.

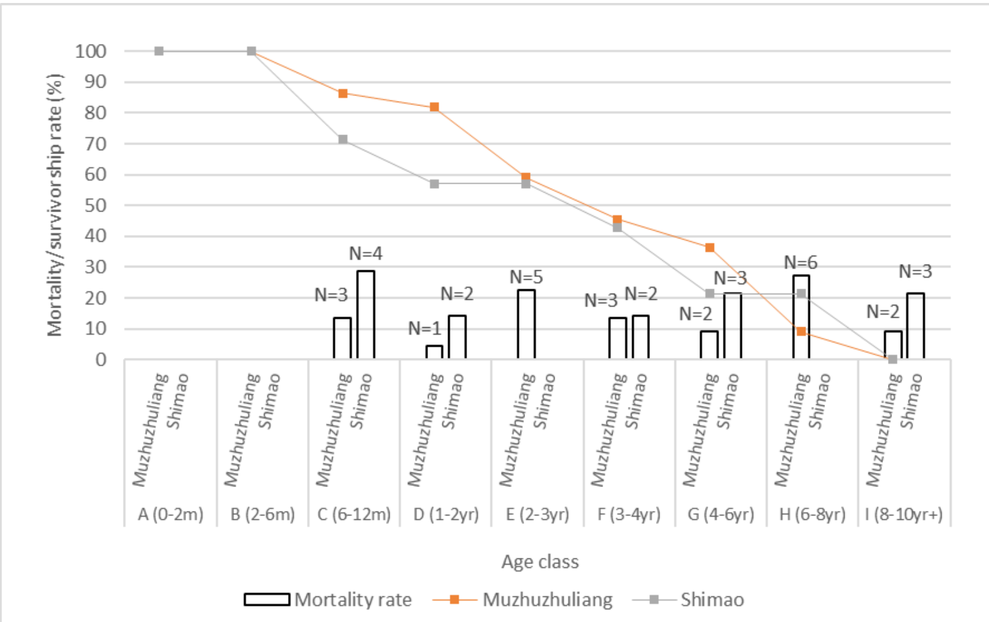


Figure 5.8. Mortality profile of goat shown by clustered columns and survivorship curve between Muzhuzhuliang (N=22) and Shimao (N=14). Age classes A (0–2 months), B (2–6 months), C (6–12 months), D

(1–2 years), E (2–3 years), F (3–4 years), G (4–6 years)–I (3–10 years and above) follow Payne's (1973) system. The lines denote the survivorship rate of goat from each of these sites. Information comes from Table 5.5.

5.7.2.4 Cattle

Figure 5.9 shows the mortality pattern of cattle at Shimao and Zhukaigou. The figure reveals that, at both these sites, cattle mostly died at the subadult stage (50% at Shimao and 60% at Zhukaigou). No cattle were found above the subadult age at Zhukaigou, but at Shimao although 50% of cattle were subadults, 40% were elderly. The Chi-square test shows that frequency counts at each age stage between these sites are statistically different [$x^2(8)=114.189$, $p<0.0001$]. Due to the low frequency counts in each age stage, the Fisher's exact test is also carried out and confirms that distributions are statistically different (Fisher's exact $p<0.0001$).

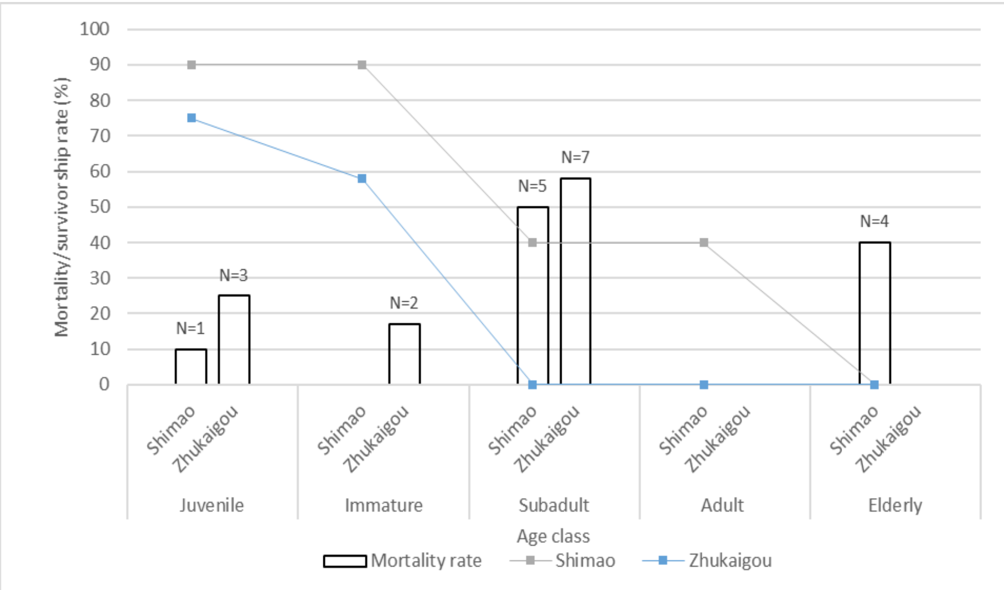


Figure 5.9. Mortality profile of cattle shown by clustered columns and survivorship curve between Shimao (N=10) and Zhukaigou (N=12). Age classes Juvenile, Immature, Subadult, Adult and Elderly follows O'Connor & Addyman's (1988) system. The lines denote the survivorship rate of cattle from each of these sites. Information comes from Table 5.6.

5.8 Discussion: differences in prevalence and consumptions of herd animals

The results of the taxonomic abundance analyses show that the NISP% and MNI% of domesticated mammals were much higher than those for wild mammals at all sites—Huoshiliang, Muzhuzhuliang, Shimao (2012–2013 and 2011–2016), and at Xinhua, Zhaimaoliang and Zhukaigou (2000–1600 BC and 1600–1300 BC). (Figure 5.2). Shimao (2012–2013) had the highest NISP% (above 90%) and MNI% (above 70%) of domesticated mammals compared to wild ones (Figure 5.2). This indicates that the domesticated mammals were already dominant in all these sites, compared with wild mammals during the period 2000–1600 BC. Wild-game hunting was therefore less common than herding in the local subsistence economy at these sites. This result is not surprising because all these sites fall firmly into the late Neolithic period. It also reveals that domesticated animals only began to replace wild ones between 2800 and 2000 BC, when wild animals still comprised a high proportion around 3000 BC: 90%, 66% and 56% at Dagujie, Wuzhuangguoliang and Yangjiesha, respectively (Hu et al., 2012, 2013).

Among domesticated mammals, sheep/goat were prominent at Huoshiliang and Muzhuzhuliang, while sheep/goat and pigs constituted almost equal proportions at Shimao, Zhaimaoliang and Zhukaigou, and pigs and dogs were prominent at Xinhua (Figure 5.3). It should be noted though that there were only a small number of samples from Xinhua, Zhaimaoliang and Zhukaigou, and thus this conclusion remains uncertain. If these sites are excluded, and we compare the patterns between Huoshiliang, Muzhuzhuliang and Shimao, which do all have higher counts, we find that the large site Shimao had a more balanced proportion between pigs and sheep/goat than the smaller sites. Among the herd animals, the proportions of sheep/goat are in general higher than cattle. This is a common phenomenon as cattle are much larger and each animal provides more meat or milk than a sheep or goat. In a mixed pastoral economy, it is also common that sheep/goats comprised the base of the economy while cattle could be highly prized (Brunson et al., 2016). This might be due to sheep and goats are easier to manage as they have fewer absolute requirements, such as sufficient water and foraging.

In terms of the mortality patterns for pigs, the age profile shows that, at Shimao, pigs were mostly slaughtered at a young age (0–8 months), at Huoshiliang at a slightly older age (12–16 months), and at Zhukaigou both at a young age (0–8 months) and at an old age (18–52 months or above) (Figure 5.4). This suggests that the slaughter patterns of pigs at Shimao and Huoshiliang were very similar. However, the pattern in Zhukaigou seems to be unusual because a large proportion died at 1.5 years old or above. The butchery of older animals may have to do with dietary preferences, but possibly due to the requirements for sturdier bones, such as for ritual purposes (scapula) or bone tools (radius) (Huang, 1996) and burial goods (mandibles) (Tian, 1988).

In terms of the results from mortality profiles, the sheep at Huoshiliang and Zhukaigou are close to the meat production model in Payne (1973), which means these sites probably mainly used sheep as meat. The pattern at Shimao is close to Vigne and Helmer's (2007) tender meat model which is based on slaughter age concentrating in stage C (6–12 months), with a smaller proportion slaughtered at stages B (2–6 months) and D (1–2 years). At Shimao, the only difference is that the mortality concentrates at stages C (6–12 months) and D (1–2 years) with a smaller proportion at stage B (2–6 months). This implies that sheep were used for both tender and non-tender meat yields (Figure 5.5 and 5.6). At Muzhuzhuliang, the pattern is in between the meat and milk mixed model and the milk and wool mixed model in Vigne and Helmer (2007), in which the former has high concentration of mortality at stage D (1–2 years) with a smaller scale at stages C (6–12 months) and E–F

(2–4 years) while the latter has a higher concentration at stage C with a balanced mortality at stages B (2–6 months), D (1–2 years), E–F (2–4 years) and G (4–6 years). The mortality at Muzhuzhuliang concentrates at 2–3 years and 3–4 years followed by C (6–12 months) and D (1–2 years), and then F (3–4 years) and H (6–8 years) (Figure 5.6), which implies that sheep were possibly used for meat along with milk and wool production.

The age profiles of goat show that they were slaughtered at an earlier stage at Huoshiliang than at Muzhuzhuliang and Shimao (Figure 5.7). At Huoshiliang, the mortality concentrates at stage D–E (1–3 years), followed by stages C (6–12 months) and then B (2–6 months), which is close to the meat and milk mixed model in Vigne and Helmer (2007). The goats at Huoshiliang were likely used for meat, but also possibly for milk production. The pattern at Muzhuzhuliang is close to the wool production model in Payne (1973), in which mortality concentrates at stages A–C (0–12 months) and H–I (6–10 years and above), whereas at Muzhuzhuliang it concentrates at stage E and H instead (Figure 5.8). This implies that the inhabitants of Muzhuzhuliang potentially used goat for wool production. This also applies to Shimao, where most of the goats died at an older age. The pattern from Muzhuzhuliang here is also similar to those from Shimao and Zhaimaoliang in Owlett et al. (2018a), with the mortality of sheep and goat concentrating at stages C–E (6 months to 3 years) with a smaller proportion at stage H (6–8 years). This is an indication of mixed production of meat, milk and wool from sheep and goats.

For cattle, the mortality at both Shimao and Zhukaigou concentrates at the subadult stage (Figure 5.9). This implies that the cattle at these sites were likely mainly used for meat. At Shimao, the slaughtered age extends to the elderly stage, which implies that the cattle were potentially also used for traction. Again, since the number of faunal remains considered are small for both sites, more evidence from a larger number of remains is needed to verify these interpretations. Although Hu et al. (2016) have suggested that the older age at which cattle died at Shimao might be associated to ploughing, so far no evidence can be observed from pathology and use of ploughing tools.

In summary, the results suggest that pigs, sheep, goat and cattle were mainly used for meat at all the sites, but sheep and goat were potentially used for milk and wool production as well . The ways of treating each of these animal species were significantly different between sites, as proved by the Chi-square test and Fisher's exact test. Huoshiliang seemed to concentrate on meat yield from sheep and goats, but potentially also used goats for milk production. Zhukaigou seemed to concentrate on meat yield from sheep and cattle. Shimao seemed to concentrate on meat yield from sheep, while goat was potentially used for wool production. Muzhuzhuliang is the only site that potentially used sheep and goat for both milk and wool production as well as for meat yield. At Shimao, pigs and sheep were slaughtered at earlier stages than at surrounding sites Huoshiliang and Zhukaigou, and Huoshiliang, Muzhuzhuliang and Zhukaigou, respectively.

The case of Xinhua is unusual since it seemed to have lacked a commitment to herd animals. The high proportion of pigs and dogs at the site might indicate a retention of the sedentary subsistence practices that were more prevalent in the Central Plains of China. In contrast, Huoshiliang, Muzhuzhuliang, Shimao and Zhukaigou were more committed to the herding that was more prevalent in the steppe area. The proportion of dogs seemed to be smaller at these sites, with a high proportion of herd animals, but pigs remained in use alongside herd animals. This is also reflected in the situation at Xinhua, where dogs seemed to be important even before herd animals were fully adopted. Both pigs and dogs were typical animals raised in the Central Plains of China, but dogs can be used as hunting aids aside from as a food source (Liu & Chen, 2012a, Chapter 4). The small proportion of dogs might be due to herd animals replacing dogs as a food source, or due to herding replacing hunting.

5.9 Conclusions

One of the major findings is that, although herd animals were increasingly used at the settlements in the south sector of the Shimao region, the choices of animal species and ways of treating and consuming herd animals differed between sites. The differences are unlikely to be associated to location because the sites are situated close to one another (Figure 5.1). Another major finding is that herd animals, especially sheep at Shimao and Muzhuzhuliang, were potentially used as secondary products—for milk and wool production—aside from meat. Specific information on sex profile as well as more evidence from larger sample sizes and organic residue analysis of pottery to identify processing of dairy products, for example, is needed to support these suggestions. These findings suggest that a new animal economy network with more common use of herd animals, involving Shimao and the surrounding sites, was formed in the south. The characteristic of this new network is that the animal subsistence economy at each site was self-sustained, with no clear evidence for centralisation at Shimao and roles of consumers and producers between Shimao and other sites, even though the practices at these sites were varied.

Combining the findings here with those from Chapters 3 and 4, we understand that a new and unique form of animal economic network was developed in the south sector of the Shimao region when settlements and population became highly concentrated in this area during the period 2000–1600 BC. The concentration of population gave Shimao an important labour force. These people may have needed good supplies of meat and secondary products to fulfil their roles in what was probably a more complex and perhaps a more stratified society. At the same time, when the larger sites such as Shimao developed more highly concentrated populations, they potentially made use of secondary products from herd animals.

Since domesticated herd animals, from our current knowledge, were new and introduced from the steppe to the region during this period, it is not impossible that these animals were brought by the herders during that shift in the loci of occupation, especially given that these animals are mobile and require transhumance that would increase the mobility of the herders. The people around Shimao adopted herd animals from further west with a more intensive exploitation and varied use at that specific time period for the purpose of supporting a more concentrated population at Shimao and more broadly the populations in the south sector of the region as a whole. This is one of the important factors that facilitated the development in the south and gave rise to Shimao. This process may also be associated with the more favourable climate in the south comparing to other areas, attracting herders to this region. The next chapter explores the adoption and modification of ceramic tripods in order to determine whether the timing of adoption and modification was also synchronous with the emergence of Shimao.

Chapter 6

The genesis and distribution of the ceramic tripods

6.1 Introduction

The findings from Chapters 3 and 4 suggested that the loci of human occupation shifted southwards, population in the south sector of the Shimao region became more concentrated during the period 2000–1600 BC. At the same time when Shimao and surrounding sites emerged, as suggested in Chapter 5, the organisation of animal economies differed between these sites. This chapter further explores whether the ceramic tripods and their modified forms became the most intensive at the same time as synchronously with the rise of Shimao. Ceramic tripods are important because they were new to, and some forms were unique in the region as pottery with flat bases dominated prior to the Longshan period. The locations where ceramic tripods have been discovered suggests that they were widely spread across the region from the Longshan period onwards around 2500 BC (Shao, 2019; Sun, 2016). In the schema outlined in Chapter 3, this would be equivalent to 2400 BC onwards (Table 3.6). Another distinctive feature of these tripods is that they are thought to have been associated with millet processing and cooking (Chen, 1996; Rawson, 2017b). The transformation of tripod shapes and forms with wider base areas suggest an intention to increase both vessel volume and contact area between the fire and the vessels.

The ceramic typology established by Neimenggu (1991) and Tian & Guo (2004) for the north sector of the region and the preliminary typology (Shao, 2019; Wang & Zhang, 2016) for the south, suggests that ceramic tripods were equally common in both the northern and southern sectors of the region. Although the general ceramic typology and transformation in the

Shimao region is well-known, the sequence of when and where different forms of tripods were first adopted and later modified, and how they were spread over space and time are not entirely clear. While the focus has long been on the Laohushan settlement groups in the Daihai Lake area, following the rediscovery of Shimao, it is worth exploring the question of whether adoption and modification of ceramic tripods became the most intensive in the south sector of the region during the period 2000–1600 BC. This chapter therefore considers the genesis and transition sequence of pottery with different shapes of base as well as different forms of ceramic tripods across the Shimao region. This is done by analysing the frequency of sites that contain each shape or form in each period and showing the distribution of different ceramic forms with illustrations over space and time.

6.2 Aims and objectives

This chapter aims to identify the changes of prevalence of different forms of pottery, especially tripods. Given that the ceramic types and forms are varied at the sites in the Shimao region, as shown in Table 6.1, the analysis of this chapter only consider the major forms for tripods, as well as different shapes of pottery base. The focus is put on providing an overview of the genesis and transformation sequence of pottery bases shapes and forms of tripods rather than exploring the detailed variation of the forms of the ceramics. Since the available data is incomplete for quantification counting of each form of tripods at individual sites, the method of counting the number of sites containing each form of tripod in each period is adopted here instead. This method was judged the best way to identify the prevalence of different forms of tripods over time.

Period (BC)	Site	Area	Base shape	Sharp-based	Flat-based	Round-based	Three-legged	Reference
2800-2400	Ashan III	South of Daqing Mountain	Flat	-	*bo, dou, guan, pen, ping, wan, weng*	-	-	Baotou, 1984, Neimenggu & Baotou, 1984, Wei & Cui, 1994
	Shamujia	South of Daqing Mountain	Flat	-	*bo, guan, pen, weng*	-	-	Baotou, 1984
	Heimaban	South of Daqing Mountain	Flat	-	*bo, guan, pen, weng*	-	-	Baotou, 1984
	Xishata	South of Daqing Mountain	Flat	-	*bo, guan*	-	-	Baotou, 1984
	Weijun	South of Daqing Mountain	Flat	-	*bo, hu, weng*	-	-	Liu, 1988
	Zhukaigou (zone VII) II	Ordos city	Sharp, flat	*ping*	*bo, dou, gang, guan, hu, pen, weng*	-	-	Tian, 1988: 486
	Xiaoshaowan	Qingshui River valley	Flat	*ping*	*bei, bo, dou, guan, pen, weng*	*ping*	-	Neimenggu, 1994: 225–234
	Zhaizita I	Qingshui River valley	Sharp, flat	*ping*	*bo, bei, dou, guan, pen, wan, weng*	-	-	Neimenggu, 1997: 280-326
	Zhaizigedan	Qingshui River valley	Flat	-	*bo, guan*	*ping*	-	Wang & Yang, 1999
	Zhuangwoping II	Qingshui River valley	Flat	-	*bo, gang, guan, pen, wan, weng*	-	-	Neimenggu, 1997: 165-178; Neimenggu, 2007
	Houchengzui II	Qingshui River valley	Flat	-	*bo, pen*	-	-	Neimenggu, 1997: 151-164
	Baicaota II	Qingshui River valley	Flat	-	*bo, guan, weng*	-	-	Neimenggu, 1994: 183–204
	Bainiyaozi III	Qingshui River valley	Flat	-	*bei, bo, guan, hu, pen, wan, weng*	-	-	Cui, 2014
	Wuzhuangguoliang	Yulin	Sharp, flat	*ping*	*bo, gang, guan, pen*	-	*jia*	Shaanxi, 2011
	Shilouloushan I	Yulin	Sharp, flat	*ping*	*gang/weng, guan*	-	-	Shaanxi, 2016; Zhang & Ding, 2016
	Zhengzemao I	Yulin	Sharp, flat, three-legged	*ping*	*bei, bo, dou, hu, guan, pen, weng, zeng*	*ping*	*jia*	Shaanxi & Yulin, 2000
	Zhaimao I	Yulin	Sharp, flat	*ping*	*bei, bo, dou, guan, pen, weng, zeng, zun*	-	-	Shaanxi, 2002
	Zhaishan	Yulin	Flat, round	-	*bei, bo, gang/weng, guan, pan, pen, ping, zeng*	*ping, weng*	*jia*	Shaanxi & Yulin, 2009

Period (BC)	Site	Area	Base shape	Sharp-based	Flat-based	Round-based	Three-legged	Reference
2400–2000	Laohushan	Dahai Lake	Flat, round, three-legged	-	*bei, dou, gang, guan, pen, weng, zeng, zun*	-	*he, jia, jia-li, yan*	Tian, 1986; Yang, 2000
	Yuanzigou	Dahai Lake	Flat, round, three-legged	-	*bei, bo, dou, gang, guan, gui* 簋 *, hu, pen, wan, weng, zeng*	-	*he, jia*	Yang, 2000
	Bancheng	Dahai Lake	Sharp, flat	-	*dou, gang, guan, pen, wan, weng*	-	*li, yan*	Yang, 2000
	Xibaiyu	Dahai Lake	Flat, three-legged	-	*bei, bo, dou, gang, guan, pen, wan, weng zun*	-	*he, jia yan*	Yang, 2000
	Damiaopo	Dahai Lake	Flat	-	*guan, pen, weng, zun*	-		Fu, 1989; Yang, 2000
	Mianpo	Dahai Lake	Flat, three-legged	-	*dou, gang, guan, pen, wan, weng*	-	*jia, yan*	Yang, 2000
	Zhukaigou I	Ordos city	Flat, three-legged	-	*guan, hu, pen, wan, zun*	-	*he, jia, li, weng, yan*	Neimenggu & Ordos, 2000
	Zhaizishang II	Qingshui River valley	Flat, three-legged	-	*guan, he, pen, weng*	-	*li*	Neimenggu, 1994: 174–182
	Erliban	Qingshui River valley	Flat, three-legged	-	*he, dou, guan, pen, weng, zun*	-	*jia, li, yan*	Neimenggu, 1994: 246–260
	Yongxingdian	Qingshui River valley	Flat, three-legged	-	*bei, bo, dou, he, guan, pen, weng, zeng, zun*	-	*jia, jia-li, li, yan*	Neimenggu, 1994: 235–245
	Xicha I	Qingshui River valley	Flat, three-legged	-	*bo, guan, pen, zun*	-	*jia, li, yan*	Neimenggu & Qingshuihe, 2001
	Zhuangwoping III	Qingshui River valley	Flat	-	*dou, guan, hu, wan, weng*	-	*jia, li*	Neimenggu, 1997: 165–178; Neimenggu, 2007
	Guandi	Qingshui River valley	Flat	-	*bo, guan, pen, weng, zun*	-		Neimenggu, 1997: 85–119
	Baicaota III	Qingshui River valley	Flat, three-legged	-	*dou, guan, pen, weng, zun*	-	*jia, li, yan*	Neimenggu, 1994: 183–204
	Zhaizita II	Qingshui River valley	Flat	-	*bei, dou, guan, pen, weng*	-	*jia, li*	Neimenggu, 1997: 280–326
	Baiyagou	Weifen River	Flat, three-legged	-	*hu, guan, weng*	-	*jia-li, li*	Shanxi, 2017
	Zhaimao II	Yulin	Flat, three-legged	-	*bei, bo, dou, guan, pan, pen, weng, zun*	-	*jia-li, li, weng*	Shaanxi, 2002
	Shilouloushan II	Yulin	Flat, round, three-legged	-	*guan, zun*	*weng*	*jia-li*	Shaanxi, 2016; Zhang & Ding, 2016

Period (BC)	Site	Area	Base shape	Sharp-based	Flat-based	Round-based	Three-legged	Reference
2000–1600	Zhukaigou II	Ordos city	Flat, three-legged	-	*dou, guan, gui* 簋 *, hu, pen, wan, zun*	-	*he, jia, li, weng, yan*	Neimenggu & Ordos, 2000
	Dakou I	Qingshui River valley	Flat, three-legged	-	*dou, guan, pen, wan, weng*	-	*jia, li*	Ji & Ma, 1979
	Bainiyaozi IV	Qingshui River valley	Flat, three-legged	-	*dou, guan, weng, zun*	-	*he, jia, li, yan*	Cui, 2014
	Bicun	Weifen River	Flat, three-legged	-	*guan*	-	*he, jia, li, weng*	Shanxi & Xingxian, 2016; Shanxi et al., 2017
	Xinhua	Yulin	Flat, three-legged	-	*Bei, bo, dou, guan, pan, pen, wan, zeng*	-	*jia, li, weng, yan*	Shaanxi & Yulin, 2005
	Zhaimaoliang	Yulin	Flat, round, three-legged	-	*bei, dou, guan, pen, weng, zeng*	*weng*	*jia, li*	Shaanxi et al., 2018
	Shimao	Yulin	Flat, three-legged	-	*guan, zun*	-	*gui* 鬶 *, jia, li, yan, weng*	Shaanxi, 2016; Shaanxi et al., 2013
	Shilouloushan III	Yulin	Flat, three-legged	-	*he*	-	*jia, li*	Shaanxi, 2016; Zhang & Ding, 2016
	Muzhuzhuliang	Yulin	Flat, three-legged	-	*dou, guan, he, pen, weng*	-	*jia, li*	Wang & Guo, 2015
	Shengedaliang	Yulin	Flat, three-legged	-	*guan, hu, pen*	-	*jia, li, weng*	Shaanxi et al., 2016
	Zhengzemao II	Yulin	Sharp, three-legged	-	*bo, guan*	-	*li*	Shaanxi & Yulin, 2000
	Wangyangpan	Yulin	Flat, three-legged	-	*bo, guan, pen, weng*	-	*jia, li, weng, yan*	Shaanxi & Shaanxi, 2011: 37-41

Period (BC)	Site	Area	Base shape	Sharp-based	Flat-based	Round-based	Three-legged	Reference
1600–1300	Yangchanggou	Dahai Lake	Flat, three-legged	-	*bo, dou, pen*	-	*jia, li, weng*	Neimenggu & Beijing, 1991
	Sandaogou	Dahai Lake	Flat, three-legged	-	*guan, pen*	-	*li, weng*	Neimenggu & Beijing, 2004
	Zhukaigou III–IV	Ordos city	Flat, three-legged	-	*dou, guan, gui* 簋 *, hu wan, zun*	-	*he, jia, li, weng, yan*	Neimenggu & Ordos, 2000
	Guandi V	Qingshui River valley	Flat, three-legged	-	*guan, pen*	-	*li, weng, yan*	Neimenggu, 1997: 85-119
	Houchengzui IV	Qingshui River valley	Flat, three-legged	-	*guan*	-	*weng*	Neimenggu, 1997: 151-164
	early Gaojiaping	Qingshui River valley	Flat, three-legged	-	*guan, pen*	-	*weng, yan*	Neimenggu, 1997: 261–271
	early Xiaomiao	Qingshui River valley	Flat, three-legged	-	*guan, pen*	-	*li, weng, yan*	Neimenggu, 1994: 272–277
	late Nanhao	Qingshui River valley	Flat, three-legged	-	*bei, guan, hu, pen, zun*	-	*guan, li, pen, weng, y*	Neimenggu, 1997: 205–224
	Qingchaota	Qingshui River valley	Flat, three-legged	-	*guan, pen, wan*	-	*yan*	Fu, 1989
	Xicha II	Qingshui River valley	Flat, three-legged	-	*bo, guan, pen*	-	*li, weng, yan*	Neimenggu & Qingshuihe, 2001
	Zhuangwoping IV	Qingshui River valley	Flat, three-legged	-	*bo, guan, pen, weng, zun*	-	*li, yan*	Neimenggu, 1997: 165-178; Neimenggu, 2007
	Dakou II	Qingshui River valley	Flat, three-legged	-	*dou, guan, pen, wan, zun*	-	*he, li, weng, yan*	Ji & Ma, 1979
	Bainiyaozi V	Qingshui River valley	Flat, three-legged	-	*bo, guan, pen, ping*	-	*li, weng*	Cui, 2014
	Zhaizita IV	Qingshui River valley	Flat, three-legged	-	*guan, pen, wan, zeng*	-	*guan, pen, li, weng, y*	Neimenggu, 1997: 280-326

Table 6.1 Variation of ceramic types and forms discovered at the sites studied in Chapter 6.

The objectives of this chapter are to:

1) collect published data for frequency of sites and sketch drawings of ceramic tripods;

2) assign the data from different sites to the four periods as set out in Chapter 3 (Table 3.6);

3) convert the data on number of sites to the percentage of sites that contain

a) pointed based, flat-based, round-based and three-legged form,

b) tripods *jia*, *li* and *yan*,

c) *gang*/*weng* in flat-based form and *weng* in round and three-legged forms;

4) present the data over the four periods with line graphs;

5) show the geographic distribution over the four periods on maps for

a) pottery in flat based and three-legged forms,

b) tripods *jia* and *li*

c) *gang*/*weng* in flat-based form and *weng* in round and three-legged forms;

6) provide illustrations of pottery in addition to objectives 5b and 5c over the four periods on maps.

6.3 Ceramic typology established in the Shimao region

The exploration of the ceramic transformation sequence in this chapter is based upon the current ceramic typology established in the Shimao region. The conventional dates for the different types of pottery discussed here were originally based on the grouping of the ceramic typology with the consideration of limited radiocarbon dates, as summarised in Chapter 2 (Table 1.2 and 2.2). Since the date ranges have been adjusted in Chapter 3 (Table 3.6), the adjusted ranges are applied here for the purposes of the comparative analysis. The accepted ceramic typology for the Shimao region suggests that pottery with a pointed base was common in the Shimao region during the Haishengbulang period before 2800 BC (Table 2.2), alongside the flat-based form that was always common throughout the prehistory in northern China (Tian & Guo, 2004; Neimenggu, 1991; Shao, 2019; Wang & Zhang, 2016). When the pointed based form of pottery began to disappear, the traditional flat-based form became dominant before the three-legged form became widely used from the Longshan period onwards, around 2400 BC.

It has been suggested that the round-based form, though less common, was a transitional form between the flat-based and three-legged forms. However, this suggestion is solely based on the limited discoveries of round-based *gang*/*weng*, a vessel with a long and straight wall, at Zhaishan and Zhaimaoliang dated between 2800 BC and 2000 BC (Figure 6.1) (Sun, 2016; Wang & Zhang, 2016). There is as yet no clear transformation sequence from the flat-based to the three-legged forms in general. In fact, the opposite sequence has been suggested from observations of the round-based pottery type *ping*, which is similar to a vase with sharp shoulders, discovered at Xiaoshawan during the Ashan III period, dated between 2800 and 2500 BC (Figure 6.1) (Wei & Cao, 1999). It has been suggested that it was transformed into the flat-based form around 2400 BC (Sun, 2016; Tian & Guo, 2004: 66) but not to the three-legged form. However, the examples of such transformation are yet too little to support this argument.

Figure 6.1. Map that shows the distribution of sites mentioned in Chapter 6.

Specifically, the currently accepted ceramic typology suggests that the tripod form *jia*, a vessel with clearly separated legs, was transformed to the transitional type *jia-li* and then *li*, a vessel with legs integrated to the body (Figure 6.2c–e) (Chen, 1996: 84–101; Shao, 2019). The *li* type has shorter and wider legs than *jia*. The later varied form with pouch-like legs has even more integrated legs, which further increases the volume of the vessel and in so doing extends the heat area. Another distinctive transformation can be observed in *gang*/*weng* (Figure 6.3). As discussed in Chapter 2, *gang* and *weng* in flat-based forms are considered together here because the terms are used interchangeably in the excavation reports., whereas the three-legged form of this type of pottery is referred to as *weng* only (Figure 6.3g–h). This type of pottery, first in flat-based form, and later appeared as a three-legged form during the period 2000–1600 BC onwards (Wang & Zhang, 2016). Some of them are in the form of an egg-shape, with a wider bottom area, similar to *li*, which have bulged legs.

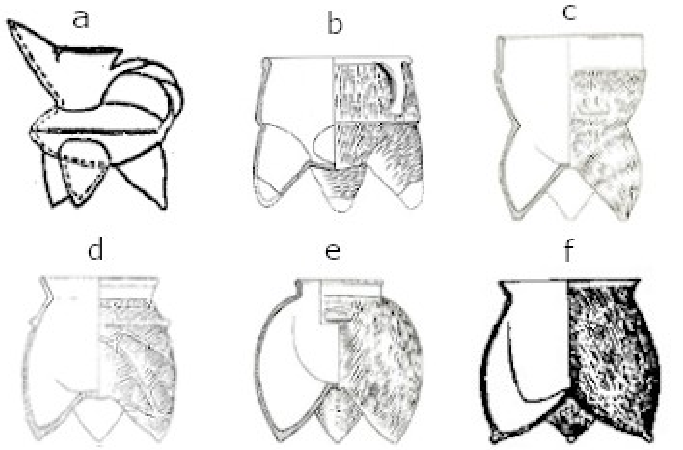


Figure 6.2. Drawings of different forms of tripods *jia* and *li*: a) *gui* from Dawenkou M47: 24, obtained from Chen (1996: 86); b) *fu*-shaped *jia* from Zhaishan F3:28, obtained from Shao (2019: 62); c) *jia* from Shimao 2012F3: 2, obtained from Sun et al. (2015: 68); d) *jia-li* from Laohushan T27: 1, obtained from Tian (1986: 46); e) *li* from Shimao 2012W2: 1, obtained from Sun et al. (2015: 66); f) *li* with budged legs from Zhaizita IV H115:1, obtained from Neimenggu (1997: 351).

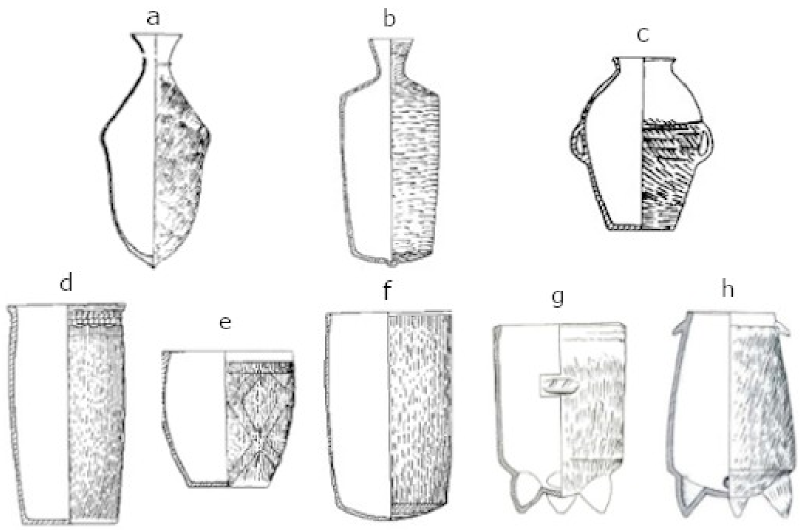


Figure 6.3. Drawings of different forms of *ping* and *gang*/*weng*: a) pointed based *ping* from Zhukaigou (zone VII) II F7004: 20, obtained from Tian (1988: 483); b) round-based *ping* from Zhaishan F1: 1, obtained from Shaanxi & Yulin (2009: 13); c) flat-based *ping* from Ashan III, obtained from Wei & Cui (1994: 131), d) flat-based *gang*/*weng* from Zhaishan F6: 1, obtained from Shaanxi & Yulin, (2009); e) flat-based *gang*/*weng* from Baicaota III F9: 1, obtained from Neimenggu (1994: 200); f) round-based *gang*/*weng* from Zhaishan F3: 21, obtained from Shaanxi & Yulin (2009: 13); g) three-legged *weng* from Shimao 2012W1: 2, obtained from Sun

et al. (2015: 66); and h) three-legged egg-shaped *weng* from Bicun H12: 1, obtained from Shanxi & Xingxian (2016: 33).

6.4 Origin and functions of ceramic tripods

Pottery with flat bases originated in northern China first used around 9,500–7,700 BC (Keally et al., 2004; Li et al., 2017). Starch residue analysis suggests that millet, along with acorns and other plants, were processed in the early pottery at Lingjing in Henan, Nanzhunagtou in Hebei, Zhuannian and Donghulin in Beijing around 10,000–7,000 years ago (Figure 6.1) (Li et al., 2017; Yang et al., 2014). At Nanzhunagtou and Cishan in Hebei, studies of husk phytoliths and biomolecular components also show evidence of the early use of millet in northern China, around 10,000 years ago (Figure 6.1) (Lu et al., 2009; Yang et al., 2012). This discovery shows a link between millet processing and cooking with pottery from the very beginning in both the lower and middle Yellow River valley, located in eastern China and the Central Plains of China. The soot marks identified on the external walls of pottery distributed in these regions also indicates that they were likely used as cooking vessels (Zhang, 2007).

The stable isotope analysis of human and animal bones, which suggests that millet appeared to become a staple food source in the Central Plains and northeast China from 5800–5000 BC (Hu et al., 2008b; Qi et al., 2004; Liu et al., 2012). Millet remains have been discovered at Miaozigou, to the northeast of the Shimao region dated to around 3500–3000 BC (Figure 6.1) (Zhang et al., 2010), and at Wuzhuangguoliang in the Shimao region around and prior to 3000 BC (Figure 6.1) (Guan et al., 2008; Sheng et al., 2021). A study based on macrofossil analysis also suggests that millet, both broomcorn and foxtail millets, dominated in the Shimao region afterwards (Sheng et al., 2018, 2021). The transformation of the shapes of ceramic base, types and forms of vessels was consistent with the developmental trajectory of millet processing and consumption. Around 6000 BC, when millet was already in use in the lower and middle Yellow and Yangzi River valleys, pottery stands were invented to support the different types of flat-based pottery, *fu*, *guan* or *pan*, that were likely used as cooking vessels, since such stands allowed space for firing below the vessels (Han, 2015a; Zhang, 2007). Around the same time, the tripod *ding*, a form that attach three legs to the above vessel types (Figure 6.4a–c), was invented in the Central Plains and spread to the lower Yellow River valley, the lower and middle Yangzi River valley and northeast China (Han, 2015a). From 5000 BC onwards, the flat-based form with stands were replaced by the *ding* tripod at most of the sites in these regions (Zhang, 2007). This is synchronous with when millet became dominant in the Central Plains and northeast China. The consistent development between pottery transformation and millet cultivation suggests that the three-legged form was likely invented intentionally for millet cooking. The later invention of the *zeng* (steam rack) vessel, a steamer-like object placed on top of the *ding*, as well as the *yan* (steamer) vessel, shows that the three-legged form was also used for steaming (Zhang, 2007) (Figure 6.4d–e), which is also applicable to millet preparation. Aside from the cooking function, the tripods such as *weng* were likely used as storage vessels, and the elaborated *jia* and *weng* tripods were used as drinking and ritual serving vessels for alcohol (Underhill, 2018).

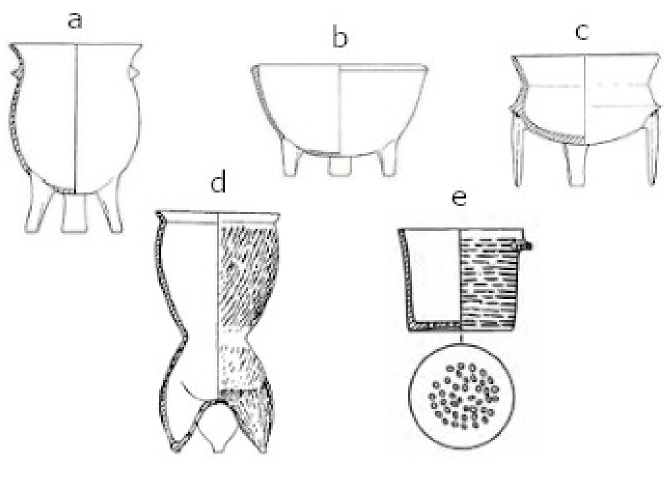


Figure 6.4. Drawings of the initial forms of ceramic tripods from eastern China and Central Plains: a) three-legged *guan*-shaped *ding* from Jiahu H198: 3, obtained from Han (2015: 70); b) three-legged *pan*-shaped *ding*

from Jiahu H240: 1, obtained from Han (2015: 70); c) three-legged *fu*-shaped *ding* from Lingkou T6⑤: 22, obtained from Han (2015: 71); d) *yan* from Hougang H50: 8, obtained from Yang & Xu (1985: 55); e) *zeng* from Miaodigou II F1: 42, obtained from Li (2017: 28).

By 2800 BC, millet was already in use and likely became prominent in human and animal diets.It remains common during the period 2000–1600 BC at Dakou, Muzhuzhuliang, Shimao, Shengedaliang, Xinhua Zhaimaoliang and Zhukaigou (Figure 6.1), as inferred by isotopic studies (Atahan et al., 2014; Chen et al., 2015b, 2017b; Zhang et al., 2010). Although millet was already used around 2800 BC, ceramic tripods were only spread across the Shimao region around 2500 BC. It is worth to explore why ceramic tripods were adopted at this point of time, but not earlier when millet was already commonly used.

6.5 The missing link between north and south sectors of the Shimao region

Although a few *ding* dating to 3500–3000 BC have been discovered at Shihushan in the Daihai Lake area of the Shimao region (Figure 6.1) (Yang, 2000), *ding* were not widespread in the area, and to the south, afterwards. Instead, the flat-based form remained a dominant type until 2400 BC, when the three-legged form became widespread across the region. The common three-legged forms used in the region included *jia, jia-li, li and weng*. These are the major ceramic types whose forms possibly transformed over time as discussed in Section 6.3. The *jia* and *li* forms might have been used for millet cooking because the prototypes of these tripods, *ding*, as discussed in Section 6.4, were likely first used for millet cooking as early as 10,000 years ago in northern China. Although the tripods *jia*, *li* and yan were likely used as cooking vessels, it is important to note that tripod *weng* may have been served as storage and alcohol vessels. Despite that, all the major tripods including *jia*, *li*, *yan* and *weng* are considered in the analysis, regardless the function of the vessels. The purpose of the analysis here is to identify the changes of prevalence of different forms of ceramic tripods over space and time in general, but not only considering the vessels that were served for millet processing and cooking.

The existing discussion of ceramic tripods only focused on the ceramic tripods discovered at the Laohushan settlement group in Daihai Lake area. Whereas the situation in the south sector of the region where Shimao emerged has long been a gap. Before the rediscovery of Shimao, the Daihai Lake area was thought to be the area where *jia* and the transitional type *jia-li* were invented and spread southwards across the region (Tian & Guo, 2004). However, this needs to be reconsidered since more evidence now shows that *jia* vessels already existed in the south sector of the region during the period 2800–2400 BC, as at Bicun, Shimao, Wuzhuangguoliang and Zhengzemao I (Shao, 2019; Shaanxi, 2016a; Shaanxi & Yulin, 2000, Wang & Zhang, 2016). As more discoveries of pottery from the sites in the south have become available in recent years, we now understand that the ceramic tripods also existed in the Yulin and Weifen River valley areas as well as the Daihai Lake area. The modified forms of *li* and *weng* with bulged bottom or leg areas, therefore, were also potentially invented or modified locally in the south, rather than spreading from the north. However, we do not know how prevalent these tripods were, or how were they distributed among sites in both the north and the south.

Because of this missing link between the north and south, our understanding of the transformation sequence of different forms of tripods across the region remains incomplete. We therefore do not know where and when these tripods were first adopted and how they spread across the region. For this reason, the recently published data alongside those published previously are considered in order to provide a more completed studies for the transformation sequence of the use of pottery across the region, on top of the current established ceramic typology. The general transformation of different base shapes. including pointed based, round-based, flat-based and three-legged forms are considered. The major forms, *gang*/*weng*, as well as *jia* and *li*, are explored separately as these are the forms that potentially experienced transformation.

6.6 Materials and methods

6.6.1 Materials and data collection

The data for illustrations, frequency analysis and distribution of pottery were collected from the Inner Mongolia archaeological reports (e.g. Neimenggu, 1994, 1997; Yang, 2000), investigations, brief and detailed excavation reports for individual sites (e.g. Yang, 2000; Tian, 1986), and journal papers with information relevant to the sites (e.g. Baotou, 1984; Fu, 1989; Sun, 2000; Wei & Cai, 1999; Wei & Wang, 1990). Data for Shimao and the surrounding sites were mainly sourced from brief and detailed excavation reports for individual sites (e.g. Shaanxi, 2002, 2005; Wang & Guo, 2015), the culture relics newspaper *Zhongguo Wenwubao* (e.g. Jia, 2015). The data for frequency analysis and distribution of the different forms of pottery come from 44 sites. The full list of sites and raw data considered in each period and sources is listed in Table 6.2. The conversion of these data to percentages is shown in Table 6.3. The additional illustrations of pottery include the sketch drawings of *gang*/*weng* from 15 sites, and *jia* and *li* from 24 sites. The full list of sites considered in each period and sources is listed in Table 6.4.

Period (BC)	Site	Area	Sharp-based form	Round-based form	Flat-based form only	Three-legged form	Flat-based *gang/weng*	Round-based *gang/weng*	Three-legged *weng*	*Yan*	*Jia*	*Li*	References
													
2800-2400	Ashan III	South of Daqing Mountain	N	N	Y	N	Y	N	N	N	N	N	Baotou, 1984; Neimenggu & Baotou, 1984; Wei & Cui, 1994
	Shamujia	South of Daqing Mountain	N	N	Y	N	Y	N	N	N	N	N	Baotou, 1984
	Heimaban	South of Daqing Mountain	N	N	Y	N	Y	N	N	N	N	N	Baotou, 1984
	Xishata	South of Daqing Mountain	N	N	Y	N	N	N	N	N	N	N	Baotou, 1984
	Weijun	South of Daqing Mountain	N	N	Y	N	Y	N	N	N	N	N	Liu, 1988
	Zhukaigou II (zone VII)	Ordos city	Y	N	Y	N	Y	N	N	N	N	N	Tian, 1988: 486
	Xiaoshaowan	Qingshui River valley	N	Y	Y	N	N	N	N	N	N	N	Neimenggu, 1994: 225–234
	Zhaizita I	Qingshui River valley	Y	N	Y	N	Y	N	N	N	N	N	Neimenggu, 1997: 280–326
	Zhaizigedan	Qingshui River valley	N	Y	Y	N	N	N	N	N	N	N	Wang & Yang, 1999
	Zhuangwoping II	Qingshui River valley	N	N	Y	N	Y	N	N	N	N	N	Neimenggu, 1997: 165–178; Neimenggu, 2007
	Houchengzui II	Qingshui River valley	N	N	Y	N	N	N	N	N	N	N	Neimenggu, 1997: 151–164
	Baicaota II	Qingshui River valley	N	N	Y	N	Y	N	N	N	N	N	Neimenggu, 1994: 183–204
	Bainiyaozi III	Qingshui River valley	N	N	Y	N	Y	N	N	N	N	N	Cui, 2014
	Wuzhuangguoliang	Yulin	Y	N	N	Y	Y	N	N	N	Y	N	Shaanxi, 2011
	Shiluoluoshan I	Yulin	Y	N	Y	N	Y	N	N	N	N	N	Shaanxi, 2016; Zhang & Ding, 2016
	Zhengzemao I	Yulin	Y	Y	N	Y	Y	N	N	N	Y	N	Shaanxi & Yulin, 2000
	Zhaimao I	Yulin	Y	N	Y	N	Y	N	N	N	N	N	Shaanxi, 2002
	Zhaishan	Yulin	N	Y	N	Y	Y	Y	N	N	Y	N	Shaanxi & Yulin, 2009

Period (BC)	Site	Area	Sharp-based form 	Round-based form 	Flat-based form only 	Three-legged form 	Flat-based *gang/weng* 	Round-based *gang/weng* 	Three-legged *weng* 	*Yan* 	*Jia* 	*Li* 	References
2400–2000	Laohushan	Daihai Lake	N	N	N	Y	Y	N	N	Y	Y	Y	Tian, 1986; Yang, 2000
	Yuanzigou	Daihai Lake	N	N	N	Y	Y	N	N	N	Y	N	Yang, 2000
	Bancheng	Daihai Lake	N	N	N	Y	Y	N	N	Y	N	Y	Yang, 2000
	Xibaiyu	Daihai Lake	N	N	N	Y	Y	N	N	Y	Y	N	Yang, 2000
	Damiaopo	Daihai Lake	N	N	Y	N	Y	N	N	N	N	N	Fu, 1989; Yang, 2000
	Mianpo	Daihai Lake	N	N	N	Y	Y	N	N	Y	Y	N	Yang, 2000
	Zhukaigou I	Ordos city	N	N	N	Y	N	N	Y	Y	Y	Y	Neimenggu & Ordos, 2000
	Zhaizishang II	Qingshui River valley	N	N	N	Y	Y	N	N	N	N	Y	Neimenggu, 1994: 174–182
	Erliban	Qingshui River valley	N	N	N	Y	Y	N	N	Y	Y	Y	Neimenggu, 1994: 246–260
	Yongxingdian	Qingshui River valley	N	N	N	Y	Y	N	N	Y	Y	Y	Neimenggu, 1994: 235–245
	Xicha I	Qingshui River valley	N	N	N	Y	N	N	N	Y	Y	Y	Neimenggu & Qingshuihe, 2001
	Zhuangwoping III	Qingshui River valley	N	N	N	Y	Y	N	N	N	Y	Y	Neimenggu, 1997: 165–178; Neimenggu, 2007
	Guandi IV	Qingshui River valley	N	N	Y	N	Y	N	N	N	N	N	Neimenggu, 1997: 85–119
	Baicaota III	Qingshui River valley	N	N	Y	Y	Y	N	N	Y	Y	Y	Neimenggu, 1994: 183–204
	Baiyagou	Weifen River valley	N	N	N	Y	Y	N	N	N	N	Y	Shanxi, 2017
	Zhaizita II	Yulin	N	N	N	Y	Y	N	N	N	Y	Y	Neimenggu, 1997: 280–326
	Zhaimao II	Yulin	N	N	N	Y	Y	N	Y	N	N	N	Shaanxi, 2002
	Shiluoluoshan II	Yulin	N	Y	N	Y	N	Y	N	N	N	Y	Shaanxi, 2016; Zhang & Ding, 2016

Period (BC)	Site	Area	Sharp-based form	Round-based form	Flat-based form only	Three-legged form	Flat-based *gang/weng*	Round-based *gang/weng*	Three-legged *weng*	*Yan*	*Jia*	*Li*	References
													
2000–1600	Zhukaigou II	Ordos city	N	N	N	Y	N	N	Y	Y	Y	Y	Neimenggu, 2000
	Dakou I	Qingshui River valley	N	N	N	Y	Y	N	N	N	Y	Y	Ji & Ma, 1979
	Bainiyaozi IV	Qingshui River valley	N	N	N	Y	Y	N	N	Y	Y	Y	Cui, 2014
	Bicun	Weifen River valley	N	N	N	Y	N	N	Y	N	Y	Y	Shanxi & Xingxian, 2016; Shanxi et al. 2017
	Xinhua	Yulin	N	N	N	Y	N	N	Y	Y	Y	Y	Shaanxi & Yulin, 2005
	Zhaimaoliang	Yulin	N	Y	N	Y	N	Y	N	N	Y	Y	Shaanxi et al., 2018
	Shimao	Yulin	N	N	N	Y	N	N	Y	Y	Y	Y	Shaanxi, 2016; Shaanxi et al., 2013
	Shiluoluoshan III	Yulin	N	N	N	Y	N	N	N	N	Y	Y	Shaanxi, 2016; Zhang & Ding, 2016
	Muzhuzhuliang	Yulin	N	N	N	Y	Y	N	N	N	Y	Y	Wang & Guo, 2015
	Shengedaliang	Yulin	N	N	N	Y	N	N	Y	N	Y	Y	Guo et al., 2016
	Zhengzemao II	Yulin	N	N	N	Y	N	N	N	N	N	Y	Shaanxi & Yulin, 2000
	Wangyangpan	Yulin	N	N	N	Y	Y	N	Y	Y	Y	Y	Shaanxi & Shaanxi, 2011: 37–41

Period (BC)	Site	Area	Sharp-based form 	Round-based form 	Flat-based form only 	Three-legged form 	Flat-based *gang/weng* 	Round-based *gang/weng* 	Three-legged *weng* 	*Yan* 	*Jia* 	*Li* 	References
1600–1300	Yangchanggou	Daihai Lake	N	N	N	Y	N	N	Y	Y	N	Y	Neimenggu & Beijing, 1991
	Sandaogou	Daihai Lake	N	N	N	Y	N	N	Y	N	N	Y	Neimenggu & Beijing, 2004
	Zhukaigou III/IV	Ordos city	N	N	N	Y	N	N	Y	Y	Y	Y	Neimenggu & Ordos, 2000
	Guandi V	Qingshui River valley	N	N	N	Y	N	N	Y	Y	N	Y	Neimenggu, 1997: 85–119
	Houchengzui IV	Qingshui River valley	N	N	N	Y	N	N	Y	N	N	N	Neimenggu, 1997: 151–164
	Early Gaojiaping	Qingshui River valley	N	N	N	Y	N	N	Y	Y	N	N	Neimenggu, 1997: 261–271
	Early Xiaomiao	Qingshui River valley	N	N	N	Y	N	N	Y	Y	N	Y	Neimenggu, 1997: 272–277
	Late Nanhao	Qingshui River valley	N	N	N	Y	N	N	Y	Y	N	Y	Neimenggu, 1997: 205–224
	Qingcaota	Qingshui River valley	N	N	N	Y	N	N	N	Y	N	N	Fu, 1989
	Xicha II	Qingshui River valley	N	N	N	Y	N	N	Y	Y	N	Y	Neimenggu & Qingshuihe, 2001
	Zhuangwoping IV	Qingshui River valley	N	N	N	Y	Y	N	N	Y	N	Y	Neimenggu, 1997: 165–178; Neimenggu, 2007
	Dakou II	Qingshui River valley	N	N	N	Y	N	N	Y	Y	N	Y	Ji & Ma, 1979
	Bainiyaozi V	Qingshui River valley	N	N	N	Y	N	N	Y	N	N	Y	Cui, 2014
	Zhaizita IV	Qingshui River valley	N	N	N	Y	N	N	N	Y	N	Y	Neimenggu, 1997: 280–326

Table 6.2. Existence of different shapes of base and forms of ceramic from the sites studied in Chapter 6. Pointed based form (*ping*) from Yangjiesha AH19: 52 (Shaanxi & Yulin 2011, plate 7); round-based form and *gang*/*weng* from Zhaimaoliang (Shaanxi et al., 2018); flat-based form and *gang*/*weng* from Shiluoluoshan H91:18 (Shaanxi, 2016b: 9); *guan* from Shiluoluoshan H86, 1 (Shaanxi, 2016b: 9); three-legged *weng* from Shimao, Houyangwan W1 (Shaanxi, 2016a: 62); *yan* from Shimao, Hujiawa F3 (Shaanxi, 2016a: 65); *jia* from Shimao, Hujiawa F3 (Shaanxi, 2016a: 64) and *li* from Shimao, Houyangwan W2 (Shaanxi, 2016a: 60).

6.6.2 Analytical process

The frequency analysis is separated into three parts. The first part considers the different shapes of base of the pottery: pointed based, round-based, flat-based and three-legged. The second considers the tripods: *jia* and *li*. The third considers *gang*/*weng* in flat-based and round-based forms and *weng* in three-legged form. In each of these parts. The existence of each form of pottery is recorded (i.e. whether they are present or absent in each site) and listed Table 6.2. The information was then converted to numerical data of numbers at the sites and thereby percentages of sites that contain each of these forms of pottery in each period. These are listed in Table 6.3. The percentages from each part were then presented in line graphs generated in Microsoft Excel. It is noted that the quantification of each form of pottery at each site is not considered here due to data limitations.

Period (BC)	Sharp-based		Round-based		Flat-based only		Three-legged		*Guan*		*Gang/weng*		Flat-based *gang/weng*		Round-based *gang/weng*		Three-legged *gang/weng*		*Yan*		*Jia*		*Li*	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
2800–2400	6	32	4	21	15	79	3	16	16	84	15	79	14	74	1	5	0	0	0	0	3	16	0	0
2400–2000	0	0	1	5	5	26	17	89	18	95	17	89	15	79	1	5	2	11	7	37	12	63	14	74
2000–1600	0	0	1	8	0	0	12	100	11	92	9	75	4	33	1	8	6	50	5	42	11	92	12	100
1600–1300	0	0	0	0	0	0	12	100	12	100	7	58	1	8	0	0	10	83	10	83	1	8	11	92

Table 6.3. Raw data and conversion to percentages considered in the frequency analysis in Chapter 6.

The geographic distribution of pottery on maps covers the same data used in the frequency analysis, which is also separated into three parts. The first part shows the distribution of sites that contain the flat-based pottery only, versus sites that contain both flat-based and ceramic tripods. The reason for doing this is that sites contain three-legged form always also contain flat-based form and no sites contain three-legged form alone. The second shows the distribution of sites that contain the *gang*/*weng* in flat-based form only, or three-legged form only, both of them or neither of them. The third shows the distribution of sites that contain the tripod form *jia* only, *li* only, both of them and neither of them. By using the data from Table 6.2, these sites were plotted on three different maps using ArcMap 10.8 with coordinates of the sites that are listed in the major database in Table 1.1.

In addition to the distribution of tripods, their illustrations are presented on maps in two parts. One for *gang*/*weng* in flat-based form as well as *weng* in three-legged form and another for the *jia* and *li* tripods. The collected sketch drawings listed in Table 6.4 were edited in GIMP 2.10.24 with the application of ArcMap 10.8 where the base maps were generated. It should be noted that the illustrations of pottery were selected based on the sketch drawings available in published materials, and therefore do not represent a full collection of the various forms present at the individual sites. Thus, the study only presents an overview of the genesis and transformation sequence of the major forms of tripods over space and time.

Period (BC)	Site	Area	Ilustraions of pottery	References
2800–2400	Zhukaigou II (zone VII)	Ordos city	Flat-based *gang* (H7008: 6)	Tian, 1988: 486
	Xiaoshawan	Qingshui River valley	Flat-based *weng* (F4: 9)	Neimenggu, 1994: 228
	Wuzhuangguoliang	Yulin	Fu-shaped *jia*	Shao, 2019: 65
	Zhaishan	Yulin	Flat-based *gang* (F6: 1) and round -based *gang* (F3: 21)	Shao, 2019: 62
2400–2000	Laohushan	Daihai Lake	Flat-based *gang* (F7: 1) and *weng* (F2: 2), *fu* -shaped *jia* (T103③: 5) and *jia* -*li* (T27: 1)	Tian, 1986: 40, 44, 46
	Bancheng	Daihai Lake	*Fu* -shaped *jia* (BF7: 11), *jia* -*li* (BF9: 2)	Wei & Cui, 1994: 133
	Zhukaigou I	Ordos city	Three-legged *weng* (H2058: 1), *li* (W2002: 1)	Tian, 1988: 305
	Erliban	Qingshui River valley	*Jia* (T1④(2)	Neimenggu, 1994: 253
	Xicha I	Qingshui River valley	*Li* (H60: 1)	Neimenggu & Qingshuihe, 2001: 62
	Yongxingdian	Qingshui River valley	*Jia* (H35: 1), *li* (H14: 1)	Neimenggu, 1994: 238-239
	Zhuangwoping III	Qingshui River valley	*Li* (H1: 2)	Neimenggu, 1997: 172
	Baicaota III	Qingshui River valley	Flat-based *weng* (F8: 1) , *li* (F8: 21)	Neimenggu , 1994: 198, 200
	Baiyagou	Weifen River valley	*Li* (F4: 1)	Shanxi, 2017: 13
	Zhaimao II	Yulin	Three-legged *weng* (AH60: 18), *li* (AT3010②: 3, AH9: 4)	Shaanxi, 2002: 11, 13
2000–1600	Zhukaigou II	Ordos city	Three-legged *weng* (W2006: 1), *jia* (W2003: 1), *li* (M1060: 3)	Tian, 1988: 308–309
	Dakou I	Qingshui River valley	*Jia* (DKT1,2⑥: 2)	Ji & Ma, 1979: 309
	Bicun	Weifen River valley	Three-legged *weng* (H12:1), egg-shaped *weng* (H12:2)	Shanxi & Xingxian, 2016: 33
	Xinhua	Yulin	Three-legged *weng* (99W1: 1, 99H155: 1), *jia* (96H18③: 20), *li* (99H150: 1)	Shannxi & Yulin, 2005: 140, 147, 153, 155
	Zhaimaoliang	Yulin	Round-based *weng* (F24: 4), *li* (F29: 3, K1: 17)	Shaanxi et al., 2018: 11–12
	Shimao	Yulin	Three-legged *weng* (2012W1: 2), *jia* (2012F3: 2), *li* (2012W2: 1, 2012F3: 1)	Sun et al., 2015: 66, 68
	Muzhuzhuliang	Yulin	*Li* (H80③: 22)	Wang & Guo, 2015: 7
	Shengedaliang	Yulin	*Jia* (M7: 1)	Shaanxi et al., 2016: 42
	Zhengzemao II	Yulin	*Li* (G2②: 4)	Shannxi and Yulin, 2000: 24
1600–1300	Yangchanggou	Daihai Lake	Three-legged *weng* (H1: 1), li (F3: 3)	Neimenggu & Beijing, 1991: 12
	Sandaogou	Daihai Lake	*Li* (T102②:1)	Neimenggu & Beijing, 2004: 17
	Zhukaigou III/IV	Ordos city	Three-legged *weng* (W2009: 2, QH91: 1), *jia* , *li* (QH79: 4, M3024: 2)	Tian, 1988: 313, 315, 320; Wei & Cui, 1994: 137
	Guandi V	Qingshui River valley	*Li* (F3: 2)	Neimenggu, 1997: 116
	Houchengzui IV	Qingshui River valley	Three-legged *weng* (H11: 1)	Neimenggu, 1997: 162
	Early Gaojiaping	Qingshui River valley	Three-legged *weng* (90ZHGF4: 4)	Neimenggu, 1994: 265
	Late Nanhao	Qingshui River valley	*Li* (IH49: 1)	Neimenggu, 1994: 220
	Dakou II	Qingshui River valley	Three-legged *weng* (DKF1: 1)	Ji & Ma, 1979: 317
	Zhaizita IV	Qingshui River valley	Three-legged *weng* (QH9: 1, 2), li (H115: 1)	Neimenggu, 1997: 315–316

Table 6.4. Sources of pottery sketch drawings considered in Chapter 6.

6.7 Results

The results are presented in two parts: frequency analysis and spatiotemporal distribution of pottery forms.

6.7.1 Frequency analysis

This section is separated into four parts: the general shapes of ceramic base, tripods *jia* and *li*, and *gang*/*weng* with different shapes of base.

6.7.1.1 Shapes of ceramic base

The frequency of sites that contain pottery with pointed based, round-based, flat-based and three-legged forms over the four periods is shown in Figure 6.5. This illustrates that 30% of sites had pottery with a pointed based form assigned to the period 2800–2400 BC. However. no sites had pointed based pottery dated from 2400–2000 BC onwards. Over 80% of sites had pottery in a flat-based form without three-legged forms during the period 2800–2400 BC but this was true of less than 30% of the pottery during the next period, 2400–2000 BC. No sites had flat-based forms without three-legged forms from 2000–1600 BC onwards. Conversely, while about 10% of sites had both flat-based and three-legged forms assigned to the period 2800–2400 BC, about 90% had such forms assigned to the next period 2400–2000 BC. All the sites had three-legged forms assigned to 2000–1600 BC onwards. The conjunction of pointed and round-based forms within sites was rare overall, but relatively more common during the period 2800–2400 BC.

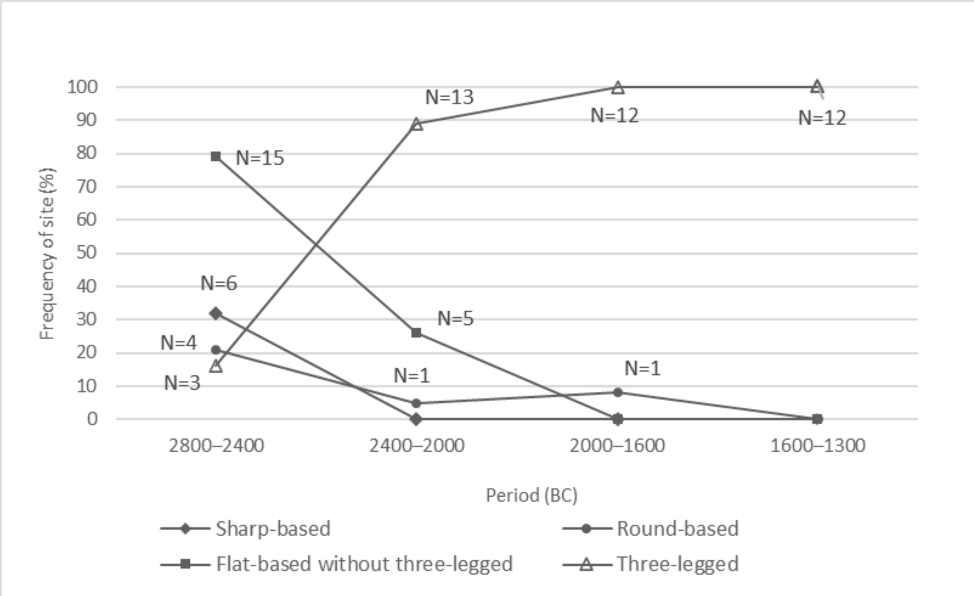


Figure 6.5. Percentages of frequency of sites discovered with pottery in pointed based, round-based, flat-based and three-legged forms in the Shimao region over the four periods from 2800–1300 BC. Period 1: N=18, period 2: N=19, period 3: N=12, period 4: N=14. Information comes from Table 6.2 and 6.3.

6.7.1.2 Tripods *jia*, *li* and *yan*

The number of sites that contain the major ceramic type *jia* and *li* over the four periods is shown in Figure 6.6. This illustrates that while *jia*, *li* and *yan* were all uncommon during the period 2800–2400 BC, the number of sites containing these types dramatically increased to around 40–60% during the period 2400–2000 BC. By the 2000–1600 BC period more than 90% of sites had *jia* and *li*, but still only 40% had *yan*. During 1600–1300 BC period, meanwhile, 90% of the sites continued to exhibit *li* whereas only 10% of the sites had *jia*. However, sites with *yan* increased to above 80% during this period

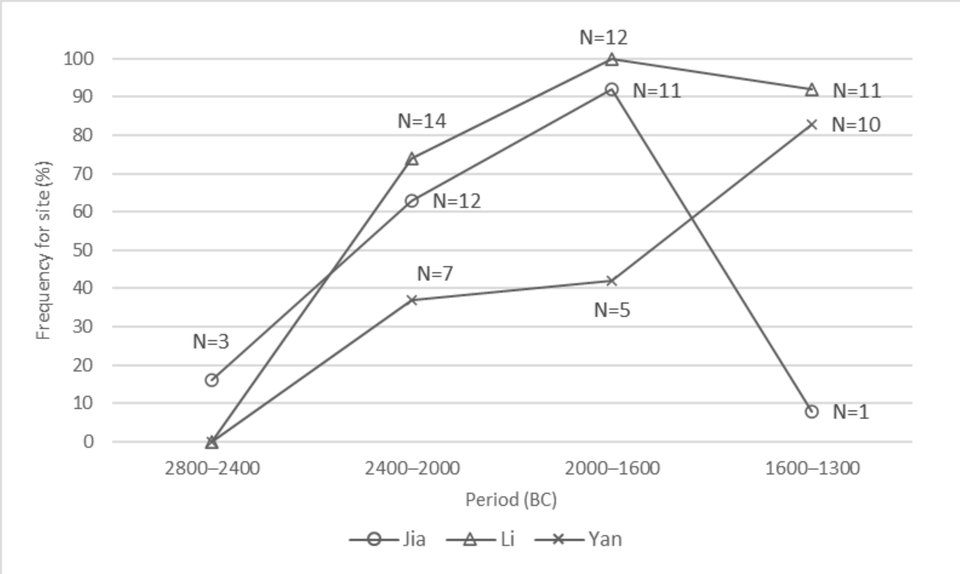


Figure 6.6. Percentages of frequency of sites discovered with tripods *jia*, *li* and *yan* across the Shimao region over the four periods from 2800–1300 BC. Period 1: N=18, period 2: N=19, period 3: N=12, period 4: N=14. Information comes from Table 6.2 and 6.3.

6.7.1.3 *Gang/weng* of different shapes of base

The frequency of sites in each period that had *gang*/*weng* in flat-based, round-based and three-legged forms is shown in Figure 6.7. This illustrates that almost 80% of the sites had *gang*/*weng* in flat-based form that were assigned to the period 2800–2000 BC. However, less than 40% of sites had flat-based *gang*/*weng* assigned to the period 2000–1600 BC and only 10% had such specimens assigned to the period 1600–1300 BC. Conversely, three-legged forms of *weng* first appeared, albeit rarely, during the period 2400–2000 BC. 50% of sites had exhibits of this form assigned to the period 2000–1600 BC and 80% of sites had three-legged *weng* assigned to the period 1600–1300 BC. Sites that had *gang*/*weng* in round-based form were few and remained below 10% over periods.

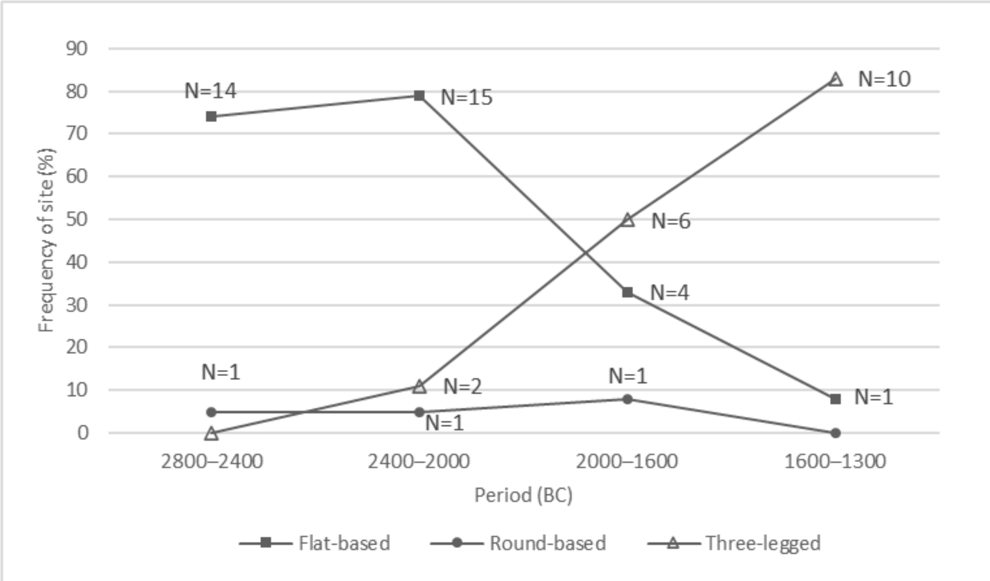


Figure 6.7. Percentages of frequency of sites discovered with flat-based, round-based *gang/weng* and three-legged *weng* in the Shimao region over the four periods from 2800–1300 BC. Period 1: N=18, period 2: N=19, period 3: N=12, period 4: N=14. Information comes from Table 6.2 and 6.3.

6.7.2 Spatiotemporal distribution

This section covers three parts: flat-based and three-legged forms, tripods *jia* and *li*, and *gang*/*weng* in flat-based form and *weng* in three-legged form.

6.7.2.1 Flat-based and three-legged forms

The spatiotemporal distribution of sites that contain flat-based and three-legged forms over the four periods is shown in Figure 6.8. This illustrates that three-legged forms became more common over time. Apart from two sites in the south sector of the region, no sites had three-legged forms assigned to the period 2800–2400 BC, with only flat-based forms appearing at these dates. However, this situation changed dramatically for pottery assigned to 2400–2000 BC. Only two sites (in Daihai Lake and the Qingshui River valley) had examples of the flat-based form at these dates but not examples of the three-legged form. All the sites had examples of both flat-based and three-legged forms assigned to the periods 2000–1300 BC, meanwhile, with these being concentrated in the Yulin area up to 1600 BC and in the Qingshui River valley area between 1600 and 1300 BC.

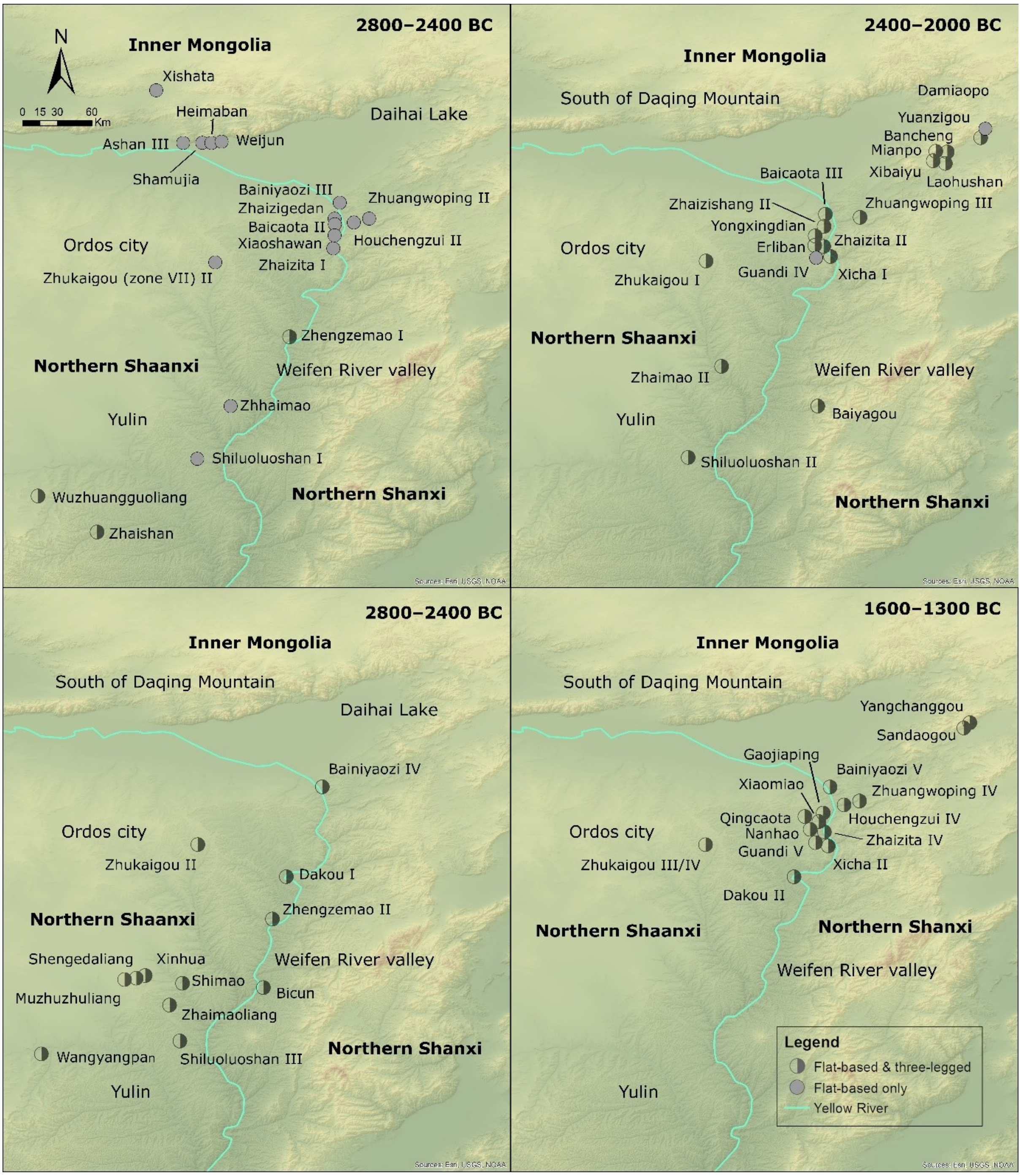


Figure 6.8. Map that shows the distribution of sites discovered with flat-based pottery only and both flat-based and tripods across the Shimao region over the four periods from 2800–1300 BC. Information comes from Table 6.2 and 6.3.

6.7.2.2 Tripods *Jia* and *li*

The spatiotemporal distribution of the *jia* and *li* tripods over the four periods is shown in Figure 6.9. This illustrates that *li* replaced *jia* over time. None of the sites had *jia* or *li* assigned to the period 2800–2400 BC, except for three sites with *jia* at these dates in the Qingshui River valley and Yulin areas. Most of the sites across the region had both *jia* and *li* assigned to the 2400–2000 BC period, with the sites having only *jia* at these dates being concentrated in the north. Most of the sites had both *jia* and *li* during the period 2000–1600 BC, when sites were concentrated in the south. During the period 1600–1300 BC, meanwhile, most of the sites had *li* alone without *jia*, when sites were concentrated in the Qingshui River valley area.

Figure 6.9. Map that shows the distribution of sites discovered with *jia* only, *li* only, and both and neither of them in the Shimao region over the four periods from 2800–1300 BC. Information comes from Table 6.2 and 6.3.

The distribution with examples of illustrations of tripods *jia* and *li* over the four periods are shown in Figure 6.10. This shows that *fu*-shaped *jia* appeared during the period 2800–2400 BC. *Jia*, *jia*-*li* and *li* appear in the entire region except the south of Daqing Mountain area during the period 2400–2000 BC. They have a bulged leg area which is more integrated into the body of the vessel, and the appearance of these forms lasted until the period 2000–1600 BC, but only in the Qingshui River valley and Yulin areas. During the period 1600–1300 BC, the leg area of *li* became even more bulged and integrated with the body, with this form concentrated in the Daihai Lake and Qingshui River valley areas.

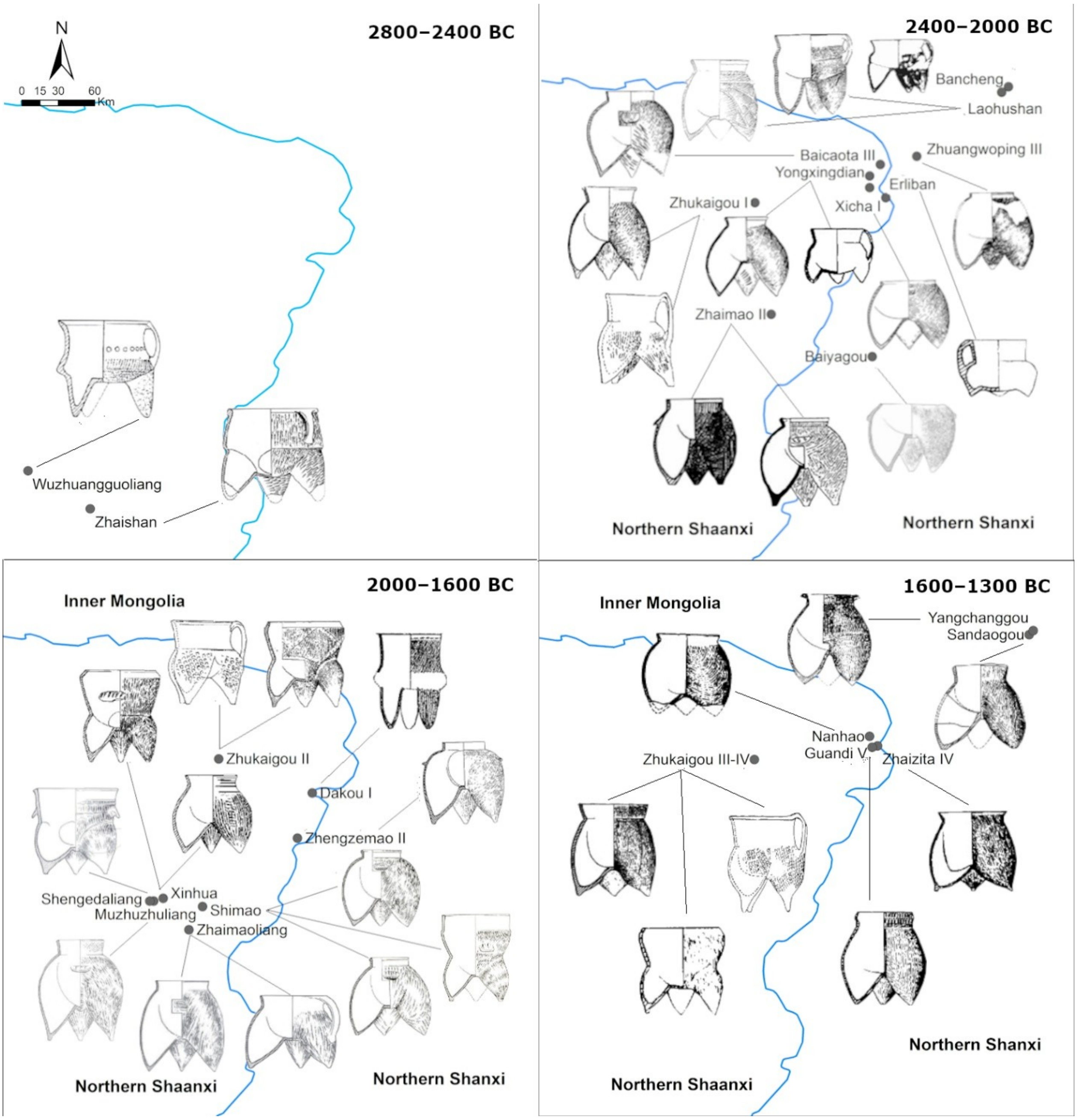


Figure 6.10. Map that shows the distribution of tripods *jia* and *li* with illustrations from the sites in the Shimao region over the four periods from 2800–1300 BC, generated via ArcMap 10.8 and GIMP 2.10.14. Information from Table 6.3.

6.7.2.3 *Gang/weng* of different shapes of base

The spatiotemporal distribution of sites that contain flat-based and three-legged forms of *gang/weng* over the four periods is shown in Figure 6.11. This illustrates that three-legged forms of *gang/weng* replaced the flat-based form over time. The *weng* with three-legged forms first appeared in the Qingshui River valley and Yulin areas during the period 2400–

2000 BC. Most of the sites had *weng* in three-legged form during the period 2000–1600 BC, when sites were concentrated in the south, but the flat-based form was still in use in this period. However, the *gang/weng* with flat-based form had been completely replaced by the three-legged form during the next period, 1600–1300 BC.

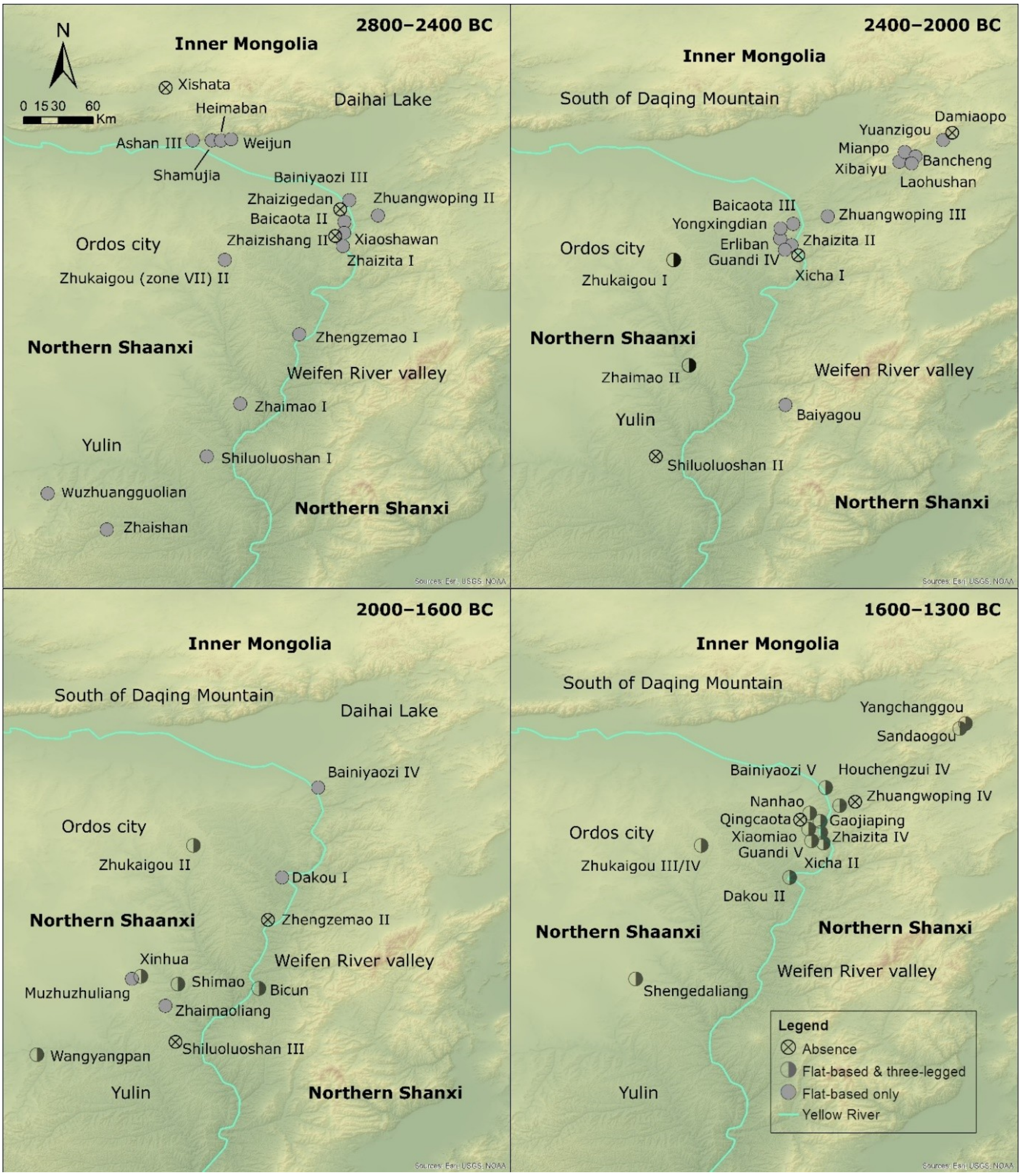


Figure 6.11. Map that shows the distribution of sites discovered with flat-based *gang*/*weng* only, both flat-based *gang*/*weng* and three-legged *weng* and neither of them across the Shimao region over the four periods from 2800–1300 BC. Information comes from Table 6.2 and 6.3.

The distribution with examples of g*ang/weng* illustrations in flat-based, round-based and three-legged forms over the four periods are shown in Figure 6.12. This illustrates that during the period 2800–2400 BC *gang*/*weng* were all in flat-based form. *Weng* in three-legged form first appeared during the period 2400–2000 BC. This form has a wider bottom area than the traditional flat-based and round-based forms. This form remained common until the next period, 2000–1600 BC. *Weng* in round-based and three-legged egg-shaped forms also appeared during this period. During the period 1600–1300 BC, *weng* in three-legged form remained common, but with a slightly different shape—the widest, bulged area shifted to the middle part of the vessel from the bottom of the vessel, as was more common in the previous period.

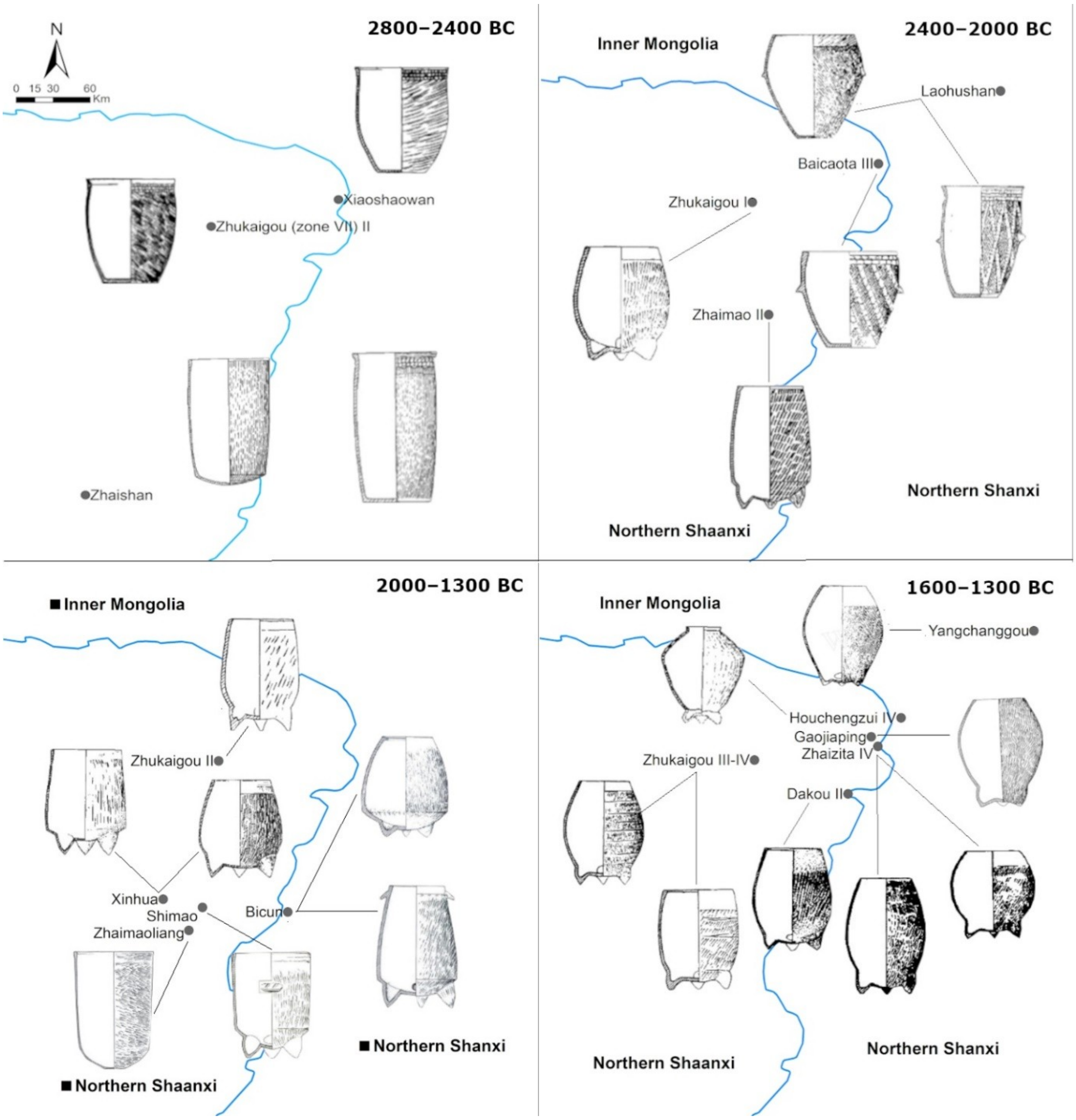


Figure 6.12. Map that shows the distribution of g*ang/weng* in flat-based form and *weng* in three-legged form with illustrations from the sites in the Shimao region over the four periods from 2800–1300 BC, generated via ArcMap 10.8 and GIMP 2.10.14. Information comes from Table 6.3.

6.8 Discussion: the genesis, prevalence, and intensive modification of ceramic tripods

The synthesis of the results suggests that tripods were most prevalent and most intensively modified during the period 2000–1600 BC, when Shimao emerged in the Yulin area. During this period, all the occupied sites had pottery in three-legged form (Figure 6.5 and 6.8), and both *jia* and *li*, as well as flat-based forms of *gang*/*weng* and three-legged forms of *weng* together became the most prevalent (Figure 6.6 and 6.7). This reflects that this is the key period for the transformation of ceramic forms, where preferable forms were selected over the others, before *li* tripods completely replaced the previous *jia* tripods, and the three-legged *weng* form completely replaced the flat-based *gang*/*weng* form during the next period 1600–1300 BC. The significance of the findings here is that intensive adoption and modification of tripods took place during the time when human occupation shifted southwards, expanded and concentrated at Shimao, supporting the development of Shimao and the surrounding site. The adoption of new ceramic forms is not only limited to Shimao and is consistent among the sites in the Shimao region. This suggests that the development of ceramic forms and shapes was formalised, without centralisation or redistribution process among Shimao and other sites. A study on petrography and surface treatment of the ceramics unearthed around the Huangchengtai platform also suggests that the ceramic production at Shimao was self-sustained and not strictly controlled (Womack et al., 2021).

One of the possibilities for the development of tripods at this specific time period is associated with cooking practice, if we consider tripods *jia* and *li* as cooking vessels. In northern China, pottery first appeared in flat-based form and the later invention of tripods *jia* and *li* has a strong link to millet cooking, although they may be used to cook other plants such as acorns (Li et al., 2017; Yang et al., 2014). It is therefore reasonable to assume that people adopted tripods and modified or invented new forms of tripods to increase cooking efficiency. The legs below the tripods allow space for fire to heat up the water inside vessels for boiling and steaming, which is a common way for millet cooking. Further modification of an even wider bottom and leg area could increase the contact area between fire and vessels, and at the same time, increase the volume of vessels. This could make boiling and steaming even more efficient and reduce the consumption of fuel. Since this happened when Shimao emerged, the changes may have taken place to support the highly concentrated population in the south that was suggested in Chapter 3.

Apart from improving cooking efficiency, another possibility of using tripods, may be related to the increase demand of using alcohol and ritual serving vessels for feasting that came along with the process of competition and urbanisation with a more concentrated population (Underhill, 2018). This suggestion is also supported by a microbotanical residue analysis undertaken for the tripod liquid containers *he*, *gui* and *weng* at Shimao, suggesting that millet, rice and other ingredients were proceeded in these vessels for beer brewing with malting method (He, et al. 2021). This may be especially important for Shimao as it may have served as a ritual centre, which allowed people from the broader region to attend ritual activities or ceremonies (Sun et al., 2018). In the wider context, the formalized use of tripods as in adopting and selecting specific forms of tripods *li*, *yan* and *weng* at most of the sites across the Shimao region, may be due to the spread of the molding production technique in northern China around that time. The evidence of using molds to produce the hollow legs of tripods such as *li*, *gui* and *yan*, for example, can be seen at the site of Lower Xiajiadian (CASS, 2003: 598).

In terms of the possible origins of tripods, given that *fu*-shaped *jia* and *jia* vessels were common at Miaodigou II and the nearby sites to the south sector of the Shimao region in

Shaanxi province during the period 2800–2500 BC (Chen, 1996: 84–101; Han, 2015b), it is likely that these types transmitted northwards to the Shimao region around that time. This suggestion is also reflected from the results, which show that the initial *fu*-shaped *jia* first appeared in the south sector of the region (Figure 6.10). *Jia* leg components found at Houzhaizimao I and Zhengzemao I during this period also shows a sign of early use of ceramic tripods (Shaanxi & Shaanxi, 2011; Shannxi & Yulin, 2000). This implies that first adoption of ceramic tripods possibly took place initially in the Yulin area. The transformation from *jia* to *li* might have also taken place in the south alongside the Daihai Lake area during the period 2400–2000 BC. This is because the transitional form *jia-li* has also been found at Shiluoluoshan II in the Yulin area (Zhang & Ding, 2016). A similar type existed at Baiyagou and Zhaimao II in Yulin and Weifen River valley areas and at Yongxingdian in Qingshui River valley area (Shaanxi, 2002; Neimenggu, 1994: 235–245; Shaanxi et al., 2017a). The *li* type also already existed in the above sites at the same time, which suggests that transformation process from *jia* to *li* potentially took place at these sites in the south.

This runs counter to the view that this transformation only took place in the Daihai Lake area, which is well-known for the discovery of the *jia-li* type. In comparison to the south, the early type *fu*-shaped *jia* and *jia* in the Daihai Lake area at the Laohushan, and Bancheng, Xibaiyu and Yuanzigou sites appeared later during the period 2400–2000 BC (Yang, 2000). This implies that the initial *jia* was possibly transmitted from the south northwards rather than other way round. The transformation of *jia-li* and invention of *li*, nevertheless, could take place in either the north or the south because these vessel types appeared in both areas at the same time from 2400–2000 BC. *Jia* and *li* then became the most prevalent in the Qingshui River valley and Yulin areas from 2000–1600 BC (Figure 6.9). The transformation process became stable from 1600–1300 BC. By this time *li* completely replaced *jia* (Figure 6.6 and

6.9). Furthermore, the leg area of *li* clearly became bulged and strikingly shorter, such as to be even more integrated with the body (Figure 6.10).

For *gang*/*weng*, given that *weng* in three-legged form had appeared as early as 7000 BC further south in Shaanxi and Henan provinces (Chen, 1996: 84–101; Wu, 1997), they were possibly first introduced from the south sector of the Shimao region. This is also reflected by the result that three-legged forms of *weng* were concentrated in the Ordos and Yulin areas (Figure 6.12). However, the *weng* in three-legged egg-shaped form was different from the *weng* from further south. The latter are usually large and tall, reaching 54 cm in height and possibly used as urn coffins (Wu, 1997). The egg-shaped form in the Shimao region, on the other hand, have a wider bottom area than the body area; a design that was unique to the region. This implies that the three-legged form was possibly adopted from further south and then modified locally, rather than transformed directly from the traditional flat-based and round-based forms of *gang*/*weng*. Given that the round-based form of *gang*/*weng* is in general scarce in the Shimao region, it is unclear whether the flat-based form was transformed to the round-based form before the three-legged form was adopted. Apart from Zhaishan, Shiluoluoshan II and Zhaimaoliang, which were included in the analysis and which had examples of the round-based form, other recently excavated sites assigned to around 2800–2000 BC, including Jiadamao, Guanhugeda and Miaoliang have also been discovered with this form (Shao, 2019; Guo & Zhu, 2018). The round-based form of *weng* seemed to be more prevalent in the south sector of the region during the period 2800–2000 BC, since they have only been discovered in this area. If the flat-based form of *gang*/*weng* did transform to round-based forms of *weng*, this more likely happened in the south during this period.

6.9 Conclusions

The major finding is that ceramic tripods were probably first adopted in the south during the period 2800–2400 BC and became prevalent across the entire Shimao region (except the south of Daqing Mountain area) from 2400–2000 BC onwards. A further outcome is that the modification process of ceramic tripods was most intensive during the period 2000–1600 BC in the south when Shimao and other sites emerged. Even though the timings of the adoption of *weng*, *jia* and *li* tripods were different, the coexistence of flat-based *gang*/*weng* with three-legged *weng*, as well as *jia* with *li* tripods, tell us that in this period certain shapes and forms took priority over others. The modification of these tripods might have been taken place locally in the south. In other words, there is a possibility that the transformation had taken place in the south sector of the region and then spread northwards rather than other way round as was previously thought.

The findings from this chapter suggests that during the period 2000–1600 BC, tripods may have adopted to increase cooking efficiency and greater demand for ritual serving vessels, not only because of population growth but also Shimao together with other surrounding sites were becoming more complex. As Chapter 5 shows, this is also the time when herd animals became prevalent and were potentially consumed as secondary products. These lines of evidence suggest that both herd animals and ceramic tripods are signs of the growing importance of Shimao together with the surrounding sites emerged in the south, supported by the people concentrated there, as suggested in Chapter 4, after the southward demographic shift, as suggested in Chapter 3. Similar to the adoption of herd animals, use of tripods was not limited at Shimao and can also be seen at other nearby settlements; this again suggests that the social economic network developed in the south, which involved the use of herd animals and ceramic tripods, is unique in a way that there is no clear evidence of centralisation and manipulation of resources and materials between Shimao and other sites. This whole developmental trajectory could be driven by the drier and fluctuating climatic condition, as mentioned in Chapter 2, and this will be further discussed in the next chapter.

Chapter 7

Discussion: the trajectory to the rise of Shimao

7.1 Introduction

Chapters 3–6 have explored the transition process of occupation shift, population concentration, and the prevalence of herd animals and ceramic tripods. The findings from each of these chapters have provided valuable information on the general developmental trajectory of the Shimao region during the period 2800–1300 BC. This chapter synthesises the findings from Chapters 3–6 and discusses how these transitions might have influenced the success of Shimao. Based on these findings, this chapter also provides insights into what we can understand of the new settlement and socio-economic network formed by Shimao with other sites in the south sector of the Shimao region.

7.2 The developmental sequence in the Shimao region

The findings from Chapters 3–6 together suggest a sequence that, after the loci of occupation shifting southwards between 2100 and 2000 BC, Shimao emerged with other much smaller sites and the population in the south became more concentrated during the period 2000–1600 BC. At the same time, the choices of animal species and consumptions of herd animals differed between Shimao and other sites, and the modification of ceramic tripods were also the most intensive. These findings are partially different from the hypothesis made at the beginning of this thesis. The timing for climate change does not match with the rise of Shimao. The possible timing for notable demographic shift is suggested to have occurred between 2100–2000 BC, which is around the end of or after the assumed drier period occurred between 2500 and 2000 BC. Besides, the settlement scale does not show significant expansion when Shimao emerged, but the findings do show that the settlements in the south became more concentrated than in earlier periods. More importantly, the extreme difference in size between Shimao and the surrounding sites suggests that population might have been highly concentrated at Shimao compared with other sites. As expected, a new socio-economic system was reflected by the use of herd animals and development of ceramic tripods for various types along with the rise of Shimao.

Despite of the differences between the findings and the hypothesis, the outcome still supports the argument that the whole transition process ultimately led to the rise of Shimao and other sites in the south sector of the region. It was a process, indeed, that had already begun during the period 2800–2400 BC, when stone fortification and ceramic tripods first appeared. The period 2400–2000 BC is the development stage, when settlements tended to appear on larger sites and when fortifications larger than 100 hectares emerged, along with early adoption of domestic herd animals and the widespread use of ceramic tripods across the region. Shimao and the other smaller sites then eventually diminished after 1600 BC. Alongside the loci of occupation shifting back to the Qingshui River valley area at this time, some of the population may have moved to other locations, possibly to Erlitou in the Central Plain (Rawson, 2017b; Zhang, 2017) and northeast China (Hosner et al., 2016; Wagner et al., 2013).

7.3 The settlement and socio-economic network of the Shimao region

The findings of this chapter allow a discussion on the unique settlement and economic network identified in the Shimao region. The settlement pattern along the Tuwei River valley in the area surrounding Shimao assigned to the period 2400–1600 BC reveals that there are some small walled sites (below 10 hectares) and several non-walled sites situated to the south sector of Shimao, with two larger walled sites (50–100 hectares) further south (Figure 4.1) (Sun et al., 2018). This pattern is similar to the settlement distribution shown in Chapter 4 in the wider Yulin area, which showed that there are a few smaller walled sites (below 10 hectares and 11–50 hectares) and a few non-walled sites surrounding Shimao during the period 2000–1600 BC (Figure 4.4). Before then, between 2800 and 2000 BC, the distribution shape seemed to be sparser, with a few small walled sites and non-walled sites distributed further south. The sites became closer to one another at the time when Shimao emerged. Since Shimao was the largest site, it presumably accommodated a higher concentration of population than other smaller sites, especially when the scale of Shimao was so much larger, at least a few times, than all other surrounding sites. This disparity in size also suggests that the smaller sites were dependant on Shimao, reinforcing its dominance as a major centre. This shows a trend of increased settlement hierarchy in the wider region context during the period when Shimao developed (Sun et al., 2018).

A similar distribution shape of settlements began to develop in the north sector of the region during the period 2400–2000 BC, when the overall site size became more diverse (Figure 4.3 and 4.4). The largest sites in this period in the Qingshui River valley area, were Houchengzui (138 hectares), and the non-walled site of Xicha (120 hectares). These must have potentially served as centres. However, the distribution shape of settlements in this area, inclined to be linear, distributed along the Yellow River valley (Figure 4.4). In contrast to the distribution pattern in the Yulin area, this area did not seem to involve a hinterland because all the sites were closely placed along the Yellow River valley. Even though there were a group of sites in the Daihai Lake area (Figure 4.4), these settlements were more like a separated cluster since their pattern was similar to those in the Qingshui River valley area—distributed linearly and close to one another along the north side of the Daihai Lake. The pattern in the Weifen River valley area, however, was closer to that of the Yulin area, consisting of large walled sites at Baiyagou (120 hectares) and Ershilipu (90 hectares), with a group of other walled sites below 50 hectares (Figure 4.1) (Wang, 2017; Wang & Zhang, 2016). However, most of these sites have not been excavated and are assigned to a broad period from 2400–1600 BC. While it is likely that these sites have different occupation periods, the changes in the distribution shape in this area are as yet unclear. The only changes over time that we recognise thus far are that the loci of the largest walled site shifted westwards, closer to the Yellow River, and at the same time the size site became smaller during the period 2000–1600 BC when Bicun (75 hectares) developed (Wang, 2017). In contrast, some sites in the Yulin area were still located further away from the Yellow River, conceptually, they then potentially serving as rural sites. More information from the Weifen River valley area is required in order to compare the distribution pattern in this area with that in the Yulin area.

It is worth noting that when Shimao and the surrounding sites emerged, the Houchengzui centre in the north remained occupied, but it seemed to become more isolated at this time. This site remained occupied, along with the large non-walled site at Xicha during the next period 1600–1300 BC, before the settlements concentrated again in the Qingshui River valley area. These larger sites might have served as centres of some kind for the nearby smaller sites (mostly non-walled).

Another noteworthy pattern is related to the existence of the large non-walled sites. While sites with areas greater than 10 hectares are already considered as uncommon, these large sites reaching 50 hectares or above should indicate some degree of population concentration and must have functioned as some kind of centre. Such large non-walled sites first appeared at Zhukaigou (50 hectares) in the Ordos area, Xicha in the Qingshui River valley (120 hectares) and Jiadamao in the Yulin area (100 hectares) during the period 2400–2000 BC. Zhukaigou remained in occupation until the period 1600–1300 BC, while Xicha was occupied again during this period (Figure 4.4). These sites shared a common feature, namely that herd animals were discovered in all of them (at Zhukaigou from 2000–1600 BC onwards), and both jades and bronzes were also discovered at Zhukaigou and Xicha. This combination is significant as the only other site that contained these three types of materials is Shimao. This suggests that these non-walled sites might have a special role in the area in which they were located since herd animals, jades and bronzes were indicators of some forms of wealth or authority—herd animals are important meat resources while jades and bronzes are prestige goods in early China (Liu, 2003). However, Zhukaigou was quite isolated from all other settlements (Figure 4.4) and may have been a rather independent site.

Along with the emergence of Shimao, sheep/goat and cattle became prevalent at Shimao and the surrounding sites (Figure 5.1). The patterns of faunal assemblages and harvesting strategies at Shimao and the surrounding sites Huoshiliang, Muzhuzhuliang, Xinhua, Zhaimaoliang and Zhukaigou helps us to understand the development of a new form of economic system. In terms of the composition of the domesticated mammal population, domesticated animals were dominant at all the sites, and the diversity of species among the domesticated mammals at these sites were consistent, comprising pigs, dogs, sheep/goat and cattle (Figure 5.3). A small number of horses and donkeys were additional species at Shimao and Muzhuzhuliang. The pattern suggests that people at Shimao and Zhukaigou (1600–1300 BC) adopted herd animals originated form the steppe but remained to consume pigs, the species that have been commonly raised in Central Plains. Zhaimaoliang and Zhukaigou (2000–1600 BC) also had a balanced use of pigs, sheep/goat and cattle, but with a higher proportion of cattle than at Shimao and Zhukaigou (1600–1300 BC). This implies that people at Zhaimaoliang and Zhukaigou (2000–1600 BC) may have concentrated on consuming cattle because these two sites show a relatively higher proportion of cattle than at other sites, which is uncommon in mixed pastoralism. Huoshiliang and Muzhuzhuliang are the sites which highly adopted toon the new domesticated species sheep/goat. Xinhua is very different from the above sites because people there concentrated on raising pigs or dogs. This suggests that Xinhua was not committed to raising the newly introduced species but kept raising the common species pigs and dogs in that region. This observation suggests a practice of different species choice at individual sites, and this formed a unique economic network involving Shimao and the surrounding sites in the south sector of the region. This network may have developed spontaneously in order to make gains for Shimao within the wider region. Although the sites inclined to be self-sustained, the formation of this network allows the settlements within it to support one another and develop as a whole; and this is an important process for the success of the large centre of Shimao.

In terms of craft production activities, we already know of a bone craft workshop located at the platform area of the fortification at Shimao, where a large quantity of animal bones and processed bone tools (mainly bone needles) have been found (Shaanxi et al., 2017b). A recent study in relate to ceramic production shows that pottery workshops, which served for local needs, also existed at Shimao (Womack et al., 2021). Although jade and copper/bronze artefacts have also been found at the same location, the current evidence does not show that these objects were manufactured at the site. Although bronze bracelets and single-edged knifes and stone moulds used for casting these bronze knives have been discovered from Shimao (Sun & Shao, 2017; Sun et al., 2018), the number of these stone moulds are small. The production of these bonze knives at Shimao was therefore likely to be random events. At present, there is no clear evidence for bronze casting workshop or industry because we do not see any remains of furnaces and slag at the site (Su, 2019). Fragments of such bronze knife have also been found at Huoshiliang (Sun & Shao, 2017), possibly linked to those from Shimao. Since there is no source for jade making around the Shimao region, the discovery of jade objects from eastern China show that these objects could be obtained through trading with the people in eastern and north-western China (Jaang et al., 2018). That said, since Shimao and Xinhua are the only two sites where large amounts of diverse jade artefacts have been discovered, it remains possible that Shimao may have exchanged these jade artefacts with Xinhua for animal resources (pigs or dogs) in return.

Since jades and copper/bronze objects were rare during the period 2400–2000 BC, they are likely to have been consumed as prestige goods from 2000–1600 BC. These objects are usually discovered in burials or pits, which suggests that they were burial and ritual goods, probably manipulated and owned by higher status groups such as elites and leaders. There is also a difference in how jades were used between Shimao and the nearby site of Xinhua. At Shimao, jades were used in diverse contexts: burials, 'altar' and wall structures (Sun et al., 2018), while those in Xinhua were only placed in what we can plausibly say were ritual pits (Shaanxi & Yulin, 2005). The types are also more diverse in Shimao. In essence those discovered in Xinhua can also be found in Shimao, whereas Shimao possessed unique types, such as a jade human head and a jade eagle, that were absent from Xinhua. This also apply to bronze objects: unique types, such as the dentate-shaped bracelets (along with jade bracelets) from Shimao (Sun et al., 2018) were absent in Huoshiliang. This suggests that Shimao as a large site managed to manipulate more diverse and unique types of prestige goods than smaller sites, which could be due to more extensive social stratification or to wider exchanges.

7.4 The drivers of the rise of Shimao

The fluctuated climate condition of the Shimao region is itself an important factor that subsequently imposed changes to the environment of the region, such as reduction of annual precipitation and vegetation. These changes would thereby affect the substantiality of subsistence activities of the region. If the EASM belt did retreat and shifted southwards, the climate in the Shimao region would be even drier and surely it would affect the north sector of the region more. The further the EASM belt shifted southwards from the region, the less favourable the climatic conditions in the area south of Daqing Mountain because of its location at the isohyets of MAP between 200 and 400 mm (Figure 2.1 and 2.4). Give that the critical point for cultivating the arid-resisting broomcorn millet is 350 mm (Lu et al., 2009), the retreating EASM belt may have encouraged people moving southwards to the region where the isohyets are between 400 and 600 mm. As the paleoclimatic studies done by Cui et al. (2019) show, the Shimao region became drier since 3000 BC, but the south sector of the region remained warm and humid between 2000 and 1700 BC; the climate and environmental setting reflected from zooarchaeological remains also suggests that the condition in the south was relatively warm and humid when comparing to the north (Hu et al., 2008a, 2016). In this situation, herders probably brought herd animals with them to the south through transhumance (Sun et al., 2018); these newcomers and the new type of meat resources that they brought help boosting the population at and around Shimao. Population growth can easily lead to exceeded land capacity and thereby make this area even more sensitive to drier and fluctuating climate conditions (Wu et al., 2018).

In the light of these changes, we can argue that they encouraged the rapid development of Shimao and other settlements in the south between 2000 and 1600 BC. It was at this time that population became more concentrated in the south especially at Shimao, as suggested in Chapter 4. During this period, herd animals were adopted and widely used because they could provide abundant meat resources to support the more concentrated population. They were adopted as an additional source of food alongside millet and pigs in order to minimise the risk for any failure in one of these sources (Brumfiel & Earle, 1987; Wang et al., 2014b). This suggestion is also supported by the finding in Chapter 5, which shows the differentiation in selecting animal species between the settlements in the south—this formed safety net to complement food supply in case there were failure in one of the meat sources. Since millet cultivation and pig husbandry remained prominent at that time period and some of the sites in the south were distributed far from the Yellow River suggest that water sources were sufficient without resort to fetching water from the main river (Figure 4.4), we know that the environment were ideal for cultivating millet and raising pigs, and herd animals were added on top of these as a preparation for competitive environment under the fluctuated climatic condition in this region.

The rise of the extraordinary fortification at Shimao, demonstrates an unprecedented systematic defensive function, which may have been due to competition between the settlement groups within or outside the Shimao region. This may have been a consequence of increasingly limited resources as the climatic conditions began to change, especially when the population became concentrated. However, evidence of extreme violent activity such as happened at Taosi has not been found thus far at Shimao. The only such sign was the use of arrowheads and the sacrificial pits with numerous young female skulls (Chen et al., 2016; Sun et al., 2018), the latter being probably the outcome of a ritual rather than warfare. The large-scale fortifications may also have served as enclosures for resources protection in the case if competition had increased. Intensive adoption and modification of ceramic tripods, as discussed in Chapter 6, also support the suggestion that people in the south sector of the region were facing a risk of having limited resources because they attempted to improve cooking efficiency and minimise the consumption of fuel by adopting new forms of tripods.

As we can see, the role of climate change is fundamental to the emergence of Shimao and the surrounding sites, but the consequences were not necessarily direct or immediate. The foremost impacts were on the occupation and subsistence. People tended to choose to live in areas where subsistence was sustainable, and this would encourage the population to become concentrated at these areas. The integrated communities thus accelerated the formation of Shimao and the surrounding sites. Along with the population growth and concentrated, people may have been spurred to build defensive fortifications, develop specialised animal economies and more efficient ceramic tripods together, to build a safety net for resources and food sustainability. Even if climatic conditions did not directly drive these socio-economic developments, the underlying reason for them was climate-related since the deterioration in the climate introduced an inherently more competitive environment, which would subsequently encourage these developments. These developments helped sustain Shimao and the surrounding sites and may have further boosted population growth. These developments would then further facilitate population growth, social stratification and differentiation between sites, as well as knowledge transmission between pastoralists and agriculturalists. The repetition of this feedback cycle further accelerated the process of the transitions. Thus, it is argued that both climatic factors and human choices were integral to the success of Shimao and the surrounding sites. These consequences of climate changes, and the human choices in response to these conditions were deeply entangled but steadily drove the process of development. The interplay of these consequences then eventually led to the success of the south sector of the Shimao region, embodied by an unprecedent organisation in settlements and economic system. Climatic and human factors are therefore both indispensable to this final result.

7.5 The urbanisation process of Shimao

The above discussion allows us to redefine the position of Shimao in the wider process of urbanisation and state formation in early China. First of all, while early China has a unique form of urbanism, it is worth clarifying in what sense Shimao can be considered as an urban centre. Shimao is undoubtedly an extremely large site; the large area occupied and the scale of the wall construction themselves, as shown in Chapter 2, indicates that Shimao could rely on large labour force, which in turn, required a moderately large population size to support it. Even though currently, we do not know the population size of Shimao, we know that there are houses, ash pits, kilns and ceramic fragments scattered within the inner enclosure, showing a sign of human inhabitation (Shaanxi et al., 2017, 2021; Sun et al. 2015; Womack et al., 2021). This site also likely had higher concentration of population than all other settlements within the wider region. In terms of settlement hierarchy, Shimao was a centre, with further settlements in the area, including two large walled sites around 50–100 hectares, several small walled sites below 10 hectares and many non-walled sites (Figure 4.1). The wider region consisted of a four-tiered settlement hierarchy (Sun, 2016); among which the size of Shimao is extreme in size by comparison with other sites, this was not seen in previous periods, as discussed in Chapter 4.

Shimao also appears to have served as a ritual centre for other settlements in the wider region. As discussed in Chapter 2, the Huangchengtai platform inside the inner wall may have served as a bone workshop (Shaanxi et al., 2017), with many jade artefacts found placed between the stone blocks of its wall (Sun et al., 2018, and stone carvings with human, animal, god and monster motifs were also used as part of the wall construction (Shaanxi et al., 2021). These must have had a purpose in influencing the spiritual world and perhaps pushing back attacks. Aside from these, the skull pits, which were likely used for sacrificial purposes can also be found around east gate at the outer wall (Chen et al., 2016). All these features suggest that Shimao as a ritual centre for the wider region, had a repertory of different forms of ritual activities, with the platform area serving as a common space for holding public ritual activities or ceremonies.

The features of a large and concentrated population, as well the roles as a major settlement and as a ritual centre fit the most basic criteria of a city. Shimao and the surrounding settlements also show features of urbanism but in a unique and specific way, as indicated by the findings of this thesis. Shimao and the surrounding sites together had developed a new socio-economic network, which involved the adoption of herd animals and forms of food preparation in ceramic tripods. These both may be related to an increased demand for meat and ritual-serving vessels for feasting as part of the growth of the settlement, that is, the urbanisation process. Using ceramic tripods as liquid containers such as *gui*, *weng* and *hu* in feasting are common in northern China. As Underhill (2018) suggests, ceramic production associated with feasting activities became diverse during the Longshan period along with the development of urbanism; and evidence for beer brewing with millet and other ingredient using tripods can actually be seen at Shimao (He, et al. 2021). The more common use of tripods may also be due to the development of ceramic production with molding techniques to support this development. Nevertheless, the adoption was not limited to Shimao but rather common across the Shimao region in that period. This suggests that the settlements in the south sector of the region were developed as a generally during the urbanisation process and Shimao was subsequently developed as a ritual centre for the wider region, attracting people from other places to stay there and attend ceremonies.

The development of urbanism here was unique: Shimao was developed as a major stone-built centre but centralisation and clear urban-rural difference in the social economy are lacking, as judged from the differentiation in consuming animals and the use of specific forms of ceramic tripods without redistribution at and around Shimao. The zooarchaeological evidence examined by Owlett et al. (2018a) also suggest that there is no clear evidence for centralisation, or well as producer-consumer relationship in animal economy for Shimao and the smaller site of Zhaimaoliang. Campbell et al. (2021) has suggested that the pastoral economy at Shimao seems to be uncentralised, but the long-distance exchange of high-valued goods including jades, cowrie shells and alligator scutes, the investment of jades in public construction, and the concentration of craft activities such as textile production show evidence of conflict and hierarchy. People at Shimao, indeed, used the prestige goods of jades in different contexts as at burial and wall construction; they also used bronze objects and also different types of high-valued goods. The manipulation of various types of resources is only be seen at Shimao and not at any other sites, even though some of the sites contained either jades or bronzes in smaller quantities. This suggest that centralisation and hierarchy cannot be seen in social economy around Shimao, but were important forces, probably existed in ritual and political or social contexts.

7.6 The position of Shimao in the development process of early China

Shimao has now generally been considered as the first urban centre in the North Loess Plateau (Sun et al., 2018) and considered in the discussion from an urbanism perspective (Campbell et al., 2021; He et al., 2021; Owlett et al., 2018a, 2018b; Sheng et al., 2021; Womack et al., 2021). The site has even been linked to the discussion of state formation (Jaang et al., 2018), such discussion has also been applied to other major settlements of early China including the sites of Liangzhu (3100–2700 cal. BC), Taosi (2300–1900 cal. BC) and Erlitou (1750–1530 cal. BC) (e.g. Campbell et al., 2021; He, 2018b; Liu, 2009a; Liu & Chen, 2013; Refrew & Liu, 2018; Xu, 2018). Some of studies focusing on the identification of the first state of early China remains debatable because there is no consensus for the definition of a state (Shelach & Pines, 2006). The definition of a state includes the criteria approach proposed by Su Bingqi and Xia Nai, and the settlement hierarchy approach (Liu, 2009a), as discussed in detail in Chapter 1. Liu, (2009a: 225–226), for example, suggest that Erlitou can be considered as a state-level society on the ground that Erlitou and the surrounding area consists of a four-tiered settlement hierarchy, and this site itself has an enclosed palatial complex as well as burials with prestige goods such as bronzes, jades, turquoise objects and white pottery.

The above discussion focusing on the identifying the major settlements at a state is limited because the development of complex societies was not unilineal in early China, but rather heterogeneous in different locations as at Liangzhu, Shimao, Taosi and Erlitou (Campbell et al., 2021; Shelach & Jaffe, 2014). Labelling these sites as a state itself, as also pointed out by Jaffe et al. (forthcoming), does not tell us much about the development process and their significance in archaeological context. If we examine the aforementioned sites from an urbanism perspective, we can see that these sites developed on their own way with diverse forms and characteristics of urbanism. Liangzhu, which developed before Shimao, involves a large-scale water management construction, a rammed-earth wall with stone foundation, and sophisticated jade objects with symbolic motifs (Renfrew & Liu, 2018). Taosi has a rammed-earth enclosure and also involves an enclosed palace, elite residential area and tombs, an observatory served for ritual purpose, and several ceramic and lithic workshops (He, 2018). In terms of pastoral economy, urban provisioning is also evident at Taosi and Zhoujiazhuang, as shown by the zooarchaeological evidence, which suggests that the latter specialized on meat and provided meat to the urban centre of Taosi while the centre itself specialized on wool production (Brunson et al., 2016). By comparing with Liangzhu and Taosi, Erlitou shows a clearer evident urban planning, structured with the palatial complex surrounded by the elite residential area, turquoise and bronze workshop and a space for ritual activities associated to burials and sacrifice, alongside the hierarchical organisation in the wider region (Xu, 2018).

As we can see, Shimao and also the above sites, all went through different and unique forms of urbanism, and the development of these major settlements do not necessarily have to be continuous. These sites are individual centres, developed at different time periods and locations with their own trajectory. In the cases of Shimao, Taosi and Erlitou, they were developed around the same time, and this allows them to communicate and interact with one another. At present, a link between Shimao, Taosi and Erlitou has been established based solely on the similar features, some of which they shared on jade and bronze bracelets, mace heads, drums and bells, music instrument ‘jews harps’, stone tools, and human or monster motifs on stone carvings as well as other artefacts (Dai, 2016b; Jaang et al., 2018; Li, 2009; Rawson, 2017b; Shaanxi et al., 2021; Shao, 2020). The discovery of the 200-hectare stone fortification at Lushanmao in Shaanxi province (Zhao, 2018), which is located between Shimao and Taosi, also shows a connection with Shimao, in that both sites share similar wall paintings and jade artefacts (Ma et al., 2018).

The linkage of the aforementioned sites implies a southwards trajectory for knowledge transmission especially for herding and metallurgy, or even for population movement and expansion (Shao, 2020; Sun et al., 2018; Jaang et al., 2018); this trajectory has been thought to have associated with the development of Erlitou (Dai, 2016b; Han 2010; Rawson, 2017b). The evidence of the violent activities and demolition of the elite tomb and palace at Taosi as well as the rebuilding with an earthed wall after 1900 BC, in this context, has been used to suggest for a southward invasion by the Shimao people (Sun et al., 2018). This suggestion is not impossible because these sites are co-existing around that time. A study of skull features at Taosi shows that the skulls unearthed from burials dated to the earlier phase are different from those from ash pits dated to the later phase; this suggests that people from these two phases can be of different groups (Shao, 2020). This however requires further direct evidence to support this possibility. So far, we only know that those sites shared similar artefacts and motifs that shows a strong linkage between them, but we do not understand enough about how they communicated with one another and what kinds of relationship the people had with one another. Further suggestion and discussion on such linkage and trajectory will require more evidence and studies from these sites. At this stage, we can suggest that the development of these different centres with various degrees and extents, as a whole, can be seen as part of the process that led to the development of the more complex society of the pre-dynastic settlement, of Erlitou, and subsequently the first dynasty of Shang.

Chapter 8

Conclusion

This thesis has explored the demographic and socio-economic development of the Shimao region. The findings have showed that population shifted and concentrated at the south sector of the region, with the increased use of herd animals and ceramic tripods, probably associated with the development of food preparation and feasting activities. The whole process facilitated the formation of a unique socio-economic network, which consisted of Shimao and the surrounding sites. In this network, Shimao acted as a ritual centre with a highly concentrated population and attracted other people to the centre; but at the same time, the sites within this network developed together as a whole and complemented one another in animal economy. This network developed along with a unique form of urbanism, in which centralisation and the roles of provider and consumer in animal economy and ceramic consumption among sites are lacking. Both the pulling factor from Shimao and the climate factor, which may have introduced indirect and gradual influences, are significant for the success of Shimao and more broadly the south sector of the Shimao region.

The social economy was not centralised at Shimao and no clear evidence showing the smaller sites have provided meat resources to the urban centre for goods in return. Nevertheless, while resources of herd animals, jades and bronzes which represent wealth or authority can only be seen at Shimao, Huoshiliang and Xinhua, these gives us a clue that exchange for these high-valued goods may have taken place between these sites. The distribution of these resources suggest that Shimao may have exchanged bronze knives for sheep/goats from Huoshiliang and exchanged jade artefacts for pigs or dogs from Xinhua. Muzhuzhuliang and

Zhaimaoliang possibly have provided Shimao sheep/goats and cattle, respectively. An important noteworthy observation is that Shimao was the only site in which there is evidence for herd animals, jades and copper/bronzes altogether. Other sites that contained all these resources and artefacts can only been seen at Zhukaigou III–IV (1600–1300 BC) and Xicha III (after 1300 BC). This emphasises the special role of Shimao, at which wealthy people or higher rulers (e.g. elite or political leaders) may have been able to manipulate animal resources and prestige goods and their exchange between Shimao and the other sites during the earlier period. The possibility of exchanging these animal resources and high-valued goods is worth to be explored once more data are available in the future.

Future research on calibration and Bayesian modelling is strongly suggested as more good radiocarbon dates with fully reported methods and stratigraphic contexts become available. Due to the limitation of sources in terms of considering published evidence only, the discussion here has focused on demographic and socio-economic patterns. The socio-political and economic aspects including burial practices and burial goods in cemeteries, and circulation or exchange of animal resources, ceramics and prestige goods, should therefore be further explored when more sources of evidence are published, or if complete data can be accessed. In terms of relationships between Shimao and the surrounding sites, the production, consumption and distribution of jades and bronzes, resources and goods exchange (e.g. Liu & Chen, 2003), standardisation of pottery in size, shape and decoration (e.g. Underhill, 1991), and production mode of pottery (e.g. Underhill, 1991) within Shimao and among Shimao and other sites should be deeply explored.

Aside from the Yulin area, the situation in the currently poorly understood Weifen River valley area in Shanxi province is also an area in which it is important to explore the development of the Shimao region. Similarly, another large walled centre, Houchengzui in the Qingshui River valley area is worth investigating in detail since it currently remains uncertain exactly what its role was a large centre in the Shimao region preceding the development of Shimao itself. The relationship of that site with its surrounding sites cannot be included much in the current discussion but if information regarding this site is made available or accessible, the said pattern should also be explored for a fully comprehensive developmental trajectory across the region.

Future works should be done in the area to the south sector of Shimao region should be explored in order to understand its relationships with Lushanmao, Taosi and Erlitou. Although the development of these sites was not unilineal, we should not neglect that, in the bigger picture of early China, there is a trend of transition of major settlements from the eastern coastal region to the ‘arc’ and eventually to the Henan Central Plain (Zhang, 2017; Zhang et al. 2019). Such transition can be driven by natural and human factors, and it is worth to better understand how this process may have taken place by exploring the human-environment relationship at the Shimao region and also the other regions to the south. Indeed, some scholars have linked such southwards transition with the drier condition occurred around 4000 years ago (e.g. Dai, 2016b; Han, 2010; Sun et al., 2018). At present, we have abundant paleoclimate and paleoenvironment studies done for the locations near Shimao, as discussed in Chapter 2, and we also have a moderate number of radiocarbon dates for Shimao including those shown in UCLA (2021). Considering these dates and studies together can help us better understand how climate factor may have associated with the demographic and socio-economic changes explored in this thesis. Human factors should also be explored if accessing or collecting new data from the Shimao region is made possible.

In conclusion, this thesis has identified the previously poorly understood development process in demography and social economy across the Shimao region. This has allowed an exploration of the urban form of Shimao and more broadly the North Loess Plateau with the consideration of multiple boundaries. The consideration of the recently published data in the south sector of the Shimao region along with the previously published data across the entire region has provided an overview of the development process in the region as a whole. The analyses done in this thesis, including the identification of occupation shift, settlement size measurement and identification of settlement distribution shape, herd animal exploitation and prevalence of ceramic tripods, have identified new development occurred at and around Shimao. These analyses involved various methodologies and sources of evidence. Considering different sources of evidence and exploring all the settlements in the region from a holistic view previously have not been done for the Shimao region. Before then, our understanding of this region was limited: the discussion of the development process tended to be hypothetical and focused on the discoveries from Shimao itself. This research encourages future studies to reinterpret and deeply explore the position of Shimao, or the North Loess Plateau, in the development process of early China as well as in the long-distance network between the Eurasian steppe and Central Plains of China, which involved transmission of knowledge, technology and goods.

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Appendix I

Site	Code	^{14}C age BP (5568 half-life)	Sigma	Dating Year	Labortory	Identifier	Dating method	Materials	Cultural layer	Reference
Ashan	Ashan1	4655	70	1965-1991	Chinese Academy of Social Sciences	ZK1184	Conventional	Charcoal (wood)	II(3)H5	CASS 1992: 60‑61
Ashan	Ashan2	4218	70	1965-1991	Chinese Academy of Social Sciences	ZK1185	Conventional	Charcoal (wood)	I(3)H39	CASS 1992: 60–61
Ashan	Ashan3	4208	80	1965-1991	Peking University	BK81005	Conventional	Charcoal (wood)	H8	CASS 1992: 60
Ashan	Ashan4	4121	80	1982	Peking University	BK81004	Conventional	Charcoal (wood)	H14	CASS 1992: 60–61
Yuanzigou	Yuanzigou1	4772	100	1988	Peking University	BK87072	Conventional	Charcoal (wood)	F3042	Neimenggu 2000
Yuanzigou	Yuanzigou2	4496	90	1988	Peking University	BK87069	Conventional	Charcoal (wood)	F3043	Neimenggu 2000
Yuanzigou	Yuanzigou3	4259	90	1988	Peking University	BK87071	Conventional	Charcoal (wood)	F3045	Neimenggu 2000
Yuanzigou	Yuanzigou4	4062	100	1988	Peking University	BK87073	Conventional	Charcoal (wood)	Y3005	Neimenggu 2000
Yuanzigou	Yuanzigou5	4004	70	1988	Peking University	BK87070	Conventional	Charcoal (wood)	F3041	Neimenggu 2000
Yangchanggou	Yangchanggou1	3362	70	1989	Peking University	BK89121	Conventional	Charcoal (wood)	88楊F2:100	Yuan et al., 1994
Laohushan	Laohushan1	3761	70	1965-1991	State Administration of Cultural Heritage	WB84-44	Conventional	Charcoal (wood)	Kiln Y3	CASS 1992: 59
Zhaizita	Zhaizita1	4174	60	1965-1991	Chinese Academy of Social Sciences	ZK2242	Conventional	Charcoal (wood)	T4(2) H48	CASS 1992: 63
Bainiyaozi	Bainiyaozi1	4110	107	1992-1993	Chinese Academy of Social Sciences	ZK2642	Conventional	Charcoal (wood)	BD: F3	CASS 1993
Dakou	Dakou1	3673	40	2014	Australian Nuclear Science and Technology Organisation	SI2940/OZO945	Conventional	Collagen (human bone)	unknown	Atahan et al., 2014

Site	Code	^{14}C age BP (5568 half-life)	Sigma	Dating Year	Labortory	Identifier	Dating method	Materials	Cultural layer	Reference
Dakou	Dakou2	3615	45	2014	Australian Nuclear Science and Technology Organisation	SI2942/OZO946	Conventional	Collagen (human bone)	unknown	Atahan et al., 2014
Erliban	Erliban1	3703	65	1965-1991	Chinese Academy of Social Sciences	ZK2241	Conventional	Charcoal (wood) and charred soil	T2(6)下H10	CASS 1992: 62
Zhukaigou	Zhukaigou1	4679	80	1965-1991	State Administration of Cultural Heritage	WB84-78	Conventional	Charcoal (wood)	II T228(4)	CASS 1992: 59–60
Zhukaigou	Zhukaigou2	4325	90	1982	Peking University	BK79053	Conventional	Charcoal (wood)	III T23(5)	CASS 1992: 59–60
Zhukaigou	Zhukaigou3	3416	70	1965-1991	State Administration of Cultural Heritage	WB84-79	Conventional	Charcoal (wood)	I(4)H1058	CASS 1992: 59–60
Zhukaigou	Zhukaigou4	3222	70	1965-1991	State Administration of Cultural Heritage	WB84-76	Conventional	Charcoal (wood)	I(3) H1071, 1073	CASS 1992: 59–60
Zhukaigou	Zhukaigou5	3192	85	1965-1991	State Administration of Cultural Heritage	WB84-77	Conventional	Charcoal (wood)	I(3)H1055	CASS 1992: 59–60
Zhukaigou	Zhukaigou6	3324	70	1965-1991	Peking University	BK80028	Conventional	Charcoal (wood)	V(2)H5018	CASS 1992: 59–60
Zhukaigou	Zhukaigou7	3576	40	2014	Australian Nuclear Science and Technology Organisation	OZM232	AMS	Collagen (human bone)	unknown	Atahan et al., 2014
Zhukaigou	Zhukaigou8	3401	40	2014	Australian Nuclear Science and Technology Organisation	OZM221	AMS	Collagen (human bone)	unknown	Atahan et al., 2014
Shengedaliang	Shengedaliang1	3090	30	2017	Beta Analytic Radiocarbon Dating, Miami AMS Lab	Beta403918	AMS	Collagen (human bone)	M7	Chen et al., 2017a
Zhengzemao	Zhengzemao1	4349	60	1992	Peking University	BK92087	Conventional	Charcoal (wood)	丙區T51 F4	Anonymous 1996
Shimao	Shimao1	3625	25	2016	Peking University	BA121536	AMS	Charcoal (wood)	F1:1	Sun et al., 2018: 38

Site	Code	^{14}C age BP (5568 half-life)	Sigma	Dating Year	Labortory	Identifier	Dating method	Materials	Cultural layer	Reference
Shimao	Shimao2	3469	50	2014	Australian Nuclear Science and Technology Organisation	SI2936/OZO954	AMS	Collagen (human bone)	unknown	Atahan et al., 2014
Xinhua	Xinhua1	3557	120	2001	Institute of Earth Environment, Chinese Academy of Sciences	XLLQ1016	Conventional	Collagen (human bone)	96H50	Shaanxi & Yulin 2005: 374
Xinhua	Xinhua2	3455	35	2014	Australian Nuclear Science and Technology Organisation	SI1595/OZN206	AMS	Collagen (human bone)	unknown	Atahan et al., 2014
Xinhua	Xinhua3	3518	120	2001	Institute of Earth Environment, Chinese Academy of Sciences	XLLQ1017	Conventional	Collagen (human bone)	96H14	Shaanxi & Yulin 2005: 375
Muzhuzhuliang	Muzhuzhuliang1	3450	30	2015	Beta Analytic Radiocarbon Dating, Miami AMS Lab	Beta364263	AMS	Collagen (human bone)	T1201M7	Chen et al., 2015b: 112–117
Shimao	Shimao3	3455	45	2014	Australian Nuclear Science and Technology Organisation	SI2938/OZO956	AMS	Collagen (human bone)	unknown	Atahan et al., 2014
Shimao	Shimao4	3445	30	2016	Peking University	BA121534	AMS	Lime floor	F6:1	Sun et al., 2018: 38
Shimao	Shimao5	3440	45	2014	Australian Nuclear Science and Technology Organisation	SI2937/OZO955	AMS	Collagen (human bone)	unknown	Atahan et al., 2014
Shimao	Shimao6	3416	50	2014	Australian Nuclear Science and Technology Organisation	SI2935/OZO953	AMS	Collagen (human bone)	unknown	Atahan et al., 2014
Shimao	Shimao7	3411	30	2016	Beta Analytic Radiocarbon Dating, Miami AMS Lab	Beta410057	AMS	Collagen (human bone)	HJGD001	Sun et al., 2018: 38

Additional information for Table 3.1 that covers the details of the radiocarbon dates studied in Chapter 3.

Appendix II

	2000–1600 BC												1600–1300 BC	
	Huoshiliang (from 2016)		**Shimao (from 2012–2013)**		**Shimao (from 2011–2016)**		**Xinhua (from 1996–1999)**		**Zhaimaoliang (from 2014–2015)**		**Zhukaigou (from 1977–1984)**		**Zhukaigou (from 1977–1984)**	
	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI
Total domestic species	**1056**	**87**	**1498**	**132**	**2604**	**92**	**155**	**19**	**381**	**23**	**114**	**15**	**795**	**120**
Dog (*Canis familiaris*)	15	4	30	3	54	12	75	4	4	1	3	1	19	6
Pig (*Sus domesticus*)	131	13	463	52	765	17	39	11	100	6	32	5	220	45
Sheep/goat (*Ovis aries*/*Capra hircus*)	693	61	651	57	1224	52	18	2	129	10	33	5	365	50
Cattle (*Bos taurus*)	217	9	349	19	561	11	23	2	148	6	46	4	191	19
Horse (*Equus Caballus*)	0	0	5	1	0	0	0	0	0	0	0	0	0	0
Total wild species	**53**	**22**	**17**	**9**	**60**	**14**	**14**	**6**	**16**	**5**	**0**	**0**	**77**	**18**
Raccoon Dog (*Nycetereutes procynides*)	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Bharal (*Pseudois nayaur*)	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Hare (*Lepus sp.*)	3	1	2	1	17	5	0	0	0	0	0	0	0	0
Roe deer (*Capreolus capreolus*)	2	1	1	1	0	0	4	2	0	0	0	0	25	5
Bactrian camel (*Camelus bactrianus*)	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Himalayan goral (*Naemorhed goral*)	0	0	0	0	0	0	0	0	0	0	0	0	1	1
European badger (*Meles meles*)	1	1	0	0	0	0	0	0	0	0	0	0	2	1
Leopard cat (*Felis bengalensis*)	5	2	0	0	0	0	0	0	0	0	0	0	0	0
Tiger (*Panthera tigris*)	2	1	0	0	0	0	0	0	0	0	0	0	0	0
Leopard (*Panthera pardus*)	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Red fox (*Vulpes vulpes*)	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Chinese zokor (*Eospalax fontanierii*)	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Gansu zokor (*Eospalax cansus*)	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Rat (*Rattus norvegicus*)	0	0	2	1	21	5	0	0	2	1	0	0	0	0
Wild boar (*Sus Scofa*)	0	0	10	4	0	0	0	0	0	0	0	0	0	0
Equus sp.	3	1	0	0	4	1	1	1	0	0	0	0	0	0
Gazella sp.	7	5	0	0	18	3	3	2	6	1	0	0	0	0
Ursus sp.	0	0	0	0	0	0	0	0	0	0	0	0	2	1
Cervus sp.	26	6	1	1	0	0	6	1	7	2	0	0	45	8
Total mammal species	**1109**	**109**	**1515**	**141**	**2664**	**106**	**169**	**25**	**397**	**28**	**114**	**15**	**872**	**138**

Additional information for Table 5.1 that covers the detailed list of mammal species considered in the analysis of taxonomic abundances in Chapter 5.

Glossary of Chinese terms

Ashan 阿善

Baicaota 白草塔

Bainiyaozi 白泥窑子

Baiyagou 白崖溝

Bancheng 板城

Baodun 宝墩

Baotou 包头

bei 杯

Beijing 北京

bi 壁

Bicun 碧村

bo 钵

Chifeng 赤峰

Cishan 磁山

Dabagou 大坝沟

Daibie 大别

Dagujie 大古界

Daihai 岱海

Dakou 大口

Damiaogedan 大庙圪旦

Damiaopo 大庙坡

Daqing 大青

Dawenkou 大汶口

Donghulin 东胡林

dou 豆

ding 鼎

Ejin 额济

Erliban 二里半

Erlitou 二里头

Ershilipu 二十里铺

Fanzhuangzi 樊庄子

fu 釜

gang 缸

Gansu 甘肃

Gaojiaping 高家坪

guan 罐

Guandi 官地

Guanhugeda 关胡疙瘩

gui 簋

gui 鬶

Haishengbulang 海生不浪

hangtu 夯土

Hanjiageda 韩家圪旦

he 盉

Hebei 河北

Heimaban 黑麻板

Helan 贺兰

Henan 河南

Hexi 河西

Houchengzui 后城嘴

Hougang 后岡

Houyangwan 后阳湾

Houzhaizimao 后寨子峁

hu 壶

huang 璜

Huangchengtai 皇城台

Hujiawa 呼家洼

Huoshiliang 火石梁

jia 斝

Jiadamao 贾大峁

Jiahu 賈湖

Jilin 吉林

Kaogu 考古

Kaogu yu wenwu 考古与文物

Laohushan 老虎山

li 鬲

Liangzhu 良渚

Liaoning 辽宁

Lingjing 灵井

Lingkou 零口

Longshan 龍山

Luliang 吕梁

Lushanmao 蘆山峁

Mianpo 面坡

wan 碗

Wangyanpan 王阳畔

Miaodigou 庙底沟

Miaoliang 庙梁

Miaozigou 庙子沟

Muzhuzhuliang 木柱柱梁

Nanhao 南壕

Nanzhuangtou 南庄头

Ningxia 宁夏

pan 盘

pen 盆

ping 瓶

Qijiaping 齐家坪

Qingcaota 青草塔

Qinghai 青海

Qingshui 清水

Sandaogou 三道沟

Sanzuodian 三座店

Shaanxi 陜西 Shamujia 莎木佳

Shang 商

Shangdong 山東

Shanxi 山西

Shengedaliang 神圪垯梁

Shihushan 石虎山

Shijiahe 石家河

Shiluoluoshan 石摞摞山

Shimao 石峁

Sichuan 四川

Taosi 陶寺

Tuwei 秃尾

Wei 渭

Weifen 蔚汾河

Weijun 威俊

weng 瓮

Wenwu 文物

Wuzhuangguoliang 五庄果墚

Xiajiadian 夏家店

Xiaomiao 小廟

Xiaoshawan 小沙灣

Xiata 下塔

Xibaiyu 西白玉

Xicha 西岔

Xinjiang 新疆

Xinhua 新華

Xishata 西沙塔

yan 甗

Yangchanggou 杨厂沟

Yangjiesha 杨界沙

Yangshao 仰韶

Yangzi 揚子

yazhang 牙璋

Yongxindian 永興店

yu 盂

Yuanzigou 园子沟

yue 钺

Yulin 榆林

zeng 甑

Zhaimao 寨峁

Zhaimaoliang 寨峁梁

Zhaishan 寨山

Zhaizigadan 寨子圪旦

Zhaizishang 寨子上

Zhaizita 寨子塔

Zhejiang 浙江

Zhengzemao 鄭則峁

Zhongguo Wenwubao 中国文物报

Zhoujiazhuang 周家庄

Zhunagwoping 庄窝坪

Zhuannian 转年

Zhukaigou 朱開溝

zun 尊