EATING IDENTITY: FOOD, GENDER, AND SOCIAL ORGANIZATION IN LATE NEOLITHIC NORTHERN CHINA

BY

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DISSERTATION

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ABSTRACT

The Dawenkou Neolithic Culture (ca. 4300-2600 cal. BC) in Shandong, northern Jiangsu and Anhui Provinces, China, has been intensively investigated because it provides insights into the origin of complex stratified societies. Dawenkou is well known for its extremely elaborate burials indicating incipient social stratification. The initial spread of rice from southern China to the millet agriculture-based societies of the Yellow River Valley, including Dawenkou region, also occurred during this period. Dawenkou is also the assumed critical transitional period during which societies were changing from matrilineal/matriarchal clans to patrilineal/patriarchal families.

In this thesis, I shall argue that rice consumption had been used as an important identity marker (including ethnicity, gender, and social status) of individuals at some Dawenkou site, and the introduction of rice possibly facilitated the development of incipient social stratification. I shall also argue that the assumed transition to patrilineal/patriarchal families did not occur simultaneously across all Dawenkou sites. Some late Dawenkou site was still matrilineal, while females seem to have special status than males at some other late Dawenkou site.

My thesis focuses on the questions of the relationships among social organization, gender relations, and staple food preferences in identity formation and the development of social complexity in four Dawenkou sites (Dongjiaying, Fujia, Huating, and Liangwangcheng). Key to understanding these questions are the integration of mortuary evidence, radiocarbon dating, stable isotope analysis, and ancient DNA analysis of human remains.

My radiocarbon dating results suggest that Liangwangcheng, Fujia, and Huating all date to 2800-2500 cal. BC, while Dongjiaying is a few centuries later (2600-2300 cal. BC). The contemporary nature of these sites permits synchronic and diachronic comparisons of diet composition and burial customs among communities over a few centuries. Despite the contemporaneity there is significant variation in the development of social stratification. Huating seems to be the most stratified with evidence of human sacrifices in some burials. Liangwangcheng also shows signs of social stratification by the lavishness of some burials, and the inclusion of exotic goods that suggest long distance trade. In addition, some females seem to have privilege over others in the community. There is no evidence supporting the hypothesis that a transition to patriarchal families occurred at this late Neolithic site with increasing social

complexity. Based on the limited information available, Fujia community seems to be more egalitarian.

My stable isotopic analysis of human and faunal remains from these sites suggests that food consumption varied across landscape and among different individuals within sites. Fujia and Dongjiaying human diets were dominated by millets and millet-fed pigs, while Huating and Liangwangcheng people had more diverse diets, including significant amount of C_3 plants such as rice and C_3-feeding animals and/or aquatic resources. Fujia and Dongjiaying are located further north, and Huating and Liangwangcheng are further south. My dietary reconstruction with stable isotopes, combined with archaeological evidence, supports a model of a late Dawenkou population with well-established millet agriculture that gradually adopted rice that was introduced from southern China and gradually spread north.

Contrary to the longstanding conventional assumption that the social organization was patrilineal by late Dawenkou (3000~2600 BC), my ancient DNA analysis results suggest that matrilineal links were quite important at Fujia, and this community was very likely matrilineal. In addition, it seems husbands were not incorporated into their wives' descent groups at death but were buried with their own matrilineal descent groups instead.

This study makes three contributions to anthropological archaeology. First, this research is the first that integrated multidisciplinary approaches, including stable isotope analysis, ancient DNA analysis, and mortuary evidence, in addressing archaeological problems, at least in Chinese archaeology. This approach is potentially applicable in other regions of the world addressing similar or different archaeological problems. It is especially useful for researchers studying prehistoric cultures who often struggle with the lack of detailed written records. Second, this dissertation introduces a new perspective on food studies in late Neolithic China. It tries to understand food consumption in its social context, such as an individual's gender, social, and ethnic identities. In addition, this study suggests that food consumption practices can play a critical role in marking social differences and facilitating the development of social stratification. Third, this research on the Dawenkou culture demonstrates that there can be significant variations in many regards at different archaeological sites belonging to the same culture, such as food consumption practices, the development of social stratification, and gender relations. We need to carefully examine each site before making assumptions in the future.

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CHAPTER 1

INTRODUCTION

This dissertation research is designed to investigate how and why rice was adopted during the late Neolithic era in northern China, and how the adoption of rice was intertwined with other social changes such as the development of incipient social stratification and changing gender relations. I use archaeological evidence from mortuary contexts, combined with genetic and isotopic analyses of human skeletons, to reconstruct changes in diet, status, gender roles, social organization and social complexity. This dissertation offers a new approach for archaeology in China. There is no previous research combining all three methods to address an archaeological problem in Chinese archaeology.

The Dawenkou late Neolithic culture in Shandong and northern Jiangsu and Anhui Provinces (area 2 in Figure 1.1; Table 1.1) has been intensively investigated because it provides insight into the independent origin of complex stratified society (Chang 1986; Liu 2004). Dawenkou (4300-2600 cal. BC) is well known for its extremely elaborate burials indicating incipient social stratification (Pearson 1981; Underhill 2000; Underhill 2002). While many graves were small and accompanied by less than ten artifacts, others were huge, elaborately constructed tombs filled with finely worked ceramic vessels, jade objects, water deer canines and pig skulls.

Dawenkou is important in several regards. The preceding Beixin culture (Table 1.1) in this region was relative egalitarian (SPICRA 2005). Dawenkou marks the beginning of an era with evidence for incipient social stratification. The Longshan culture, which follows Dawenkou, evinces more pronounced social stratification (Table 1.1; SPICRA 2005). The complex mortuary tradition of the early Bronze Age Shang dynasty—the first recorded dynasty in China (ca. 1600-1050 BC)—had its precursor in Dawenkou culture, sharing features such as stratified burials, similar styles of tomb construction and elaborate drinking vessels as grave goods. Dawenkou is also the assumed critical transitional period during which societies were changing from matrilineal/matriarchal clans to patrilineal/patriarchal families (He 1994; Luan 1997). This model of the evolution of social organization reflects the overwhelming influence of Engels (1884) in China.

The initial spread of rice from southern China also occurred during this period. Millet had been the main staple in cool-arid northern China, including Shandong Province, since the early Neolithic; rice was the staple in warm-humid southern China (Lu 1999; Yan 2000; Crawford 2006; Figure 1.2). However, rice has been found sporadically in Dawenkou sites, and all across Shandong in the later Neolithic Longshan culture sites (ca. 2600-2000 cal. BC, Jin 2001; Luan 2008; Figure 1.3). Scholars have proposed different explanations for the adoption of rice agriculture in northern China during late Neolithic and early Bronze Age. Some attribute the adoption of rice in northern China to a warmer and moister climate in the late/middle Holocene (Chen 1996; Jin et al. 2004). The rationale behind this argument is that rice has higher yields than millet (Chang 2000). Therefore people should adopt rice agriculture whenever possible. However, there are two lines of evidence that contradict this proposition. First, rice yields were not higher than those of millet until the Han Dynasty (206 BC –AD 220) according to historic records (Wu 1985: 194). Second, paleoenvironmental reconstructions (Jin and Liu 2002; Qi 2006) suggest that the later Longshan period was cooler than the earlier Dawenkou period despite the wider distribution of rice in northern China. Climate change cannot fully explain why rice was adopted. Therefore we also need to consider other economic, social, cultural and political factors (Underhill 2002), and several hypotheses have been proposed by different scholars.

Crawford and colleagues (2005) propose that farmers at the site of Liangchengzhen, Longshan culture, used a combination of millet and rice agriculture as a risk-management strategy. McGovern and colleagues (2005) argue that an alcoholic beverage made with rice was more effective in communicating with ancestors. Based on residue analysis of pottery at Liangchengzhen, they found that the alcoholic beverage was made exclusively of rice, even though both millet and rice were present at the site. Fuller and Qin (2009) argue that the spread of rice agriculture was triggered by the development of more intensive management systems, and thus would have required certain social changes towards hierarchical societies rather than just rice cultivation per se. The archaeological, isotopic and genetic evidence presented in this dissertation may contribute to tests of some, but not all of these models and hypotheses.

Despite much previous study on Dawenkou culture, many questions remain, such as gender relations, dietary change, kinship systems, regional interaction patterns, geographic origins of cultural practices, and the relationships among diet, status and identity. This dissertation research is the first in Chinese archaeology to consider dietary change from the perspective of identity, and more broadly by considering social status, gender relations, and ethnicity or social affiliation[1]. In addition to considering mortuary evidence, stable isotope analysis and ancient DNA analysis are especially useful in addressing my research questions. In my dissertation research stable isotope analysis is used to reconstruct individual's diet, and ancient DNA analysis is used to find out individual's geographic origins and reconstruct social organization. More detailed discussions of these two methods are presented in "Materials and Methods" section of this chapter and in Chapters 5 and 6.

Objectives and Hypotheses

Food consumption often constitutes an important part of individual's ethnic, social, and gender identities (Hastorf 1991; van der Veen 2003; Lewis 2007; Twiss 2007). This research will explore how people may have chosen different staple foods to represent their identity, how political and economic factors might influence food choices, how such choices may have facilitated the process of developing social stratification, what kind of role gender played in the process, and also whether there was large scale northward population migration contributing to the spread of rice farming into regions where millets had been the dominant crops for over two millennia.

Hypothesis 1: Rice consumption among different individuals from the same site, as measured by carbon isotope ratios of human bones, varies independently with individual's identities, such as ethnicity, social status, and gender. It implies that rice was not used as an identity marker, and people had equal access to it and generally accepted this new crop. If all individuals within sites have similar low carbon isotope ratios indicating rice consumption, then this hypothesis is supported.

Hypothesis 2: Rice consumption among different individuals from the same site, as measured by carbon isotope ratios of human bones, varies directly with an individual's ethnic identity, as measured by the individual's genetic signatures. In other words, rice consumption was used to signal the ethnic identity of individuals. This hypothesis is based on the assumption that people who consumed more rice originally came from southern China where this staple crop

[1] Here for " ethnicity", I am referring to different cultural groups defined by archaeological features, such as Dawenkou and Liangzhu.

was domesticated. In order to affirm their respective ethnic identities, southern immigrants consumed rice, and local people continued to consume millet. If rice consumers in Dawenkou sites, as indicated by low carbon isotope ratios, have genetic signatures more similar to southern Chinese populations than to northern populations, and millet consumers have genetic markers associated with northern Chinese populations, then this hypothesis is supported.

A correlation between geographical affinities and diet could be considered evidence for a cultural preference for rice consumption, and thus a dietary expression of identity maintenance. However, whether people were consciously asserting identity through culinary practices or simply maintaining traditional practices without reflecting on its consequences (Bourdieu 1977) cannot be conclusively demonstrated.

Hypothesis 3: Food consumption among different individuals from the same site, as measured by stable isotope ratios of human bones, varies directly with individual's social status, as determined by archaeological evidence from burials, including grave size, type, associated artifacts, graveside feasting rituals, and human sacrifices. In other words, individuals used differential food consumption as a marker of their social status. Regardless of individual's geographic origins, rice was regarded as a high status food due to the labor involved in production, and only people of higher social status had access to rice or consumed more rice. If higher status individuals have lower carbon isotope ratios and higher nitrogen isotope ratios, reflecting diets with more rice and meat, and and if lower status individuals have higher carbon isotope ratios and lower nitrogen isotope ratios, indicating diets with more millet and less meat, then this hypothesis is supported.

Hypothesis 4: Food consumption among different individuals from the same site, as measured by stable isotope ratios of human bones, varies directly with individual's sex, as determined by osteological and/or genetic analyses. Because of the assumed transition to patrilineal and patriarchal societies during this period, men are expected to have played a special role in the adoption of rice. If males have lower carbon isotope ratios and/or higher nitrogen isotope ratios compared to women, reflecting diets with more rice and/or meat, then this hypothesis is supported.

Related to this hypothesis, I also try to reconstruct forms of social organization with ancient DNA analysis of genetic relatedness among individuals within sites, and evaluate gender relations based on mortuary evidence.

Hypothesis 5: The society had changed from matrilineal/matriarchal clans to patrilineal/patriarchal families during late Dawenkou. This critial transition includes three aspects: (a) late Dawenkou communities traced their descent patrilineally, individuals from the same community should have high mtDNA diversity and low Y-chromosome diversity; (b) the communities were patriarchal that males had higher social status than females, males should have more elaborate burials with more complex tomb construction and more associated grave goods; (c) nuclear families are considered important, hence married couples should be buried in the same burial or at least at the same cemetery. Married-in individuals should have distinctive genetic signatures from the majority of the population if we assume exogamy.

Materials and Methods

In this section I briefly summarize the sources of archaeological materials analyzed, and the basic principles of reconstruction of diet and identity from bioarchaeological (genetic and isotopic) analyses of human bones.

I studied four late Dawenkou sites—Dongjiaying, Fujia, Huating, and Liangwangcheng—in order to assess synchronic and diachronic regional variation in diet and status among Dawenkou communities. Fujia and Dongjiaying are located relatively further north in Shandong Province, and Huating and Liangwangcheng are further south in Jiangsu Province. All four sites have been excavated in previous salvage projects. The excavation report of Huating has been published; the report of Liangwangcheng is close to publication, while the reports of Fujia and Dongjiaying are not available. I did not have the opportunity to excavation at any of sites. However, I have worked closely with directors of previous excavations from Shandong Provincial Institute of Cultural Relics and Archaeology (Fujia and Dongjiaying), and Nanjing Museum (Huating and Liangwangcheng). My collaborators have generously given me permission to work on the collections and provided relevant background information.

Diets are reconstructed with stable carbon and nitrogen isotope analysis of human skeletons. Individual identities are established using several lines of evidence. Social status is inferred from mortuary evidence. Individual sex is identified by osteological analysis and by DNA markers. Areas of origin and population affinities are determined by sequencing the mitochondrial DNA (mtDNA) and the non-recombining region of the Y chromosome of male individuals. In addition, social organization is reconstructed with ancient DNA analysis.

Diet reconstruction with stable isotopes of bone is based on the observation that you are what you eat: the isotopic composition of consumer tissues is a direct and constant function of that of the diet (Ambrose and Norr 1993). Carbon and nitrogen isotope analysis of bone is widely used for reconstructing rice and millet consumption, and amounts of marine and terrestrial animal protein in China (Pechenkina et al. 2005; Hu, Ambrose, and Wang 2006; Dong et al. 2007). Plants with C_4 and C_3 photosynthetic biochemical pathways have discrete bimodal non-overlapping distributions of carbon isotope ratios (van der Merwe and Vogel 1978). Because Chinese millets are C_4 plants, and rice and most other plants in northern China are C_3 (Pyankov et al. 2000), carbon isotope analysis of human bones in China can easily tell us whether the main dietary staple was millet or C_3-based foods such as rice, wheat or wild plants. Wheat and soy were not introduced until the later Longshan culture, so rice would be the most likely Dawenkou C_3 staple crop. More thorough review of the methods and discussion on the applicability of the methods at Dawenkou sites are presented in Chapter 5.

I use stable isotope analysis instead of archaeobotanical and faunal analysis to study people's diet at these Dawenkou sites for two reasons. First, systematic flotation to recover archaeobotanical remains is not a routine practice in China, so the evidence for prehistoric agricultural practices is limited. No flotation results are available for the sites studied in this dissertation. Neither botanical nor faunal evidence can be used to provide quantitative data on proportions of dietary items consumed by individuals. My isotopic analysis partly overcomes this problem because it provides a quantitative method to study plant and animal food consumption of individuals. Second, compared to alternative methods, stable isotope analysis can provide information on food consumption of each individual instead of site- or section-specific information. By combining mortuary evidence and genetic information, I can accurately reconstruct aspects of the identity of individuals and evaluate how food consumption is related to individual identities.

Both stable isotope analysis and ancient DNA analysis have the potential to reveal the geographical origins of individuals. Strontium and lead isotope analyses of teeth have been successfully used to determine migration and residence changes (Montgomery, Budd, and Evans 2000; Price et al. 2010). However, it is only possible to determine at most two generations of residence history from isotopic analysis of teeth formed before and after weaning (Gulson et al. 1998). Genetic markers of origins and dispersals have much greater time depth than chemical and isotopic composition of teeth and can be used to determine descendants of migrants even after hundreds of years. For this reason, I chose ancient DNA analysis in this dissertation in order to identify possible immigrants.

Multiple lines of evidence suggest that modern northern and southern Chinese populations are discernible by genetic markers (Etler 1992; Chu et al. 1998; Yao, Kong, et al. 2002; Yao, Nie, et al. 2002). The overall frequencies of the northern East Asian-dominating mitochondrial haplogroups (A, C, D, G, M8a, Y and Z) are much higher in northern Han (55%, 49–64%) than are those in southern Han (36%, 19–52%). In contrast, the frequency of the mitochondrial haplogroups that are dominant in lineages in southern natives (B, F, R9a, R9b and N9a) is much higher in southern (55%, 36–72%) than it is in northern Han (33%, 18–42%) (Wen et al. 2004). In addition, the frequencies of Y chromosome haplogroups C and N are higher in northern China than southern China, while the frequency of Y chromosome haplogroup O is higher in southern China (Xue et al. 2006). The genetic structure in modern populations is very likely the residual of ancient genetic structure due to different population histories in northern and southern China (Chu et al. 1998; Ding et al. 2000; Ke et al. 2001; Karafet et al. 2001; Xue et al. 2006). Several large-scale population migrations and integrations in Chinese history have blurred this genetic structure (An 2010). I expect Neolithic populations to have a clearer divide between northern and southern China. If so, then ancient DNA analysis can be a viable method in identifying possible southern immigrants in Dawenkou sites.

Ancient DNA analysis is also useful in reconstructing social organization. Genetic analyses of modern populations show that different forms of social organization and marital residence can be reflected in genetic structures (Oota et al. 2001; Chaix et al. 2007; Gunnarsdóttir et al. 2011). The markers I used are mtDNA and the non-recombining region of Y chromosome. mtDNA is maternally inherited (Giles et al. 1980; Merriweather and Kaestle 1999), and can be used to trace maternal relatedness. The non- recombining region of Y-chromosome is paternally inherited and can be used to trace paternal relatedness. Based on the relatedness of individuals found within a cemetery, I could infer whether the community was matrilineal or patrilineal. If marriage ties were important at death and spatial arrangement of burials can represent marital residence, I could further infer whether the community was matrilocal or patrilocal.

Overview of This Dissertation

This dissertation is divided into seven chapters. Chapter 1 is the introduction, briefly outlining the research questions. Chapter 2 introduces the theoretical background of my research, including food and identity, kinship, and social organization. I will discuss why it is important to study food, kinship, and social organization, how we can address these questions with archaeological evidences, and how they have been studied in Chinese archaeology in general. Chapter 3 presents the background information on the Dawenkou Neolithic culture. In this chapter, I will first introduce the characteristic defining features, geographic distribution, and chronology of the Dawenkou culture, followed by discussions on subsistence. Then I will move on to its social organization, including incipient social stratification, kinship and gender relations. Chapter 4 describes the archaeological background of the four late Dawenkou sites (Dongjiaying, Fujia, Huating, and Liangwangcheng) and discusses signs of incipient social stratification and gender relationships at each site, mostly drawing on mortuary evidence. My radiocarbon dating results of human remains from these four sites are presented at the end of this chapter. Chapter 5 presents my stable isotopic analysis results and ties food consumption and identity together. I will first discuss the applicability of stable isotope analysis in dietary reconstruction at Dawenkou sites. Next, I will describe the methods and results of stable isotope analysis. Thereafter I will situate the food consumption patterns at each site in their specific social context. Chapter 6 presents the results of ancient DNA analysis and the insights it provides on social organization. One of the primary objectives for using ancient DNA analysis was to investigate possible links between rice consumption and geographic origins. Unfortunately, this goal was not achieved due to the poor preservation condition of human remains at Liangwangcheng, Huating, and Dongjiaying. However, human remains at Fujia were preserved well enough to yield reproducible sequencing results. I was able to reconstruct social organization at Fujia based on ancient DNA analysis results. Chapter 7 summarizes the key findings, discusses significance of the finding for testing alternative models for the development of social complexity in northern China, and suggests avenues for future research.

Table

Table 1.1. Chronology of major Neolithic and early Bronze Age cultures and early in the central and lower Yellow River Valley and lower Yangtze River Valley (adapted from H. Zhang 2003: Tables 4-6 and 4-8 and Liu 2004: Table 1.1).

Period/Era	**Central Yellow River Valley**	**Lower Yellow River Valley**	**Lower Yangtze River Valley**	**Approximate Date Range (BP)**
Early Bronze Age	Shang	Shang		3550-3000
	Erlitou	Yueshi		3850-3450
Late Neolithic	Henan Longshan Culture	Shandong Longshan Culture	Liangzhu Culture	4500-4000
		Late Dawenkou Culture		5000-4500
Middle Neolithic	Yangshao Culture	Middle Dawenkou Culture	Songze Culture	5500-5000
		Early Dawenkou Culture		6000-5500
		Beixin Culture	Majiabang Culture	7000-6000
Early Neolithic	Peiligang Culture	Houli Culture		8000-7000

Figures

Figure 1.1. Major Neolithic Cultural areas in China: 1) the central Yellow River Valley; 2) the lower Yellow River Valley; 3) the northeast; 4) the central Yangtze River Valley; 5) the lower Yangtze River Valley; 6) southernmost China (from Underhill and Habu 2006: Figure 7.1).

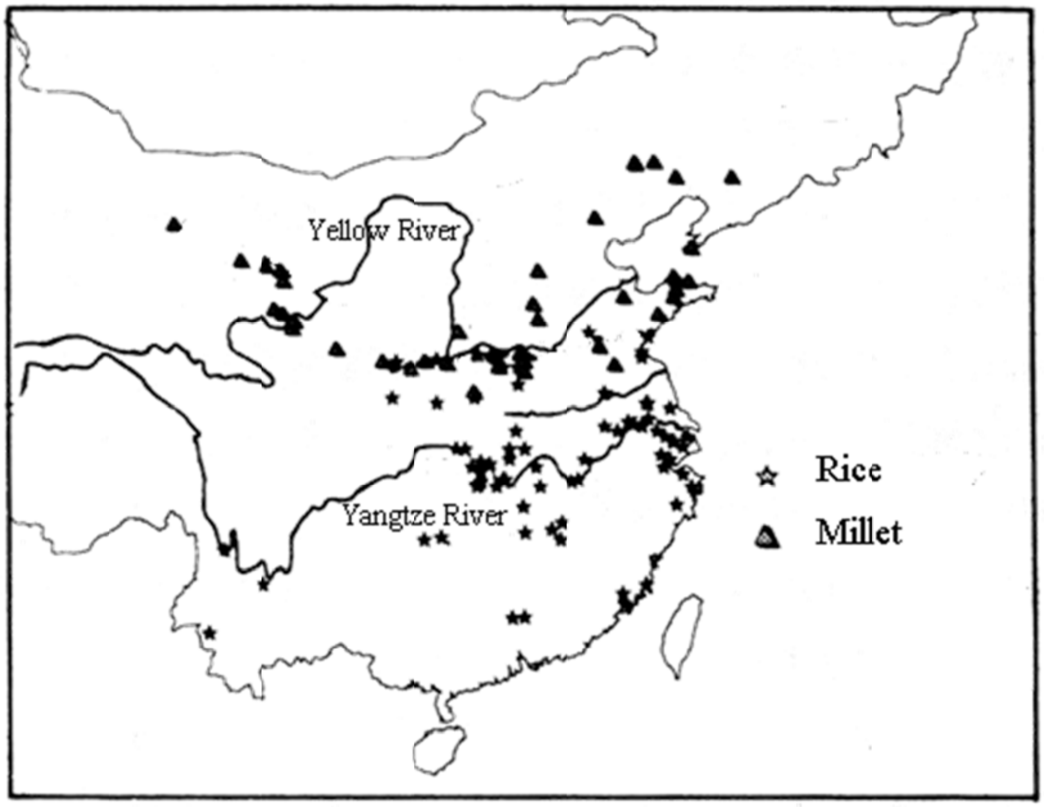

Figure 1.2. Distribution of millet and rice remains dating between 5000-2000 B.C. in China (modified from Fang et al. 1998: 17).

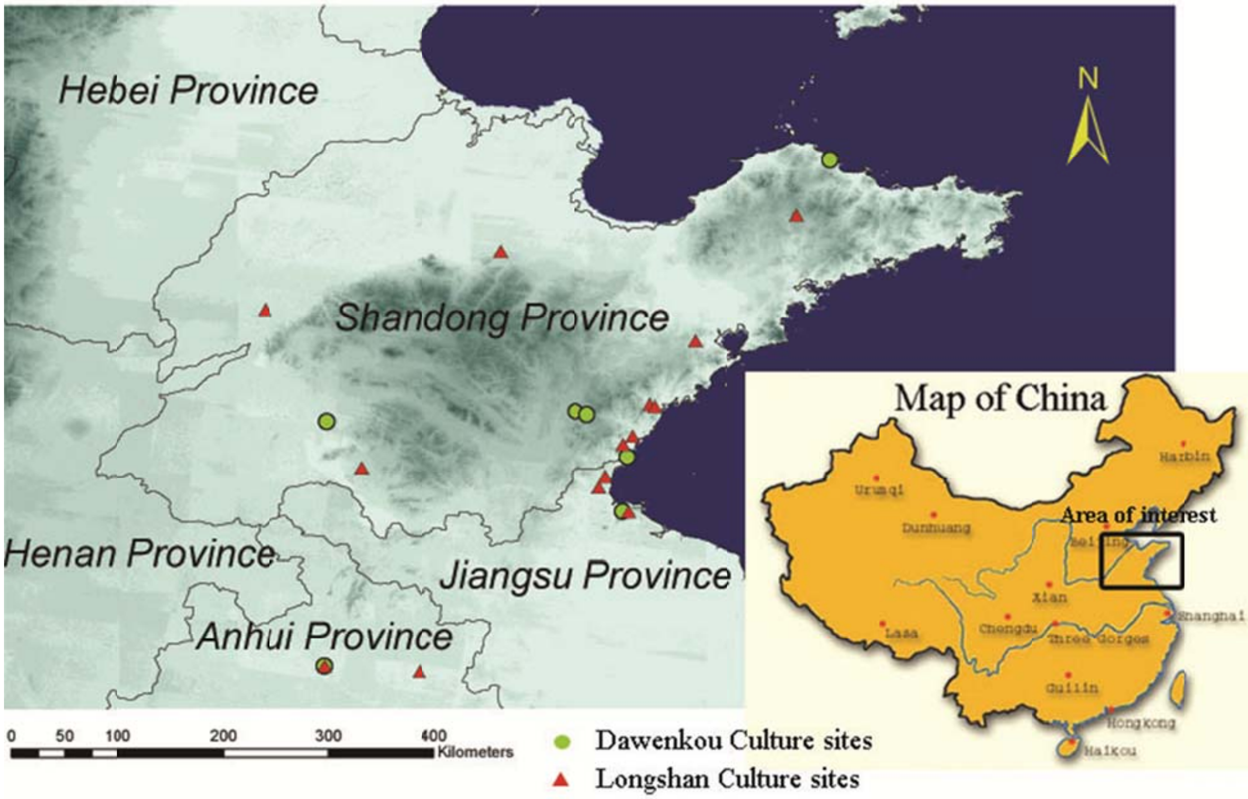

Figure 1.3. Distribution of Dawenkou and Longshan Culture sites with archaeobotanical evidence of rice, including carbonized grains and other plant parts, pollen or phytoliths.

CHAPTER 2

THEORETICAL BACKGROUND: FOOD, KINSHIP, AND SOCIAL ORGANIZATION

As discussed in the previous chapter, three critical changes took place during the Dawenkou period, including the introduction of rice, the assumed changes in gender relationships and kinship systems, and the incipient development of social stratification. In order to further investigate these changes in this dissertation, I will first lay out the theoretical background of food consumption, kinship systems, and social organization. In this chapter, I will discuss why it is important to study food, kinship, and social organization, how we can address these questions with archaeological evidence, and how they have been previously studied in Chinese archaeology.

Social Dimensions of Food Consumption

The social and symbolic, rather than subsistence and economic, dimensions of food consumption and culinary practices have gradually gained more attention from archaeologists in the last two decades (Dietler and Hayden 2001; Bray 2003; Mills 2004; Smith 2006; Twiss 2007, 2012; Baker et al. 2008; Fuller and Rowlands 2009; Klarich 2010). The interaction between people and food can be classified into four types of activities: food production, food processing, food consumption, and food discard. Due to the method I have chosen—stable isotope analysis—and the emphasis on millet versus rice consumption in this dissertation, here I mainly review the literature on food consumption.

Within the domain of food consumption, feasting has generated much scholarly work because it is usually more visible in the archaeological record, and it is often charged with special social and political meanings. As argued by Dietler (2001), feast-hosting is often a key strategy in the acquisition and maintenance of political capital. Feasting can be an avenue to signal superiority of one social group over another by competitive display and debt creation (Junker 1999). It can also be a medium to bolster partisan loyalty and craft a strong group image by “inclusionary feasts” (LeCount 2001). Graveside feasting in Neolithic China is considered to have been important for connecting to ancestors, and also critical for competitive display of wealth and power (Liu 2000; Fung 2000; Underhill 2002; Nelson 2003). However, food consumed in daily meals is also charged with social meanings, such as ethnicity, status, and gender, etc. Comparing to feasting, everyday food consumption has received much less attention. The discussion below is largely based on daily consumption practices.

Food often constitutes an important part of cultural identity (Smith 2006). The use of a particular cuisine or staple food often marks the boundary between ethnic groups, for example, rice-eating Asians versus bread-eating Europeans (Ohnuki-Tierney 1993), the millet-eating northern Chinese versus rice-eating southern Chinese in Neolithic China (Lu 1999), and the wheat-eating northern Chinese versus rice-eating southern Chinese in recent and modern traditional China (Anderson 1988). Ancient South Arabia provides an archaeological example: the desert fringe agriculturalists perceived themselves as radically distinct from both the nomadic dwellers of the open desert and the farmers of the highlands by the appropriation and consumption of symbolically meaningful foods, even though they shared rituals of communal feasting in honor of national deities (Lewis 2007).

Food is also critical for social and economic status expression and negotiation. Exotic or labor intensive foods are often associated with high social status; the elites may actively use food or food practices to differentiate themselves from other social classes. Faunal analysis of Postclassic Maya communities suggests that large game animals are more frequently represented in upper status and ritual contexts (Masson 1999). By studying the spatial distribution of metates, Turkon (2007) demonstrated that Mesoamerican elites actively used the consumption and preparation of foods to visibly distinguish themselves from other social groups. Hendon (2003) reached similar conclusions by comparing ceramic vessels among households. In addition, how food is consumed can be used to signify status differences. A big impetus for the development of table manners and menu by the upper class Europeans was to distinguish themselves from common people during the early post-Medieval period (Van der Veen 2003).

Food production is often gendered. For instance, food production in hunter-gatherer societies is generally pictured as man the hunter and woman the gatherer, or man the farmer and woman the weaver in farming societies. However, by integrating ethnogaphic, ethnohistoric, and archaeological evidence of food production in Maya communities, Robin (2006) demonstrates that women probably also played a critical role in farming activities. In addition, food processing is also gendered. Food processing is often assumed as women's task (Brumfiel 1991; Hastorf

1991; Crown 2000; Turkon 2007; Joyce 2010). Food consumption is generally gendered as well. Unfortunately, little archaeological research on daily food consumption and gender has been published so far, possibly due to the limitation of available methods. An ethnographic example comes from Hindu South Asia: even though women are the cooks, men usually eat first, and women only eat what is left (Appadurai 1981). An archaeological example is provided from late prehispanic Andean highlands: Hastorf (1991) demonstrated that female activities were more constrained and intensified during Wanka III, representing an escalation of women's labor to support social-political activities, however, females consumed less maize and meat compared to males.

To summarize, food consumption is intertwined with various aspects of social and cultural identities. Food studies provide a critical lens through which we can view how people may have chosen different foods to represent and negotiate their ethnic, social, and gender identities in ancient societies. Previous research on how daily food consumption is related to the identities of individuals is relatively rare. It is especially true in Chinese archaeology. My research will add to the limited literature on the subject and help us better understand how daily food consumption could contribute to individual's identity negotiation and affirmation.

Kinship System

Kinship in humans is more than biological relatedness: it is also socially constructed, and kinship systems vary widely among cultures (Carsten 2000). This is summarized nicely by Marks (2002: 251): "kinship is a way of defining social networks, establishing obligations, and organizing the transmission of property across generations". Through marriages, which are sanctioned social reproduction, social networks are further extended. Some relationships are emphasized, while others are discounted in different societies (James 2008). Gamble (2008) argues that extended and socially constructed kinship systems distinguish us from other primates, and facilitated the early modern human global diaspora. Leaf and Read (2012) claim that kinship is the primary course through which human infants learn the linguistic, conceptual, and organizational fundamentals of self-construction, role taking, and reciprocity.

Common components of kinship organization include rules about incest, marriage, inheritance, residence and membership. It seems that rules of post-marital residence (matrilocal, patrilocal and neolocal) and membership are more flexible and predominantly neolocal for extant hunter-gatherers (Hill et al. 2011), and more fixed, either matrilocal or patrilocal, for sedentary farmers who are more attached to the land and tend to localize the majority of the members of at least one sex on or near the land of the descent group (Gough 1961).

There are diverse ways of tracing descent in both mobile hunter-gatherers and sedentary farmers (Murdock 1967). Based on rules of descent, we can divide societies into patrilineal ones that trace their descent through paternal lines, matrilineal ones that trace their descent through paternal lines, and bilateral ones that trace their descent both ways. There are many unresolved debates regarding whether early human descent reckoning was matrilineal or patrilineal (Knight 2008).

It is likely that kinship was the primary form of social organization for most prehistoric societies, and even for some historic societies. It has been assumed that the organization of the state institution was much less kinship-based (Adams 1966), because kinship is not as effective for organization beyond a certain population size. Trigger (2003: 48) also argues that "class displaced kinship and ethnicity as the main organizing principle of society", while "religious concepts replaced kinship as a medium for social and political discourse" in early civilizations. However, scholars have recently realized that there are many variations in social organization among societies, and kinship probably still played a significant role in early states (Stone 1995; Stein 1998). For example, in Mesopotamia, which was famous for its extensive bureaucracy, kinship remained an important element in social organization (Ur and Colantoni 2010). Kinship, descent ties especially, was fundamental for social organization during the first recorded dynasty in China—the Shang (Keightley 1999a; Chang 2005; Lu and Yan 2005). It was probably the primary form of social organization during the late Neolithic as well (Liu 2000; Fung 2000).

Kinship studies in Chinese archaeology

Chinese archaeologists commonly assume that early Chinese Neolithic societies were organized in matrilineal/matrilocal clans, and gradually evolved to patrilineal patrilocal monogamous families, with patrilineal clans as a transitional stage. This model of the evolution of social organization reflects the dominating influence of Engels (1884) in China. Matrilineal, matrilocal[1], matriarchal are used relatively synonymous among Chinese archaeologists, and the

[1] The translation of matrilocal into Chinese is *cong mu ju* (从母居), which literally means living with the mother. This translation might cause confusion for Chinese readers. C*ong mu ju* in Chinese is generally understood as living with the mother's family

assumption is that a matrilineal society is always a matrilocal and matriarchal one, and vice versa (e.g., Wang 1982; Zhang 2000; H. Zhang 2003). However, these three terms actually refer to three different aspects of gender-based organization. Matrilineal refers to descent reckoning through the female lineage. Matrilocal emphasizes post-marital residence location: females remain at their birthplace, while males move to and live with the wife's family. Matriarchy refers to female-based leadership or power (Haviland 1996: 261, 275, 301). Matrilineal and matrilocal do not always go hand in hand (Schneider and Gough 1961), and matriarchal societies are extremely rare (Hua 2001; Murdock 1967; Schneider and Gough 1961).

We know little about prehistoric kinship systems because they are hard to reconstruct with most kinds of archaeological evidence (Jiao 2001). However, with the help of ancient literature and early writings on oracle bones and bronze wares (e.g. von Falkenhausen 2006), we do know something about the kinship systems of ancient Chinese societies. During the Shang dynasty, kinship was fundamental for social organization. The Shang king was the lineage head on the main line of descent. Political power was largely determined by the individual's position in his kin group. All Shang cemeteries were lineage cemeteries organized according to a patrilineal descent system (Chang 1980; Keightley 1999a; Chang 2005; Lu and Yan 2005). It is speculated that kinship and patrilineal lineages were probably the primary form of social organization during late Neolithic as well.

At the dawn of Bronze Age civilization, the Taosi cemetery, Shanxi Province (Xie 2007), and the Chengzi cemetery, Shandong Province (CDWGZ and Zhucheng County Museum 1980), share two distinctive features: tombs are distributed in groups, and each group contains large, medium, and small tombs. It is argued that each group represents a lineage, while the categories of tombs within a group represent the different social ranks of its member. A similar argument was made for the middle Neolithic Yangshao cemetery of Yuanjunmiao. Zhang (1985) analyzed the burial arrangements of the cemetery and argued that two clans were represented in the cemetery with extended families within each clan. In addition, he noted that juvenile females had

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instead with the fathers' family, either before or after the children get married. In this sense, *cong mu ju* is very similar to matrilineal. However, matrilocal in English emphasizes post-marital residence pattern.

more elaborate burials than males, and argued that the community was organized in matrilineal and probably matriarchal clans[2].

In addition to analyzing the spatial distribution of burials in cemeteries, some scholars have tried to reconstruct prehistoric kinship system with residential features. Ember (1973) and Divale (1977) used cross-cultural ethnographic analysis to propose that based on the living floor area of the average house, one could predict post-marital residence patterns, with matrilocal societies having larger living floor area than patrilocal ones[3]. Similar to this approach, Ma (2004) analyzed houses at Xihe site, Houli culture, and compared them with ethnographic examples supported with historic literature; he argues that this Xihe community was organized in matrilineal clans with men visiting women of another clan in the evening and returning to their own matrilineal clan in the morning.

In sum, we know that the early Bronze Age Shang people were organized in patrilineal lineages. It is widely assumed that this tradition started during the late Neolithic Dawenkou and Longshan cultures. Early and middle Neolithic cultures are believed to have been matrilineal ones. It is hypothesized that Dawenkou was the critical period during which the society began to change from matrilineal/matriarchal/matrilocal to patrilineal/patriarchal/patrilocal (He 1994; Luan 1997c). However, this hypothesis has been challenged (Pearson 1988; Shelach 2004), and has not been thoroughly tested. In Chapter 3, I will briefly review how kinship and gender relationships in Dawenkou culture sites were analyzed in previous studies.

Other approaches to kinship studies

Above, I have briefly reviewed kinship studies in Neolithic and early Bronze Age in China, mostly relying on archaeological evidence. In this section, I will add to that review and discuss kinship reconstructions with stable isotopes, bioarchaeology, and genetic markers analysis.

Strontium isotope ratios of human tooth enamel reflect a person's geographic origin for the

[2] Zhang (1985) argued that the special treatment of some juvenile female burials implied the inherited power or wealth from their mothers, and special power of females. However, the sex identification of preteen skeletons based on morphology alone can be very problematic, and should be confirmed by ancient DNA analysis whenever possible (Stone et al. 1996).

[3] Ember (1973) and Divale (1977)'s conclusions were largely based on statistical analysis by lumping many ethnographic examples together. The potential problem with this approach is that there are many other factors affecting the decision of whether to build a large house in different communities. A more reliable approach might be a statistical analysis using ethnographic, historical, or archaeological data from one region instead of drawing examples all over the world. However, even when using examples from one region, we still need to bear in mind possible changes through time.

enamel that was forming during childhood after weaning. However, a substantial part of the calcium and related elements in teeth formed before weaning may be have originated from the mother's skeletal store of these elements (Gulson, Jameson, and Gillings 1997). Therefore teeth formed before weaning may record, in part, the locations where the mother's skeleton had formed. Analysis of male and female strontium isotope ratios of early and late-forming teeth can reveal post-marital residence patterns of ancient populations, but this has not yet been systematically studied. Bentley and colleagues (2005) compared the strontium isotope ratios of tooth enamel of single teeth of males and females from a prehistoric site in Thailand, and concluded that the community was likely matrilocal because females had more restricted isotopic variance than males, suggesting more restricted geographic origins of females. In other words, most females were probably local people, while males with more diverse geographic origins married into the community. Haak and colleagues (2008) combined strontium isotope and ancient DNA analysis and demonstrated that this Late Stone Age society was exogamous and patrilocal.

Stojanowski and Schillaci (2006) provided an extensive review on how biodistance analysis based on phenotypic data from the cranium or dentition can provide insights on kinship and post-marital residence. Kinship analysis is based on a simple and familiar premise: members of a family are more phenotypically similar to each than to contemporary unrelated individuals. Bioarchaeological kinship analysis could identify individuals who are likely to be closely related but rarely specify the exact genealogical nature of this relationship. Biodistance analysis could also be applied in inferring post-marital residence based on three primary theoretical assumptions: 1. Within a group, the sex with the greater variability is assumed to be the more mobile sex; 2. Among groups, the sex with the greater between group variability represents the non-mobile, or resident, sex; 3. Individual skeletons within a cemetery were members of the community that used that cemetery. Biodistance analysis has been applied at one Neolithic site in China —Shijia. Gao and Lee (1993) analyzed craniometric measurements of human remains at Shijia and found that individuals within one burial were more closely related than among burials. Because female burials were underrepresented in this site, the authors rejected the possibility of a matrilocal and matriarchal community[4].

[4] Females are underrepresented in many other Neolithic cemeteries in China (Chen, 1990). Various explanations have been proposed, such as selective infanticide, more females dying young, different burial treatments from males, and sex identification bias (Keightley 1999b).

Genetic analysis for kinship and post-marital residence reconstruction is based on assumptions similar to those for biodistance analysis. It has been proven to be an effective method to study the social organization of ancient communities (Keyser-Tracqui, Crubézy, and Ludes 2003; Haak et al. 2008; Baca et al. 2012). Mitochondrial DNA (mtDNA) analysis can identify maternal relationships among individuals; the non-recombining region of the Y-chromosome (nrY) traces paternal relationships and population history. Microsatellite analyses of autosomal nuclear DNA are regularly used in kinship identification in forensic science (Butler 2012). Genetic analysis is especially effective for distinguishing post-marital residence patterns due to sex-biased migrations. For example, matrilocal societies should have relatively lower mtDNA diversity and higher Y-chromosome diversity. Conversely, among patrilocal communities, we expect relatively higher mtDNA diversity and lower Y-chromosome diversity. This hypothesis has been well tested in modern matrilocal and patrilocal communities (Gunnarsdóttir et al. 2011; Oota et al. 2001; Kumar et al. 2006).

Ancient DNA analysis has been completed on only a few prehistoric populations in China (ADLJU 2001; Gao et al. 2007; Li H. et al. 2007; Zhang et al. 2010). Whether ancient communities changed kinship organization and post-marital residence in different regions within China remains largely untested. In Chapter 6, I will describe my attempt to discern the maternal and paternal relationships among individuals by sequencing the mtDNA and Y-chromosomes of individuals from two Dawenkou culture sites. Based on results of ancient DNA analysis I will discuss the social organization in this community 4800 to 4500 years ago.

Reconstructing Social Organization

Reconstructing aspects of social organization is of great interest to archaeologists (Costin and Hagstrum 1995; Kolb and Snead 1997). By social organization, I refer to both the organization within communities, including kinship systems, social ranking among individuals, and the organization among communities such as the development of settlement hierarchy. Below I will first summarize the scholarly debate on reconstructing social organization with burials, and discuss how this approach is applicable in Chinese archaeology. Then, I will briefly review previous research on social organization in Neolithic China.

Debates on reconstructing social organization with burials

Starting with Binford (1971), much emphasis has been put on reconstructing social organization by burials in North America archaeology. However, through a cross-cultural survey, Carr (1995) found a wide array of factors that affect mortuary practices and remains. These factors include social organization, philosophical-religious beliefs, world views, physical constraints, circumstances of death, and ecological relations. More archaeologists (Parker Pearson 1999; Underhill 2000; Flad 2001; Underhill 2002) are now aware that burial practices are the results of complex human behaviors that involve both strategic motives and emotional decisions of the mourners. In addition, burial practices are often constrained by available resources and also by social norms. Therefore, burials do not necessarily provide an accurate reflection of social ranking.

Reflecting the hopes of an emerging processual archaeology, Saxe (1971) and Binford (1971) relied on ethnographic data to identify cross-cultural regularities in the way burials mirror the society with which they are associated. In this view of funerary practice, differential expenditure of energy, the use of symbols of authority or wealth within certain tombs, and a departure from a normal demographic profile all point to the existence of different social roles, in particular, hierarchically ranked social positions (Brown 1981). Some scholars identify direct correlations between the rank of interred individuals and the amount of energy expended on their burial, a value that reflects differential access to the labor required to construct or produce burial structures or offerings (Tainter 1978).

Other scholars have problematized many of these simplistic direct associations by focusing on the activities and statuses of the mourners rather than on the identity of the deceased or the social structure (Peebles 1971). van Gennep (1960), among the others, first proposed that death rituals not only play an important part in establishing and re-creating the social relations between the living and the dead, and also amongst the living themselves. Rather than simply reflecting the existing social reality, funerals are in fact dynamic loci providing opportunities for the reiteration, contestation or even concealment of this reality and its attendant inequalities (Shanks and Tilley 1982; Hodder 1984; Parker Pearson 1993; Cannon 1989). In addition to the physical settings of the funeral, such as the lavishness of the tomb and the quality and quantity of grave goods, the individual body could also be used as a site for the negotiation of social identities and claims about authority (Metcalf and Huntington 1991; Parker Pearson 1999).

Carr (1995) tried to distinguish mortuary practices reflecting social organization and practices reflecting philosophical-religious beliefs. He found that some mortuary variables that appear most useful for reconstructing social organization, in that they are determined more often by social than other kinds of factors cross-culturally, include the internal organization of the cemetery, the overall energy expended on disposal, the number of socially recognized burial types, the number of persons per grave, and the quantity of grave furniture. Variables that appear most useful for reconstructing philosophical-religious beliefs, in that they reflect them more commonly, include body orientation, body position, and the spatial arrangement of furniture in the grave. In particular, burial orientation was found most commonly to reflect society's beliefs about the afterlife, universal orders, and the soul's journey to the afterlife.

Even though scholars in various world areas have argued that burials may not reveal information about the status of people when they were alive, this is often the case in China. For millennia mortuary rituals have been important in this way. The lavishness of tomb construction and the accompanying grave goods directly correspond to the different social status of the deceased as early as the Shang dynasty (Lu and Yan 2005). In addition, burial treatments can also express the status of the mourning kin. The quantity and quality of grave goods could reflect the ability of the hosts to accumulate wealth and get access to exotic goods and labor. The lavishness of a certain burial might represent the aspirations for higher status of a nuclear or an extended family.

Social organization in Neolithic China

Many scholars have attempted to reconstruct social organization in Neolithic China. Some have focused on a specific community, some have used a regional approach, and others have compared evidence from multiple regions and outlined general trends.

Several studies have addressed the social organization at the Jiangzhai site, Yangshao Culture, dated to 5000–4000 BC. Jiangzhai is the most completely excavated and reported agricultural community in the middle reaches of Yellow River Valley. Shelach (2006) compared the layout of residential structures of Zhaobaogou site (northeastern China) and Jiangzhai. He found that houses at Zhaobaogou are arranged in paralleling rows, houses at Jiangzhai are in central facing circles; storage pits are found inside the house at Zhaobaogou, pits are all outside at Jiangzhai. He argued that households were relatively independent production and consumption units with little sharing and exchange among households at Zhaobaogou, while Jiangzhai was more communal sharing oriented. Lee (2007) combined evidence of settlement plan and the distribution of material remains, and suggested that Jiangzhai represented a segmental community with substantial food sharing. Peterson and Shelach (2012) reanalyzed the Jiangzhai dataset from multiple sociospatial and socioeconomic perspectives. They studied the production, consumption, and exchange of foodstuffs and craft goods at two different scales—the residential sector and the individual household. They argued that Jiangzhai displays substantial variability among residential sectors and constituent households in terms of activity emphases and surplus accumulation; it was not a segmental society composed of redundant homologous units.

Extending beyond the community level, scholars studying Neolithic and early Bronze Age China also attempted to investigate social organization at a regional level. Three international collaborative teams carried out systematic survey in Henan Province, central China, Shandong Province, eastern China, and Inner Mongolia, northeastern China, respectively, and they all found some level of settlement hierarchy in each region (Linduff et al. 2004; Liu et al. 2004; Underhill et al. 2008). In the Yiluo River Valley archaeological evidence suggests that the Erlitou core area was a highly centralized political system, and the Erlitou site represents a well-developed hierarchical society. It is likely that some elite items, including white wares, were redistributed through the Erlitou elite. However, independent craftsmen making both elite and non-elite artifacts (such as dolomite spades produced in the Erlitou levels of the Huizui site) in the hinterland did not just play a subordinate role in support of the urban elite: they may have actively pursued status and wealth through their craft skills (Liu et al. 2007).

Some scholars have discussed social organization beyond a specific region and outlined general trends across different regions. Pei (2007) reviewed settlement patterns in several regions of China, including northeastern China, the middle and lower reaches of Yangtze River Valley and the Yellow River Valley. These regions have been relatively thoroughly studied. Pei argued that Neolithic societies were largely organized by kinship and marriage ties between 10,000-7,000 BP. Differences among settlements began to accumulate and form tiers between 6,000-5,000 BP. More complex and stratified organization forms were dominant thereafter, but kinship persisted as a basis for social organization. Based on the analysis of burial patterns at several archaeological sites in the Yellow River Valley, Liu (2000) proposed that different ancestor worship practices— “group ancestor worship” and “individual ancestor worship”—were associated with various social organizations during the Neolithic period. The former may have been associated with an egalitarian social organization, and the latter seems to have deeply influenced the religious and political systems of the Shang dynasty.

Summary

In this chapter I have reviewed the theoretical background of food consumption, kinship system, and social organization for my study. In next chapter I review the general archaeological background of the Dawenkou culture, including chronology, geographic distribution, and defining cultural traits. I also discuss how food, kinship, and social organization have been studied with respect to the Dawenkou culture, and which aspects need further investigation.

In short, food consumption studies provide a critical lens through which we can view how people may have chosen different foods to represent and negotiate their ethnic, social, and gender identities in ancient societies. Previous research on how daily food consumption is related to the identities of individuals is relatively rare, especially in Chinese archaeology. My dissertation addresses this deficiency and tries to investigate how daily food consumption could contribute to identity negotiation and affirmation through dietary reconstruction with stable isotope analysis (Chapter 5).

Archaeologists have attempted to reconstruct kinship systems with both mortuary and residential evidence in Neolithic China. In addition to this archaeological evidence, stable isotopes, bioarchaeology, and genetic markers can also be used to reconstruct kinship systems. In general, we know little about kinship systems in Neolithic China. In Chapter 3, I will briefly review how kinship and gender relationships in Dawenkou culture sites were analyzed in previous studies. In Chapter 6, I will describe my attempt to discern the maternal and paternal relationships among individuals by sequencing the mtDNA and Y chromosomes of individuals from two Dawenkou culture sites.

Even though scholars in various world areas have argued that burials may not reveal accurate information about the status of people when they were alive, this is often the case in China. Archaeologists have used mortuary evidences and settlement patterns to reconstruct social organization in Neolithic China. In next chapter I will discuss signs of incipient development of social ranking in Dawenkou culture with both mortuary and residential evidences. In Chapter 4, I will mostly draw on mortuary evidence from my four Dawenkou sites (Dongjiaying, Fujia, Huating, and Liangwangcheng) and discuss the development of social ranking at each location.

CHAPTER 3

ARCHAEOLOGY OF THE DAWENKOU NEOLITHIC CULTURE

The Dawenkou late Neolithic Culture in Shandong, northern Jiangsu and Anhui Provinces dates to ca. 4300-2600 cal. BC.[1] Based on evidence of archaeobotany, archaeo-fauna, and stable isotope analysis of human remains, Dawenkou people mainly practiced millet agriculture and raised pigs; they also supplemented their diet with hunting and fishing. Three critical changes happened during this era: the development of incipient social stratification, the introduction of rice agriculture, and the assumed changing gender relationship and kinship organization. This dissertation will investigate how these changes happened and how the changes may have affected each other in the process. In this chapter, I will lay out the background information on Dawenkou, i. e. what kind of evidence we have so far about the three critical changes, and what remains not well understood. I will first introduce the characteristic defining features, geographic distribution, and chronology of the Dawenkou culture, followed by discussions on subsistence. Then I will move on to its social organization, including incipient social stratification, kinship and gender relations.

Chronology and Geographic Distribution

The Dawenkou culture was named after the Dawenkou site[2], Tai'an County, Shandong Province, which was first discovered and excavated in 1959 (SACR and Jinan Museum 1974).

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[1] In this dissertation, I will try to use calibrated ages if that information is available, abbreviated as cal. On the other hand, BC, before Christ, and BP, before present, will both be used depending on how the date was reported in the original report.

[2] In order to distinguish the Dawenkou site itself, located at Tai'an, and other sites that belonged to Dawenkou culture, I will refer to the former as the Dawenkou type site, and refer to the latter as Dawenkou culture site or Dawenkou sites.

The Dawenkou culture is defined by its unique ceramic vessel style, including the hollow-foot tripod pitcher (*gui*), jar with one side flat (*beihu*) and goblet (*guxingbei*). Dawenkou sites also shared some cultural practices, such as tooth ablation (maxillary lateral incisors in most cases) and artificial skull deformation. However, those practices were not present in every Dawenkou culture site, or found in every individual from the same site.

The Dawenkou culture dates to ca. 4300-2600 cal. BC. It was preceded by the Houli (ca. 6500-5500 cal. BC) and Beixin cultures (ca. 5500-4000 cal. BC) and followed by the Longshan culture (ca. 2600-2000 cal. BC) in this region during the Neolithic era (SPICRA 2005). Based on the changes in pottery typology and other cultural traits, the Dawenkou culture can be divided into three phases. Early, middle, and late Dawenkou are dated to approximately 4300-3500 cal. BC, 3500-3000 cal. BC, and 3000-2600 cal. BC, respectively (SPICRA 2005: 167).

The geographic distribution of Dawenkou sites varied among early, middle, and late Dawenkou (Figures 3.1 and 3.2). Early Dawenkou culture sites are mainly distributed in Shandong and northern Jiangsu Provinces. During middle Dawenkou, the distribution of Dawenkou culture, or at least its influence, extended further west into eastern Henan and northeastern Anhui Provinces. During late Dawenkou, more Dawenkou culture sites are found in eastern Henan and northeastern Anhui, and some are even found in Liaodong Peninsula across the Bohai Strait (Gao and Luan 2004: 53-55). I will focus my discussions on late Dawenkou because my four sites—Dongjiaying, Fujia, Huating, and Liangwangcheng—all date to this phase according to radiocarbon dating results (Chapter 4); early and middle Dawenkou will also be discussed when relevant. The sites that have a late Dawenkou component and have been formally excavated are listed in the caption of Figure 3.3; their locations are drawn in Figure 3.3 (Dancheng County Cultural Center 1981; APICRA 1992; AAT IA CASS 1993; Gao and Luan 2004; SPICRA 2005).

There are several propositions regarding how to further divide Dawenkou culture sites into subgroups based on pottery typology and geographic location (SPICRA 2005: 168-170). It is generally agreed that geographic distance and barriers among different regions are the main cause for regional variations. Below I will briefly discuss the geography in the region and how the geography might have affected the development of cultural traits and social interactions.

As we see in Figure 3.2, Tai Mountain in the center of this region probably retarded communications among sites to the southeast, southwest, and north side of the mountain, which could have facilitated communities on each side of the mountain to develop some unique cultural traits. Sites located on Jiaodong peninsula, in Jiangsu, Anhui, and Henan Provinces are further away from the center, and had different local traditions before late Dawenkou culture expanded into that region, it makes sense that they had some variations unique to that region. For example, the houses built in rows found at Yuchisi site were unique among Dawenkou culture sites. Note that rivers are drawn on the map in their current locations. The Yellow river was probably further north in prehistory, so it did not impede communications among Dawenkou sites. In addition, there were probably smaller rivers and lakes in the region that we no longer know their locations.

Four Dawenkou sites—Dongjiaying, Fujia, Huating, and Liangwangcheng—were selected in this dissertation to cover the possible regional variations across the landscape (Figure 3.3). Fujia is located to the north of Tai Mountain, Dongjiaying is on the southeast side of the Tai Mountain. Both Liangwangcheng and Huating are located in northern part of Jiangsu Province. These two sites share certain pottery styles with other Dawenkou sites, and they also have some unique traits defining a local variant of the early and middle Dawenkou components found at Liulin and Dadunzi sites (Nanjing Museum 2003; Nanjing Museum, Xuzhou Museum and Pizhou Museum n. d.).

The geographic neighbors of Dawenkou are the Yangshao culture (ca. 5000-3000 cal. BC) to the west, and Songze (ca. 4000-3000 cal. BC) and Liangzhu cultures (ca. 3200-2000 cal. BC) to the south (Table 1.1 and Figure 3.1). While Dawenkou was developing incipient social stratification, Yangshao also developed a three-tiered hierarchy of settlement sizes, ranging from less than one hectare to about 75 hectares (Liu et al. 2004). Liangzhu Culture (ca. 5200-4000 BP, An 1997) constructed huge artificial platforms, burial mounds, and altars, also made elaborate jade and lacquer objects (C. Zhang 2003).

In addition to some shared ceramic styles, Dawenkou and Yangshao also shared some cultural practices. For example, the tooth ablation practice commonly found in Dawenkou sites is also found in some Yangshao sites in Henan Province (Pechenkina et al. 2012). The urn burial—placing deceased children, sometimes adults, in two opposing pots as a form of burial—commonly found in Yangshao sites is also present in some Dawenkou sites, such as Yuchisi (IA CASS 2001) and Liangwangcheng (Nanjing Museum, Xuzhou Museum and Pizhou Museum n. d.). The contact between Dawenkou and Liangzhu culture (and Songze culture) not only fostered dynamic exchange of objects and ideas and sharing of certain practices (Luan 1997a), but also may have facilitated the introduction of rice agriculture from Yangtze River Valley to northern China (Jin 2001; Zong et al. 2007; Luan 2008; Fuller et al. 2009).

Evidence for Subsistence and Diet

Most Dawenkou sites were excavated in the 20th century when systematic sampling and flotation were not practiced. In addition, only a few Dawenkou residential sites have been excavated, so domestic subsistence and culinary practices remain poorly understood. Floral and faunal remains found at burials site may have had ritual significance and do not necessarily reflect daily food consumption practices. As a result, we have only a rough idea of people's diet at Dawenkou culture sites. No systematic flotation was done at my four Dawenkou sites (Dongjiaying, Fujia, Huating, and Liangwangcheng), and archaeo-faunal analysis results are only available at Liangwangcheng. Below I will discuss other Dawenkou sites with evidence for diet and subsistence from archaeobotanical, archaeo-faunal, and stable isotopic analysis of human and animal bones, so I can infer the possible subsistence and diet at my four sites.

Dawenkou archaeobotanical evidence

Broomcorn millet (*Panicum miliaceum*) and foxtail millet (*Setaria italica*) were the most important crop in northern China in general, including Dawenkou region, starting from the early Neolithic (Lu 1999; Yan 2000; Crawford 2006). By northern China, I am referring to the broad region to the north of Huai River and Qinling Mountians, including northeastern China, northwestern China, and North China. It was unclear whether millets were domesticated once or several times independently within China (Zhao 2004; Bettinger et al. 2010; Bar-Yosef 2011). Early findings of millets appeared in northwestern, northeastern, and central China, respectively (Liu et al. 2004; Zhao 2004; Lu et al. 2009; Barton et al. 2009). It is not clear whether the millet farmers had contact with each other (Cohen 2011).

Before I discuss the subsistence at Dawenkou sites, I would like to briefly introduce the subsistence in Neolithic cultures preceding Dawenkou in the same region because subsistence at Dawenkou sites probably derived from these earlier cultures. Carbonized broomcorn millet, foxtail millet, and rice have been found at Yuezhuang site, Houli culture, the earliest Neolithic culture in Shandong Province. However, whether these grains were domesticated and how much they contributed to people's diet are not clear (Crawford et al. 2006; Hu et al., 2008). It is generally believed that millet agriculture was established during the Beixin culture (SPICRA 2005). Carbonized foxtail millet remains were found in one pit, Beixin site (Wu 1983). Flotation samples collected during systematic survey in the Rizhao area (Underhill et al. 2008) revealed six carbonized broomcorn millet grains and one lotus seed from Nantunling site (Beixin component; Chen 2007). In addition to macrobotanical remains, the chaff phytoliths of foxtail millet and broomcorn millet were found at Baishicun site (Jin 2008). In addition, various stone tools found at Beixin site are believed to have been used in cultivation practices (SAT IA CASS and TCM SP 1984). However, no systematic flotation has been done at any Beixin culture site that has been formally excavated, and we do not know how agricultural products contributed to people's diets.

The Dawenkou culture continued millet agriculture and also adopted rice in later Dawenkou sites in several areas (Jin 2001; Luan 2008). Phytoliths of foxtail millet have been found at Xigongqiao site (late Dawenkou; Jin 2008). Carbonized foxtail millet remains have been found at Beizhuang (early Dawenkou; Wu 1983), Fujia (SPICRA and Guangrao Museum 1985), Jianxin (late Dawenkou; Kong and Du 1996), and Sanlihe (late Dawenkou; Shandong Team 1977). The systematic survey in the Rizhao area also yielded three carbonized broomcorn millet, two carbonized foxtail millet, and one carbonized rice grains from Xujiacun site (Chen 2007). Systematic flotation at Beiqian site suggests that both broomcorn and foxtail millet were present in relative small quantities during early Dawenkou (Zhao 2009). People probably supplemented their diets with fishing and hunting (Wang et al. 2012). Flotation at Yuchisi site (late Dawenkou component), Anhui Province, also yielded carbonized remains of foxtail millet, broomcorn millet, and rice; foxtail millet was much more abundant than broomcorn millet (Zhao 2006). The abundant carbonized foxtail millet remains found at Sanlihe and Yuchisi sites demonstrate that millet agriculture was well established in this region no later than late Dawenkou.

Meanwhile, the micro- and macro- botanical remains of rice were also found at several Dawenkou sites. One phytolith of rice was found at Dazhongjia site. Because only one phytolith was found, we cannot say rice was grown here. Rice pollen was found at Wangyin site, yet the identification might be problematic (Jin 2008). As we noted above, carbonized rice remains were found at Xujiacun (Chen 2007) and Yuchisi (Zhao 2006). Millet and rice were probably equally important by late Dawenkou at Yuchisi (Zhao 2006).

Dawenkou archaeo-faunal evidence

Faunal analyses have been conducted at several Dawenkou culture sites (Song 2012). However, many analyses done in the last century had put the emphasis on species identification rather than quantifying faunal consumption patterns. Pig, dog, cow, and chicken remains were found at Dadunzi site, among which pigs and dogs are more abundant (Nanjing Museum 1981). Deer, pig, fish, and turtle bones were found at Liulin site; many show burning marks (JPCRT 1962). Pig, deer, chicken, raccoon, bird, and alligator remains were found at Dawenkou site (Li 1974). Bones of pig, deer, rabbit, bird, carp, and freshwater bivalves were found at Jianxin site (Shi 1996; Song and He 2010). Remains of mollusks, crab, urchins, and four kinds of marine fish were found at the coastal site Sanlihe (Cheng 1988; Qi 1988). Abundant remains of domestic pig, deer, carp, freshwater and marine bivalves were found at Wucun site; smaller numbers of wild boar, wild dog, badger, bovine, and sheep[3] were also found (Kong 1989).

[3] Shang, Zhou, Han, and Tang components are also present at Wucun site. Because sheep was apparently

Relatively thorough faunal recovery methods were used and quantitative descriptions were provided for Shishanzi, Wangyin and Yuchisi sites. Deer dominated the faunal assemblage at Shishanzi (51% of the identifiable bones); pig was also common (30%); shellfish, bovine, chicken, badger, and catfish were also found (Han 1992). The faunal assemblage from Wangyin site has a diverse range of species, including mammals, birds, reptiles, fish, and shellfish. Despite the proximity to many lakes, aquatic species only constitute 9.4% of the identifiable bones at Wangyin. Domestic animals are abundant, especially pigs, which constitute 65.4% of the assemblage (Zhou 2000). Unfortunately, faunal remains from Beixin and Dawenkou components were lumped together in the report; we cannot determine if faunal species utilized at Wangyin changed significantly from Beixin to Dawenkou. Abundant and diverse faunal remains were also found at Yuchisi: the assemblage includes 51% domestic pig, 35% deer, 5% dog, 2% wild boar, and less than 1% fish, turtle, bird, rabbit, bovine, badger, and tiger by minimum number of individuals, excluding shellfish (Yuan and Chen 2001).

Among the different species found at Dawenkou culture sites, pigs were most abundant. In addition to being an important food source, there were probably other social and cultural meanings attached to pigs. Interments of pig skulls were found in many Dawenkou sites, sometimes even the whole pig skeletons (Wang 1981). In addition, pig figurines were found at Dawenkou and Sanlihe (SACR and Jinan Museum 1974; IA CASS 1988). Kim (1994) proposed that intensive pig production was important not only for human diet and rituals, but also for the display of individual wealth and status in the rise of political elites. However, Underhill (2000) compared the quantity of pig skulls at the Dawenkou type site and found no association between the number of pig skulls and the lavishness of the burials.

Evidence of domestic pigs are found in China as early as 8000 BP at Xinglongwa site, Inner Mongolia Province (Yuan 2006), Cishan site, Hebei Province (Zhou 1981; Yuan and Flad 2002), Jiahu site, Henan Province (Luo and Zhang 2008), and Kuahuqiao site, Zhejiang Province (Yuan and Yang 2004). Genetic evidence also supports independent domestication of pigs in China

introduced later from the West (Fu et al. 2009), I suspect the identified sheep remains were mixed in from later components.

(Giuffra et al. 2000; Larson et al. 2005; Ramirez et al. 2009). However, whether the domestication happened once or several times within China is not yet clear. After systematically reviewing pig remains at Houli culture sites, Song (2012: 67) argues that it is possible that pigs were domesticated locally. However, we cannot rule out the possibility that they acquired the idea of domestication from neighboring cultures, such as Peiligang culture.

Dog remains were found in many Dawenkou sites, sometimes in burials. Dogs were probably domesticated. However, the number of dog remains was never significant in the fauna assemblage. They were probably used for other purposes, such as hunting, instead of as meat sources (Song 2012: 77).

Water deer canine teeth were frequently found in burials, often placed by the hand(s) of the deceased. Sometimes they were attached to a bone handle and made into a composite tool. Water deer canines were found in both elaborate and poor burials, it is not likely that they were status markers, what they represent is unknown. They were most frequently found at Dawenkou culture sites to the southwest side of Tai Mountain, and in lower frequencies in other regions (Luan 1997b).

It is worth noting that even though bovine remains were found at several Dawenkou culture sites, whether they represented domestic cattle is unknown. Cattle were and still are an important beast of burden in northern China. How cattle were domesticated and how they were utilized in prehistory, as meat resources or for traction or transport, is not clear. Lyu (2010) systematically reviewed the archaeological findings of cattle in Neolithic sites. Based on the combined criteria of morphology, metric traits, age profile, high percentage in the faunal assemblage, and archaeological context, Lyu argued that cattle were not domesticated until the terminal Neolithic in northern China. Confirmed cases with domestic cattle are all located in northwestern and central China. Yuan and colleagues (2007) came to a similar conclusion by reviewing findings dated between 2500-1500 BC in central China.

Stable isotope analyses of Dawenkou human remains

The previous two sections on archaeobotanical and archaeo-faunal evidence discussed the kind of crops and faunal species that were present at different Dawenkou sites. These lines of evidence cannot provide insights into the proportions of plant and animal foods in human diets, or inter-individual variation in diet composition. Stable isotope analysis of human remains can provide more insight on the subject. Isotopic analysis has previously been performed on 46 humans from six Dawenkou sites. Cai and Qiu (1984) analyzed carbon isotope ratios of a single human skeleton from Lingyanghe, and found some intake of millet, but mainly C_3 food such as rice or wild animals. Zhang et al. (2003) found that millet was the staple food for four individuals from Guzhendu and one individual from Beizhuang. High nitrogen isotope values from both sites suggest the consumption of freshwater aquatic or marine resources. One individual from Xiaozhujiacun analyzed by Qi et al. (2004) had relative high carbon isotope ratios suggesting substantial millet consumption. Hu et al. (2005) analyzed 19 individuals from Xigongqiao; the usable results from eight individuals indicate the consumption of a wide range of food resources, possibly including millet, rice, and terrestrial and aquatic resources. Analysis of human remains from Beiqian (early Dawenkou) suggests substantial consumption of marine resources and millet (Wang et al. 2012).

In sum, the subsistence of Dawenkou culture probably varied through time and across the landscape. Pigs and deer were dominant in the faunal assemblage in most Dawenkou culture sites, supplemented by other terrestrial and aquatic resources, similar to other Neolithic sites in northern China (Yuan et al. 2008). During early Dawenkou, we do not have much evidence for rice consumption, millets were probably generally present (Zhao 2009; Wang et al. 2012). During late Dawenkou, we have more evidence of rice consumption (e. g., Xujiacun, Yuchisi, Lingyanghe, and Xigongqiao). However, consumption varied among different sites and among different individuals within the same site. It is worth mentioning that most sites with evidence of rice consumption are located to the south of Tai Mountain, yet rice has also been reported for sites further north (Figure 3.3). It is possible that rice was introduced to people who lived in the Dawenkou culture area from more than one direction. Also, rice seems to have been introduced prior to the Dawenkou period (for example, Yuezhuang site with carbonized rice remains dates to Houli culture), but increased dramatically during the Dawenkou period.

Another aspect worth noting is that grinding slabs and hand stones are consistently found in Shandong Province throughout the Neolithic era, without observable trend of decrease in numbers (Wang 2008). Grinding slabs and hand stones were traditionally associated with cereal processing. However, recent experimental studies and starch residue analysis indicate that they were more often used in nut processing instead of cereal processing (Liu et al. 2010a). If that was also how grinding slabs and hand stones were used in Dawenkou sites, then nuts may have already been a part of Dawenkou sites.

The Introduction of Rice Agriculture into Shandong

Rice agriculture in northern and southern China

The oldest rice remains found in Shandong Province are from Yuezhuang site, Houli culture (the first Neolithic culture in the region). Carbonized rice fragments from Yuezhuang were directly radiocarbon dated to 6060-5750 cal. BC. However, whether the rice found at Yuezhuang belonged to domestic or wild species is unknown, and it is also not certain whether they were grown locally or were obtained through trade or exchange (Crawford et al. 2006). No rice is found in the subsequent Beixin culture in Shandong. The next evidence for rice comes from late Dawenkou sites. The earliest evidence for rice paddy agriculture in this region dates to the Longshan era (Luan et al. 2007).

In contrast to the paucity of evidence in northern China, rice agriculture has a continuous history in southern China starting with the early Neolithic. The earliest rice remains found in the lower reaches of the Yangtze River are from Shangshan site (11,000-9,000 cal. BP; Jiang and Liu 2006). However, because the evidence comes from pottery temper and does not allow further quantitative analysis, it is difficult to determine whether it represent a domesticated population (Liu et al. 2007). Rice remains that are more certain to be put in the domestic category were found at Kuahuqiao (8200-7200 cal. BP), Luojiajiao (ca. 7000 BP), Tianluoshan (ca. 7500-6500

BP), and Hemudu sites (7000-6500 cal. BP) (Liu et al. 2007; Fuller et al. 2007; Zheng et al. 2007; Fuller et al. 2009). In addition, rice paddy fields were found at Caoxieshan and Chuodun (Majiabang culture, 7000-5800 cal. BP), demonstrating intensive investments in water management (Zou et al. 2000; Cao et al. 2006; Li C. et al. 2007). Rice remains that date to the early Neolithic were also found in the middle reaches of the Yangtze River. For instance, carbonized rice husks were observed in pottery fragments recovered from Pengtoushan and Lijiagang sites (ca. 9000-8000 BP; Pei 1989), and large amount of domestic rice remains were found at contemporary Bashidang site (Zhang and Pei 1997). However, no systematic analysis of rice remains has been done in this region. Whether rice was domesticated independently is unknown. Whether rice or wild resources, such as acorns, were the main staple resource in the middle Yangtze River region is also unknown (Liu et al. 2010b).

Given that rice agriculture was well established in southern China and there is not much evidence of rice agriculture in Shandong before Dawenkou, it is likely that rice was introduced from southern China to Shandong. This is consistent with the fact that rice has been recovered from the southernmost Dawenkou sites. Fuller and colleagues (2009) argue that the process of domestication can take hundreds of years. However, unlike southern China, no similar progressive change in morphology was observed in Dawenkou culture rice remains. Because northern China is drier than southern China, the practice of rice agriculture in northern China probably required the construction of irrigation systems; otherwise the yield of rice will drop significantly. Fuller and Qin (2009) argue that only when society achieved a more centralized form of social organization could labor be effectively organized for water management projects. Until then, rice agriculture could not have been adopted and successfully practiced in northern China. However, the Hohokam culture from southwestern American shows no signs of centralized organization despite its extensive canal and water management system (Gumerman 1991). It is not clear whether the introduction of rice into Dawenkou region was related to the incipient development of social stratification and whether the emerging elites played a critical role in water management projects related to rice agriculture.

Environmental change and subsistence change

Climate change is one of the important forces that can affect human subsistence and economies. The climate became warmer and wetter in both northern and southern China at the beginning of Holocene around 11.5k BP (Yi et al. 2003; Feng, An, and Wang 2006). The Asia summer monsoon also became stronger and influenced most parts of China (Morrill, Overpeck, and Cole 2003; Yuan et al. 2004). The relative stable climate with higher temperature and rainfall has made the practice of agriculture feasible since the beginning of Holocene (Lu 1999; Cohen 2011). Around 4000 BP, climate became colder and drier again in most parts of China. It was proposed that the dramatic climatic change around 4000 BP lead to several major cultural changes in northern China.

In northwestern China, the transition from crop farming to nomadic pastoralism was generally attributed to a cooler and drier climate during the late Neolithic (Mo et al. 1996; Shui 2001; An et al. 2005). Similarly in northeastern China, the cooler and drier climate between 5000~4000 BP was argued to have caused severe crop failures. This coincides with and may have contributed to the decline of the Hongshan Neolithic culture and replacement with Xiaoheyan culture (Xia et al. 2000; Jin 2004). Fang and Sun (1998) argued that cooler climate around 4000 BP caused insufficient heat for millets farming and the abrupt disappearance of Laohushan culture in Daihai region, Inner Mongolia.

Similar explanations have been proposed for the adoption of rice agriculture in northern China. One hypothesis is that people would adopt rice agriculture quickly when the climate permitted it (Chen 1996; Jin et al. 2004). The rationale is that rice generally has higher yields of calories and protein per hectare than millet when well-tended (Chang 2000). It is true that the climate during mid-Holocene optimum (c. 6000-5000 BP) was generally warm and moist (Jin and Liu 2002; Xiao et al. 2004), which may have made rice farming more feasible compared to early Holocene in northern China. However, more archaeological evidence for rice agriculture was found in northern China when the climate turned cooler and drier during the late Holocene (Feng, An, and Wang 2006; Gong et al. 2007). For example, evidence for rice agriculture is more abundant during the Longshan era (ca. 2600-2000 cal. BC) than the preceding Dawenkou in Shandong (Jin 2001; Luan 2008), even though the Longshan era was cooler and drier than Dawenkou based on pollen and oxygen isotope analysis results in Hebei and Shandong Provinces (Jin and Liu 2002; Qi 2006). On the other hand, historical records indicate that the yield of rice was lower than other crops in Han Dynasty (206 BC – 220 AD), and only began to exceed other crops after Tang Dynasty (618－907 AD) (Wu 1985: 194). We can probably assume that the yield of rice was not higher than millet in prehistory. This counterintuitive observation about climate change suggests that alternative explanations are needed for the adoption and spread of rice agriculture.

Alternative explanations for the adoption of rice agriculture

Crawford and colleagues (2005) argued that farmers used a combination of millet and rice agriculture at Liangchengzhen site (Longshan period) as a risk-management strategy. McGovern and colleagues (2005) proposed that Longshan people might have believed rice fermented beverage was especially effective in connecting to ancestors. Therefore they made rice rather than millet fermented beverage even though millet was certainly available. In addition, one pig found at pit H31, Liangchengzhen, has lower $\delta^{13}C$ values, and might have been fed on a rice dominant diet for ritual purposes (Lanehart et al. 2008). Most pigs found at the site had high $\delta^{13}C$ values indicating a millet dominant diet. Over 200 intact pots were recovered from H31. Lanehart et al. (2008) propose that this pit was related to some ritual practices, and this pig may have been fed exclusively for those rituals. Therefore the ritual and symbolic meanings associated with rice and other cultural and social factors probably facilitated the adoption of rice during the Longshan era despite the relatively unfavorable environment. It is possible that rice was a preferred food by higher status people during the Dawenkou period due to the labor involved in rice production. The higher status people may have played an important role in the adoption of rice.

Similarly, the adoption of wheat in northern China was probably also due to cultural preferences rather than to factors related to economic efficiency. Wheat was introduced into northwestern China as early as 4650 BP (Li X. et al. 2007), and was also found at Liangchengzhen, Shandong Province (Crawford et al. 2005). The energy and protein composition of wheat and millet are comparable, while millets have higher fat content than wheat (Table 3.1; Leung et al. 1972). Even though the yield of wheat is significant higher than millet nowadays, the yield of millet was even higher than wheat in 1930s and 1950s in China (Table 3.1; Walker 1984: Appendix 2; Wu 1985: 201). Millets have a low response to high fertility and abundant water (Baltensperger 1996). Millet yields have not changed much since 1950s. However, wheat yields have increased by a factor of eight with the introduction of new varieties and fertilizers (IGSNRR CAS 2012). Before the potential of wheat was fully expressed, the area planted with wheat was already significantly larger than that with millet in 1930s and 1950s (Walker 1984: Appendix 2; Wu 1985: 202). We can probably assume that the yield of wheat was not higher than millet when it was first introduced. Therefore the adoption of wheat may have also been for other reasons.

The adoption of wheat could be related to the cultural preferences for sticky grain food (Fuller and Rowlands 2009). The waxy genotypes of broomcorn millet, foxtail millet, and rice are only cultivated in East and Southeast Asia nowadays, where sticky foods have been favored traditionally (Sakamoto 1996; Fukunaga, Kawase, and Kato 2002; Olsen and Purugganan 2002; Kawase, Fukunaga, and Kato 2005; Hunt et al. 2010; Hunt et al. 2012). For example, the New Year cake (*niangao*) is usually made of waxy type rice, while in Shanxi and Shaanxi Provinces it is made of waxy type broomcorn millet.

Despite the cultural preference for sticky food, the adoption of wheat took at least 2000 years in China. According to historical literature, wheat was only consumed by elites during Warring States period (475-221 BC), while it became more common in eastern China during Han Dynasty (206 BC – 220 AD; Ho 1969: 164-165). However, wheat was considered an inferior food and was priced less compared to millet during the Han Dynasty (Yu 1977). Stable isotope analyses of human remains dated to Warring States period suggest a millet dominant diet in northwestern China (Ling et al. 2010a, b).

The adoption of these new staple foods required new sets of knowledge associated with rice or wheat farming, and also changes in culinary practices. Wheat is a drought tolerant dry land crop like millet, while rice is quite different from both and grows in irrigated paddy fields. It probably took longer for farmer in prehistoric Shandong to adapt to the paddy growing rice farming system comparing to the adaptation to wheat farming. In addition to the technical challenges associated with the changes in farming system, there were also cultural and social challenges, such as identity represented by former staple foods, symbolic meanings connected to certain foods in ritual practices, forms of social organization, labor organization and seasonal scheduling of activities related to farming, etc. I will address these issues in the following chapters.

Signs of Incipient Social Stratification

The development of social complexity and social stratification is of great interest to archaeologists (Wright 1984; Earle 1991; Hayden 1995; Price 1995; Shao 2000). In this section, I will first discuss evidence from Dawenkou burials for incipient social stratification. Then, I will consider the limited evidence for social stratification from Dawenkou houses.

Burials at Dawenkou sites

Dawenkou is well known for its extremely elaborate burials. They are assumed to reflect differences in wealth, incipient social stratification and changing gender relationships (Pearson 1981; He 1994; Luan 1997c; Underhill 2000, 2002). While many graves were small and accompanied by less than ten artifacts, others were huge, elaborately constructed tombs filled with finely worked ceramic vessels, jade objects, water deer canines, and pig skulls. However, disparities in burial treatment varied through time in different regions, and among different Dawenkou sites. Below I will discuss the mortuary practices in Dawenkou sites, starting with early Dawenkou, and then middle Dawenkou, and late Dawenkou. I intend to show the trend of more elaborate mortuary traditions through time, such as the use of large number of grave goods, *ercengtai* (earthen ledge, Figure 3.4), wooden coffin, and jade objects. I also intend to discuss the development disparities in different regions, and how my four sites fit into different regions.

During early Dawenkou, most burials had few or no grave goods, and tombs were barely larger than the bodies. For example, among the 62 burials belonged to layer four (early Dawenkou) at the site of Wangyin, Shandong Province, most had two or three grave goods, and the richest burial had ten (IA CASS 2000: 308). A similar pattern was also found at the early Dawenkou component (phase two and three) of Yedian site, Shandong Province (Shandong Museum and SPICRA 1986: 135). However, some burials dated to the early Dawenkou period at the Dawenkou type site had more than a hundred grave goods; ten out of 46 burials had *ercengtai* style walls, which probably required higher labor input in tomb construction; one burial (M1018) had a stone coffin (SPICRA 1997). Dawenkou, Wangyin and Yedian sites are all located near the southwest foothills of Tai Mountain. They probably shared ritual practices at funerals and beliefs in the afterlife. The differences found in burial treatment among the three sites might suggest the existence of aggrandizers (probably the hosts of the funerals) at the Dawenkou type site, who strive to become dominant in a community (Hayden 1995). They were likely absent at Wangyin and Yedian.

Burials at the penecontemporary Liulin site, northern Jiangsu, were a little richer than Wangyin and Yedian, yet not as elaborate as some burials at Dawenkou. Out of 145 burials excavated at Liulin, 100 had grave goods in numbers ranging from one to eight, and eight had more than 19 grave goods. Ornaments made of jade, turquoise, or delicately carved bone and teeth were found at this site (JPCRT 1962; Nanjing Museum 1965). Two of my sites, Liangwangcheng and Huating, are located in this region and date to late Dawenkou. Unfortunately, the excavation reports of several other early Dawenkou culture sites, such as Beizhuang and Beiqian, have not yet been published. The available information discussed above suggests that disparities in burial treatment started to appear in some sites during early Dawenkou.

During the middle Dawenkou, *ercengtai* burials were more common. Two out of ten burials dated to middle Dawenkou (phase four) at Yedian site have *ercengtai*. The number of whole ceramic vessels in each burial ranged from 14 to 53; some also had wooden coffins (Shandong Museum and SPICRA 1986). Coffins and *ercengtai* were more commonly found in burials dated to the middle Dawenkou period at the Dawenkou type site (SACR and Jinan Museum 1974). Chengzi site is located to the east of Tai Mountain. Only 12 burials at Chengzi are dated to middle Dawenkou (phase I); five contained more than one individual. Many burials had *ercengtai*, and nine had wooden coffins. The number of grave goods ranged from one to 13 in the burials with only one individual (CDWGZ and Zhucheng County Museum 1980). One of my sites, Dongjiaying, is also located in the same region as Chengzi.

Neither *ercengtai* nor coffins were found in the region to the north of Tai Mountain or northern Jiangsu during middle Dawenkou. Burials from Wucun site, located to the north of Tai Mountain, had no or a few grave goods. Tombs with *ercengtai* have not been found at Wucun (SPICRA and Guangrao Museum 1989). One of my sites, Fujia, is also located in this region. Dadunzi site, located in Pi County near Liulin, Jiangsu Province, generally had more and better quality grave goods than those found at Liulin. The majority of the burials (102/156) dated to the middle Dawenkou at Dadunzi site (Huating phase) had less than ten grave goods. However, eight burials had more than 25 grave goods. No *ercengtai* or coffins have been found at Dadunzi (Nanjing Museum 1964, 1981). Huating, located in the same region as Dadunzi, is famous for the presence of human sacrifices suggesting social stratification, and for the abundance of artifacts resembling those from the southern Liangzhu Culture. Many delicately produced jade objects were found in the north cemetery, which is dated to middle and late Dawenkou[4]. However, no *ercengtai* or coffins were found (Nanjing Museum 2003).

The distribution pattern of elaborate burials with *ercengtai* and coffins suggests that this tradition probably started in the region to the southwest of Tai Mountain during early Dawenkou (at the Dawenkou type site), gradually spreading to the region east of Tai Mountain during middle Dawenkou (e.g., Sanlihe, Chengzi, and Lingyanghe sites), and reaching northern Jiangsu during late Dawenkou (Liangwangcheng site; Nanjing Museum, Xuzhou Museum and Pizhou

[4] Two human bone collagen samples from the north cemetery were directly radiocarbon dated and fall into the range of late Dawenkou (Chapter 4). It is possible that individuals dated middle Dawenkou were not sampled.

Museum n. d.). On the other hand, the tradition of including delicate jade objects as grave goods probably started in northern Jiangsu (Liulin site) during early Dawenkou, and expanded into the region to southwest of Tai Mountain (the Dawenkou type site) during late Dawenkou.

During late Dawenkou, Shao (2000) argues that four distinct classes of cemeteries can be discerned based on the scale and percentage of large tombs present at each. She used Dawenkou, Sanlihe, Jingzhi, and Nanxingbu sites to make her point. However, those four sites are not located in the same region: Dawenkou and Nanxingbu are located to the southwest of Tai mountain, and Sanlihe and Jingzhi are located to the east of Tai Mountain. Regardless, we can see the general pattern in the region to the southwest of Tai Mountain: large and elaborately furnished burials are common at some cemeteries, such as Dawenkou (SACR and Jinan Museum 1974) and Xixiahou sites (SAT IA CASS 1964, 1986), and not found at others, such as Jianxin (SPICRA and ZMBC 1996) and Xigongqiao sites (SPICRA 2007). A similar pattern can be observed in the region to the southeast of Tai Mountain: Lingyanghe (Wang 1987) and Dazhujiacun sites (Su et al. 1989; SPICRA and Juxian Museum 1991) had more elaborate burials, and Dongjiaying site had only a few (Mingkui Gao, personal communication).

It is worth noting that *gaobingbei* (tall stemmed cup), which is the most labor intensive form of pottery vessel at Dawenkou culture sites, and is possibly related to alcohol drinking (Underhill 2000), appeared in several regions, including southwest and southeast of Tai Mountain and northern Jiangsu at Liangwangcheng site during late Dawenkou (Nanjing Museum, Xuzhou Museum and Pizhou Museum n. d.). The distribution pattern of *gaobingbei* and many other serving vessels might indicate that graveside feasting was widely practiced during late Dawenkou. Underhill (2000, 2002) found that there was a clear increase in energy expenditure in mortuary ritual by the Late Period at Dawenkou type site. This could mean that “aggrandizers” may have been actively acquiring labor intensive objects such as *gaobingbei* and they used the funerals to display wealth and gain power. Social status was probably quite fluid during Dawenkou. However, it marked the important beginning for the more intensified social stratification process that followed.

Houses at Dawenkou culture sites

Some societies exhibit a great range of variation in the size and quality of housing, and these factors depend on the level of a household's access to goods and services. Residential architecture has been proven useful for social rank reconstruction other parts of the world, especially if the houses were built with stones that last for centuries and are highly visible in archaeological record (Hirth 1989). However, Dawenkou houses were built with posts and mud, sometime partly underground, and sometimes above ground. The impermanent nature of Dawenkou houses provides little architectural evidence of social ranking. In addition, Dawenkou sites were usually occupied for a long time. Later storage pits, houses, burials, and other features have disrupted many earlier houses and left few undisturbed traces of earlier residential structures. This process may lead to the disturbance of the associations among artifacts and features within houses that Smith (1987) has demonstrated to be very useful for measuring household wealth as evidence for social stratification. I will briefly summarize the evidence from houses that were relatively well preserved at two Dawenkou culture sites: Jianxin and Yuchisi.

Houses at Jianxin were all built above ground. Most of them were in rectangular or square and a few were round (SPICRA and ZMCB 1996). The majority houses (25 out of 27) had only one room, and two had double rooms. House size ranged from less than 10 m^2 to 30 m^2; most were between 10 and 20 m^2. Among the 27 houses found at the site, pottery and stone tools were found on the floors of eight, with the number of goods ranging from zero to 14 in each house. Most pottery vessels were intact and placed vertically, which might indicate that the houses were abandoned in a hurry. In general, we do not see much difference in wealth among houses. Considering the few goods found inside each house, we can probably say that there were not significant differences in wealth among households at Jianxin.

Rather than the detached single room houses commonly found in other Neolithic sites in northern China, most houses at Yuchisi site had multiple rooms in a row, ranging from two to six rooms per house (IA CASS 2001). There are two types of rooms based on their size: the smaller ones are usually 4~5 m^2 in floor area; the larger ones range from 10 to 30 m^2, with most of them between 12 and 15 m^2. Larger rooms were often constructed with two doors and one hearth. Many utilitarian pottery vessels and some tools were usually found in the larger rooms. The smaller rooms had only one door with few pots left inside. It is believed that the smaller rooms were used for storage, the larger rooms were occupied by nuclear families, and the houses with multiple rooms represented extended families. There are no significant differences in room size or the number of pots and tools found in each room within the same house, but there are some differences among houses. Considering the fact that the goods recovered from the houses are mostly utilitarian, the number of goods in each room could reflect the number of individuals in each household instead of reflecting differences in wealth.

Kinship and Gender Relationships at Dawenkou sites

Kinship (descent reckoning), post-marital residence and gender relationships are separate concepts in anthropology. However, the terms matrilineal/patrilineal, matriarchal/patriarchal, and matrilocal/patrilocal are relatively synonymous in usage among Chinese archaeologists (Chapter 2). These aspects of social organization are often discussed in the interpretation of Neolithic archaeological remains in the Chinese literature (Wang 1982; Zhang 2000; H. Zhang 2003). Below I will discuss how kinship and gender relationships are addressed in the context of Dawenkou culture.

The reported archaeological evidence for social organization and the transition from matrilineal/matriarchal clans to patrilineal/patriarchal families comes mainly from Dawenkou cemeteries. Han (1994) argued that the cemetery at the Dawenkou type site can be grouped into several sectors based on the spatial distribution of burials, and each sector represented one extended family. He found that burials in certain sections were more elaborate than others. Therefore social stratification was initially among extended families, not among individuals, and social organization was transforming from clans to families. Wei (2004) combined evidence of spatial distribution of the cemetery and houses at Yuchisi and argued that the society was organized in nuclear families, extended families, and lineages. In contrast to the detached single room houses commonly found in other Neolithic sites, most houses at Yuchisi site had multiple rooms and were aligned in a row, with the number of rooms per house ranging from two to six. It is believed that the smaller rooms were used for storage, the larger ones were occupied by nuclear families, and the houses with multiple rooms were occupied by extended families (IA CASS 2001).

The appearance of "couple burials" at some Dawenkou culture sites, with one male adult and one female adult buried together, was also used to argue for the shift of the emphasis to nuclear families (He 1994). However, in most cases, "couple burial" was not the dominant form in the cemetery; it comprises 1% to 5% of burials among Dawenkou culture sites. Han (1994) argued that some "couple burials" were questionable at the Dawenkou type site. For instance, in burial M1, the male was placed in the center of the tomb, while the tomb extended abruptly on the female side. In addition, the male and female bodies were not at the same horizontal plane, with the female body a little higher in profile than the male. Another questionable "couple burial" is M13, in which the female body was 7cm above the male body in profile. Both M1 and M13 may fit a scenario in which the female was interred later and disturbed the earlier male burial. Therefore they may be cases of two independent burials instead of one "couple burial". In addition, even if the male and female were indeed interred together as one burial, it is unknown if they were actually married couples, siblings, or had other forms of relationships.

Mortuary evidence suggests the decline of female power during the Dawenkou era. Pearson (1981) found that females tend to have more pottery as grave goods than males in early Dawenkou, possibly suggesting a matriarchal society. However, in middle and late Dawenkou, in addition to cases in which females have more pottery than males, there are also cases of males with more pottery than females. Pearson proposed that this is a sign of the decline of women's power. Underhill (2002) also noted that more males received special treatment than females during late Dawenkou in western Shandong area. In addition, known male graves tend to have more drinking vessels for alcoholic beverages, while some graves of females have large quantity of food vessels, possibly indicating different kind of rituals for males versus females.

Details of arrangements within “couple burials” can also provide hints on the status of the deceased (Sun and Yang 2004). In burial M101 at the Dadunzi site, the male was in extended supine position, and the female was in flexed position, and was placed by the waist of the male (Nanjing Museum 1981). In burial M47 at the Yedian site, all or most of the graves goods were placed on the male side, with few on the female side (SPICRA 1986). He (1994) argued that these cases suggest the subordinate status of females, and provides evidence for the transition to a patriarchal society. However, these are rare exceptions to the general pattern of similar proportions of male and female Dawenkou graves with large disparities in numbers of mortuary artifacts, so more evidence is needed to test this hypothesis.

Summary

In this chapter I have reviewed the chronology, geographic distribution, subsistence, and aspects of social organization of the Dawenkou Neolithic culture. The Dawenkou Neolithic culture spans a transitional period during which subsistence, social organization and social complexity may have all changed. During the earlier phases of Dawenkou millet was the primary staple crop. However rice was added to the diet no later than late Dawenkou. Rice may have been used preferentially by people of higher status. This hypothesis will be tested with isotopic analysis of human bones in Chapter 5. Mortuary evidence suggests increasing disparities in wealth and status through time and among sites. It is assumed that matrilocal/matriarchal social organization may have characterized earlier Dawenkou sites, and patrilocal/patriarchal organization may have characterized later Dawenkou sites. This hypothesis will be tested with mortuary evidence in Chapter 4, isotope evidence in Chapter 5, and ancient DNA evidence in Chapter 6. These changes toward greater social complexity and social inequality foreshadow the highly stratified Shang Dynasty in the early Bronze Age.

In next chapter, the mortuary evidence from four late Dawenkou sites will be presented and used to illustrate these wider trends in incipient social stratification and gender relationship.

Radiocarbon dating results of human and faunal remains from the four sites will also be discussed in order to get a better temporal control.

Table

Table 3.1. The energy, protein content, and fat content in whole grains of wheat, rice, foxtail millet, and broomcorn millet (Leung et al. 1972), the average yearly yield of wheat, rice, and foxtail millet between 1931 and 1936 across China (Wu 1985: 201), and the average yearly yield of wheat, rice, and millet[5] in 1952 and 1957 in northeastern China (Walker 1984: Appendix 2).

<table>
<tr><th></th><th>Energy (calories per 100 gram)</th><th>Protein content (%)</th><th>Fat content (%)</th><th>Average yearly yield between 1931 and 1936 across China (100 kg/hectare)</th><th>Average yearly yield in 1952 and 1957 in northeastern China (100 kg/hectare)</th></tr>
<tr><td>Wheat</td><td>329</td><td>10.5</td><td>2.0</td><td>11.094</td><td>6.983</td></tr>
<tr><td>Rice</td><td>354</td><td>7.6</td><td>1.8</td><td>25.650</td><td>22.839</td></tr>
<tr><td>Foxtail millet</td><td>341</td><td>9.5</td><td>2.9</td><td>12.594</td><td rowspan="2">10.996</td></tr>
<tr><td>Broomcorn millet</td><td>326</td><td>12.7</td><td>3.5</td><td></td></tr>
</table>

[5] The soure did not specify which kind of millet.

Figures

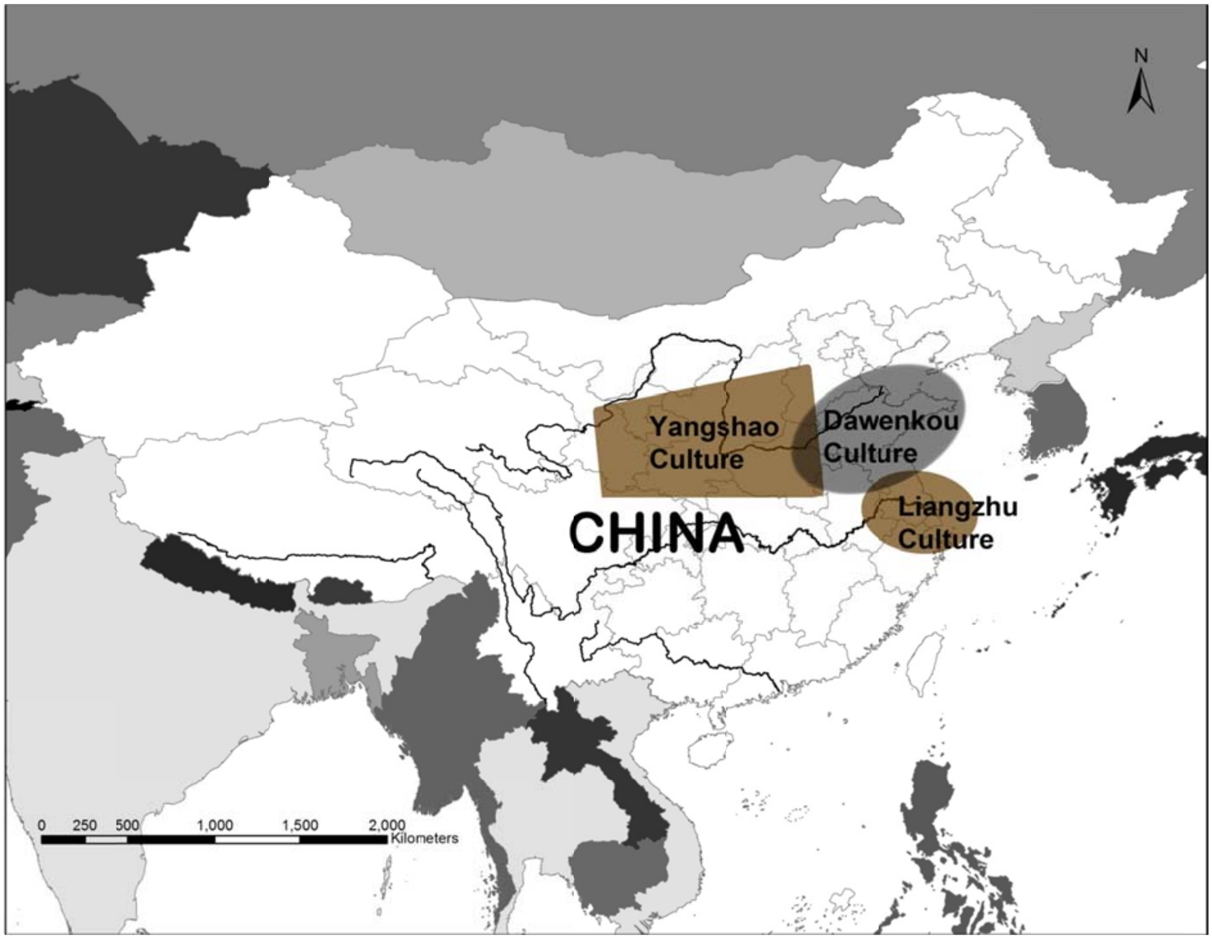

Figure 3.1. The distribution of the Dawenkou culture (ca. 4300-2600 cal. BC) and its neighbors, the Yangshao (ca. 5000-3000 cal. BC) and Liangzhu (ca. 3200-2000 cal. BC) cultures during late Neolithic.

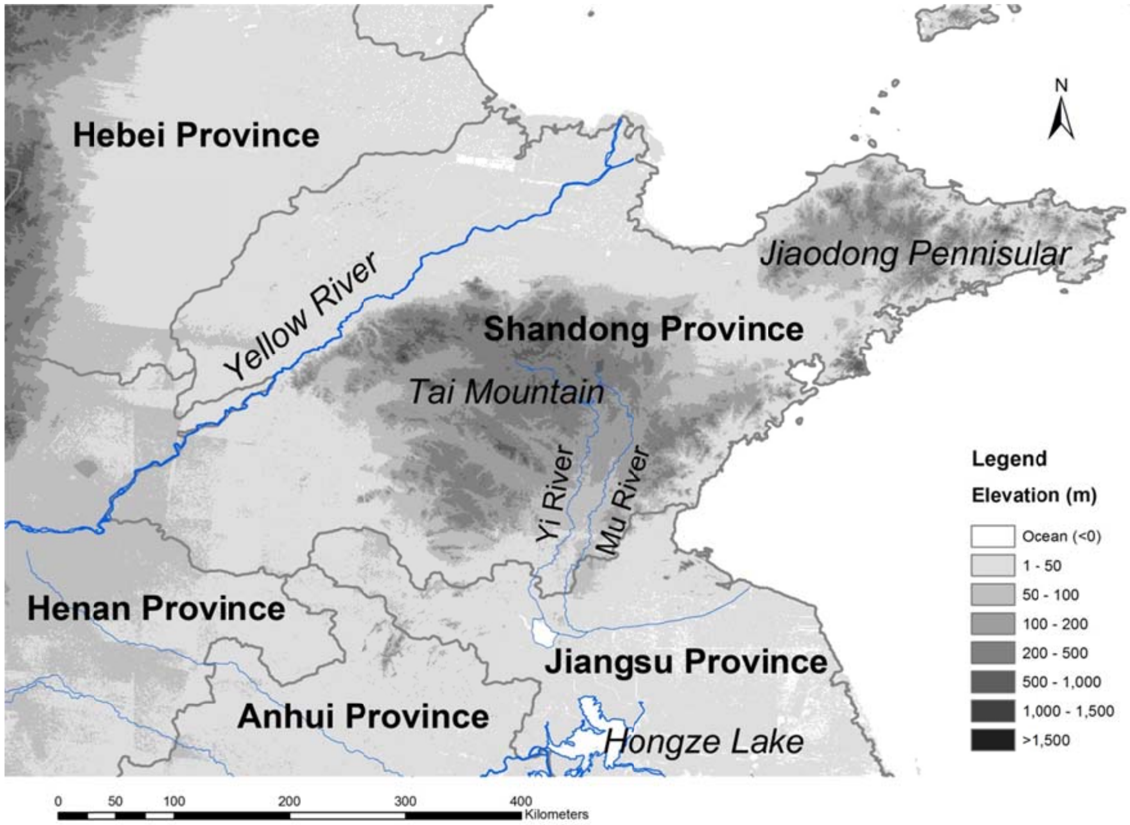

Figure 3.2. The geography of the Dawenkou culture region.

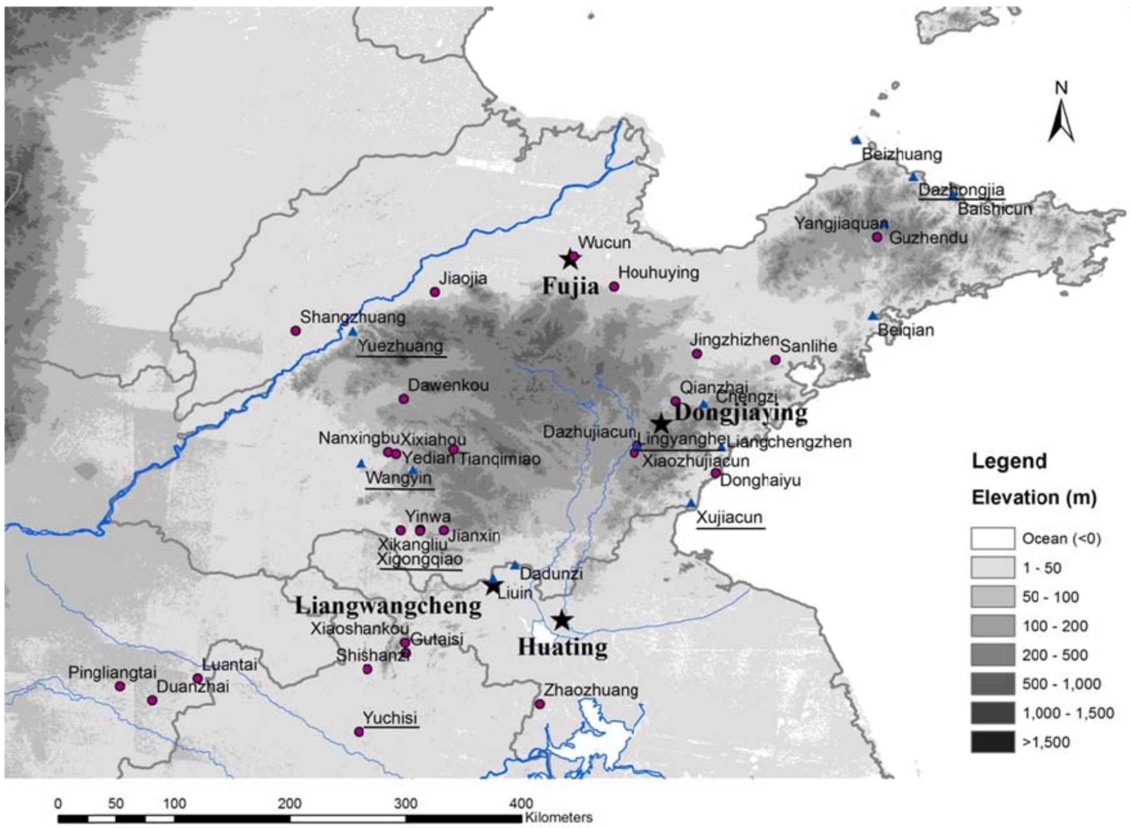

Figure 3.3. The geographic location of Dawenkou sites that have a late Dawenkou component and have been formally excavated and other sites mentioned in the text. Sites with late Dawenkou component are marked with a dot, include Dawenkou, Dazhujiacun, Donghaiyu, Duanzhai, Fujia, Gutaisi, Houhuying, Huating, Jianxin, Jiaojia, Jingzhizhen, Liangwangcheng, Lingyanghe, Luantai, Nanxingbu, Qianzhai, Sanlihe, Shangzhuang, Shishanzi, Tianqimiao, Wucun, Xiaoshankou, Xigongqiao, Xikangliu, Xixiahou, Yangjiaquan, Yinwa, Yuchisi, and Zhaozhuang. Sites marked with stars are sites that are sampled and studied in this dissertation. Sites marked with triangles are other sites in the region that are mentioned in the text, including Baishicun, Beiqian, Beizhuang, Dadunzi, Dazhongjia, Guzhendu, Liangchengzhen, Liulin, Xiaozhujiacun, Xujiacun,Yuezhuang, and Wangyin. Sites with archaeobotanical or stable isotopic evidence of rice are underlined, including Yuezhang, Wangyin, Dazhongjia, Xujiaun, Xigongqiao, Lingyanghe, and Yuchisi.

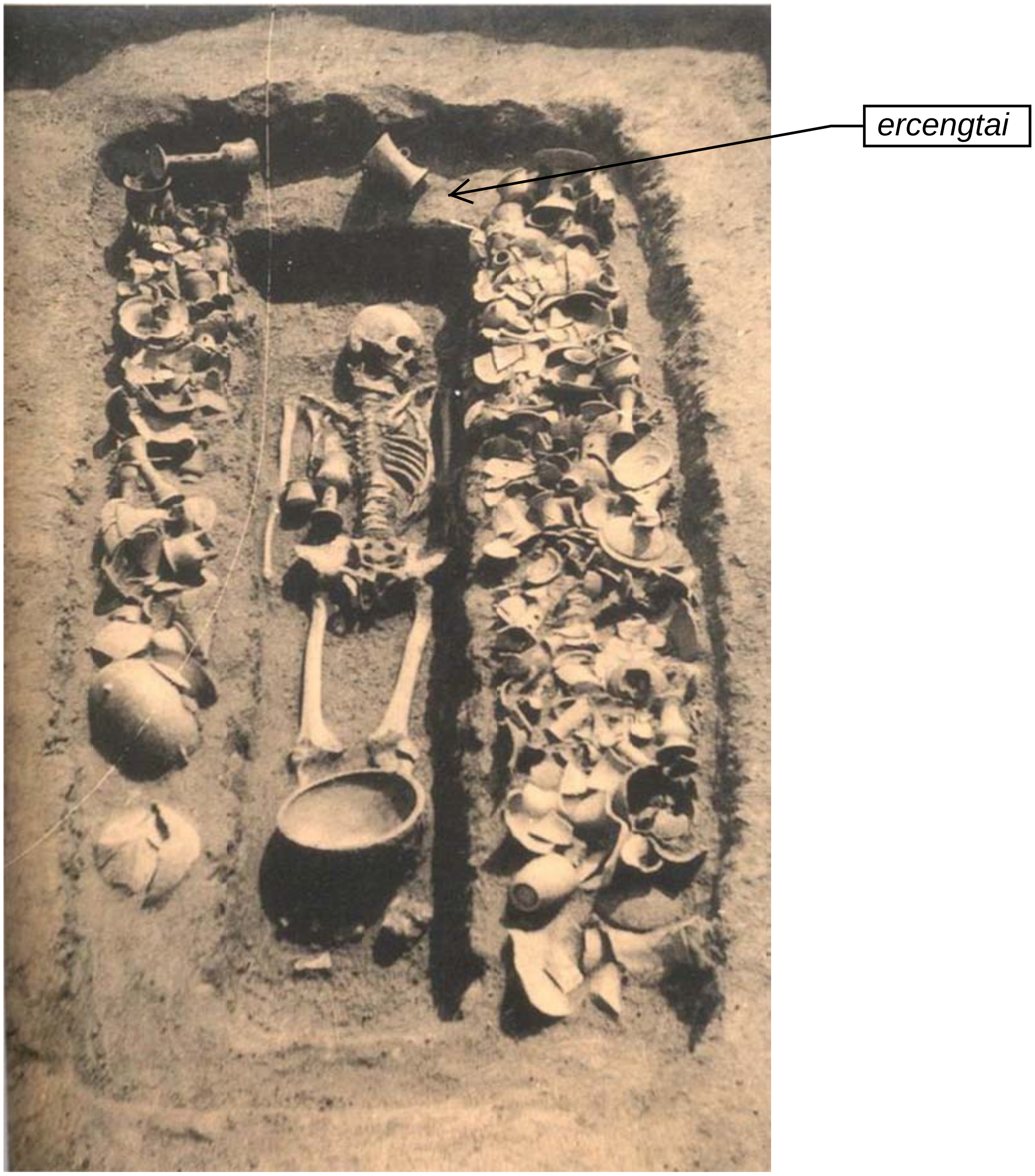

Figure 3.4. Burial 1 with *ercengtai* (earthen ledge) at the Xixiahou site, Qufu, Shandong Province, Dawenkou Culture (IA CSSA 1993: 55)

CHAPTER 4

ARCHAEOLOGICAL BACKGROUND OF FOUR DAWENKOU SITES

I have chosen four sites, named Huating, Liangwangcheng, Dongjiaying, and Fujia, for analysis in this dissertation. They all date to late Dawenkou according to radiocarbon dates, which facilitates comparisons and contrasts among penecontemporaneous sites. Fujia and Dongjiaying are located further north in Shandong Province, and Huating and Liangwangcheng sites are further south in Jiangsu Province (Figures 3.3). In this chapter I will describe the archaeological background of these four sites and discuss signs of incipient social stratification and gender relationships, mostly drawing on mortuary evidence. The information provided for each site varies depending on the information available. Only Huating has published excavation report; the excavation report of Liangwangcheng is soon to be published, the excavation reports of Dongjiaying and Fujia are unavailable. Radiocarbon dating results of human remains from these four sites are presented at the end of this chapter.

Huating

Huating is one of the most intriguing Neolithic sites in this region because it has clear evidence for significant social stratification, and contains many artifacts resembling those from the southern Liangzhu Culture (Nanjing Museum 2003). Huating is located north of Huating village, Xinyi City, Jiangsu Province, in the Mu and Yi River valley (Figures 3.2 and 3.3). The site is located on the top of two elevated points on the landscape, which are natural remnant hills. The cemeteries are located on the west hill, and the residential area is on the east hill (Figure 4.1). Huating people are assumed to have practiced millet agriculture, and supplemented their diet with domestic pigs and hunting and gathering. Flotation to recover botanical remains has not yet been undertaken.

Huating was found accidentally by local farmers, who began to dig for jade artifacts in early 1950s. The Nanjing Museum and Subei Group, Zhihuai Cultural Relics Team excavated five exploratory trenches and one burial in 1952. The Nanjing Museum team carried out the first formal excavation in three sections in 1953: 28 exploratory trenches and 19 burials in the south section, two exploratory trenches in the north section, and eight exploratory trenches in the east section. The Nanjing Museum carried out two major excavations in 1987 and 1989 and found 26 and 40 burials, respectively.

The residential area (the east section of Huating) was excavated in 1953. No detailed information is available, except for the fact that 17833 pottery sherds, eight stone tools, two bone tools, 532 pieces of faunal remains, and one human skeleton were found in this area. The excavation report provided more detailed information on the two cemeteries that were excavated in 1980s (Nanjing Museum 2003). These cemeteries are about 600 m apart. The south cemetery is a typical Dawenkou cemetery with 23 burials, which all date to middle Dawenkou. The north cemetery, with 62 burials, dates to middle and late Dawenkou. Burials in the north cemetery include cultural traits of both Dawenkou and Liangzhu cultures. Evidence of human sacrifice was also found in this cemetery. The nature of this cemetery and Huating is highly debated because of the presence of Liangzhu traits. I will focus my discussions on the north cemetery.

Evidence of human sacrifice

Evidence of human sacrifice was found in several elaborate burials from the north cemetery. Among the ten elaborate burials, eight had more than one individual. In burial M18, the statuses of the two individuals in the same burial seem relatively equal. The other seven multiple burials each has one dominant individual, and one or more subordinate ones. The subordinates are argued to be sacrifices. I will present a few examples below.

Burial M20 is one of the elaborate burials. The tomb was built in the *ercengtai* (earthen ledge) style. The area including the *ercengtai* is about 5×3 m; the size of the inner part is about 2.7×3 m (Figure 4.2). The skeleton in the center of the burial is identified as an adult male, with his head oriented to the east. Above the earthen ledge toward the feet of the adult male lie two teenagers with heads oriented to the north. A total of 66 grave goods were found in this burial, including pottery vessels, jade artifacts, and stone tools. The jade artifacts are mostly placed near the head of the adult male. One jade bracelet was found on the forearm of one teenager. Pottery vessels were mainly found by the legs of the adult male, or above the earthen ledge on the sides. Eight pig mandibles, one pig skull, one incomplete pig skeleton, and one complete dog skeleton were found in this burial. Pig mandibles and one pig skull were placed near the adult male; the incomplete pig skeleton is near the heads of the teenagers; the complete dog skeleton lies next to one teenager. Red pigment was found on the floor near the head of the adult male, and a patch of red and black pigment was found near his left arm. These pigments might be the remains of lacquer wares.

Burial M50 is another example with reported human sacrifices. This tomb is a relative large simple pit, about 5×3 m in area (Figure 4.3). The skeleton in the center of the pit is identified as an adult male about 25 years old at death, with his head oriented to the west. Two juveniles lie by his feet, with heads oriented to the northeast (Figures 4.3 and 4.4). The east juvenile was about 8~9 years old at death, and the west juvenile was about 11~12 years old at death. It is worth noting that the distal ends of tibias of the two juveniles seem to have been bundled together. Burial M34 also had two juveniles seem to had their tibias tied together. Seventy grave goods were found in burial M50 including pottery, jade artifacts, polished turquoise beads, stone arrow heads, and bone awls. By the right shoulder of the adult male, a large area of red pigment was found in the floor, which might be the remains of a large lacquer ware artifact. Twelve pig mandibles and one incomplete pig skeleton were also found in this burial.

Multiple burials M16, M34, M35, M60, and M61 have similar features. Burials M16, M20, M34, and M50 all had one dominant individual placed in the center of the burial and two juveniles placed at one end of the burial perpendicular to the dominant one. Burial M35 had one dominant individual and one juvenile by his or her feet. Burial M60 had one adult male placed in the center of the burial, about 30 years old at death, and one adult male, one adult female, and three children in the northeast corner of the burial. Burial M61 had one female late adolescent in the center and one juvenile on the side with likely tied distal ends of its tibias.

These seven burials all have large tombs and large numbers of elaborate grave goods. All individuals in the same burial were interred at the same time; no evidence suggests that the tombs were reopened. It is possible that multiple individuals died around the same time and were placed in the same tombs. However, judging from the layout of these burials, it is fairly obvious that the individual placed in the center of each burial was dominant. Considering the fact that several subordinate individuals look like that they had the distal ends of their tibias tied, it is possible that they were sacrifices.

Human sacrifices in other Neolithic sites

Human sacrifices are also found in other Neolithic sites. For example, female pottery figurines, one human skeleton, and some pig and deer bones are found near an altar at Dongshanzui site (ca. 3500 BC), Liaoning Province, Hongshan Culture (Guo and Zhang 1984). At Bancun site (ca. 2800 BC), Henan Province, Longshan Culture, one big pit is surrounded by seven small pits in the storage area of the site. Human and fauna remains are found in the big pit. Human remains are attributed to four individuals. Blunt traumas are found in some limb bones (Jiang 1993). These two cases (Dongshanzhui and Bancun) are believed to be related to human sacrifice during ritual practices.

Human sacrifices are also argued to be used in foundation laying ceremonies during the Neolithic Era (Huang 2004). In these cases, human remains, mostly infants and children, are found beneath the house, and they are believed to be human sacrifices. However, they could also be special mortuary practices for infants and children instead of sacrifices. In two cases, Wangyoufang and Wangchenggang sites, adult skeletons are also found. Three adult male skeletons are found beneath house F20, Wangyoufang (ca. 2500-2300 BC), Henan Province, Longshan Culture. In all three crania, the portion above the eyebrows was removed with blunt forces. They probably died violently, potentially related to the foundation ceremony of the house (HAT IA CSSA 1987). Seven individuals are found in 20 layers of rammed earth inside one pit WT48H760 at Wangchenggang (ca. 2000 BC), Henan Province, Longshan Culture. There are thirteen pits like this in total found at Wangchenggang. They are believed to be sacrificial pits related to the foundation ceremonies (HPICRA and AD NMCH 1992: 38-40).

Human sacrifices are sometimes found in Neolithic burials (Huang 2004). Some cases are arguable, others are more convincing. For example, many primary multiple burials are found at Huangniangniangtai and Qinweijia sites, Gansu Province, Qijia Culture (ca. 2000 BC; Gansu Museum 1960, 1978; GAT IA CASS 1975). In one typical burial, one adult male was placed in extended supine position, and one adult female in extended side position facing the male. More grave goods were found on the male side and fewer on the female side. In some cases the male was placed inside the coffin and the female was placed outside the coffin. These observations all suggest the subordinate status of the female (Sun and Yang 2004). Even though there is no clear evidence suggesting the tombs were reopened, whether the male and female were interred at the same time, and whether these cases represent human sacrifices, are arguable.

More convincing evidence of human sacrifice in burials was found at Taosi site, Shaanxi Province (ca. 2500-1900 BC; SXAT IA CSSA, SXPICRA, and LMBC 2003). One young male was found in the fill of burial M22. This burial was large, 5×3.65×8.4 m, and relative elaborate, with 11 dedication niches in the walls of the tomb. Unfortunately, this burial was robbed. More than 100 grave goods remained, including jade objects, lacquer wares, and painted pottery vessels. Ten pigs and one pig mandible were also found. Five human crania were found in the tunnel dug by the tomb robbers. These five individuals and the young male found in the fill are possibly human sacrifices to the owner of the tomb.

In general, human sacrifices are rare in Neolithic sites. Current evidence suggests that human sacrifices were used in three kinds of major events: ritual practices, foundation layer ceremonies, and mortuary practices. Many cases are argued to represent human sacrifices (Huang 2004). However, we should critically examine the context before accepting that conclusion.

Debates on the nature of Huating

Both Dawenkou and Liangzhu style artifacts are found at Huating, sometimes in the same burial. Liangzhu style jade artifacts included highly symbolic jade *cong* (a tube with a circular inner section and square or circular outer section), *bi* (a flat jade disc with a circular hole in the centre), and *yue* ("battle axe"). They are believed to be ritual objects. Their presence at Huating suggests possible influence of Liangzhu ideology. Luan (1997d) divided the artifacts from Huating into three groups: the first group is commonly found in Dawenkou sites and is dominant at Huating; the second group is comprised of modifications of typical Dawenkou style counterparts blending traits of Liangzhu culture and is only present at Huating; the third group consists of typical Liangzhu artifacts.

Whether these Liangzhu style pottery and jade artifacts were manufactured locally or traded was investigated by X-ray diffraction and petrographic analysis of 19 pots with either Dawenkou or Liangzhu traits (Chi et al. 1995). The results suggest that pots with Liangzhu traits have different compositions and thus geographic origins from pots with Dawenkou traits. Dawenkou pots were likely manufactured locally; those with Liangzhu traits were either produced in the Liangzhu region or produced nearby using different clay and temper sources. One black chert and one quartz crystal were found in burial M41; both are unfinished preforms (Nanjing Museum 2003: 84). They are assumed to have been used for jade working. Two large pieces of jade were found in one remnant burial in the north cemetery (Nanjing Museum 2003: 196). They are assumed to be the byproduct of manufacturing large jade discs. There are several known jade sources not far from Huating, so is possible that jade artifacts were manufactured locally.

Scholars debate the identity, influences and affinities of Huating (Xu 1997; Yan and Xia 1998). The most compelling hypotheses were proposed by Yan (1990) and Gao (2000b). Yan (1990) proposed that burials in the north cemetery belong to Liangzhu soldiers that died during an expedition based on two major arguments. First, traded items should be mainly small and delicate artifacts, which are easier to carry for long distances. Large numbers of Liangzhu-style pots were found in tombs at Huating. They are not likely superior to Dawenkou ones in function, and it seems counterintuitive to carry such big artifacts for trade. Second, the dominant individuals in burials with human sacrifices are all adults or late adolescents. Among the four individuals whose sex was identifiable, three were male and one was female; the subordinate individuals in their burials were largely women or children. Yan (1990) suggested that Liangzhu style artifacts were included to commemorate their Liangzhu identity, the Dawenkou style artifacts were trophies, and Dawenkou women and children were taken as human sacrifices.

Gao (2000b) proposed that the north cemetery belonged to Dawenkou local elites who adopted Liangzhu culture. As noted above, the south cemetery is a typical Dawenkou cemetery: skeletons are in extended supine positions, head oriented to the east. The burials in the north cemetery have similar skeleton positions and orientations, indicating continuity. According to a cross-cultural survey by Carr (1995), both skeleton positions and burial orientations are commonly related to philosophical-religious beliefs of the community. Pig mandibles and complete pig skeletons in burials are commonly found in Dawenkou burials. Including dog skeletons in burials is a Dawenkou practice that is also found at Liulin and Dadunzi, not far from Huating. Gao (2000b) argued that the Liangzhu culture was mighty and threatened Dawenkou people in northern Jiangsu. Huating elites were forced to accept Liangzhu culture. Hence these burials both reflect local Dawenkou tradition and also the influence of Liangzhu culture.

The main discrepancy between the two hypotheses by Yan (1990) and Gao (2000b) is whether the north cemetery belong to Liangzhu soldiers or Dawenkou elites. Both hypotheses seem posssible based on available information. However, if strontium isotope analysis or ancient DNA analysis on human remains can be performed in the future, we might be able to find out the geographic origins of the deceased and test these hypotheses. It is clear that there was intense contact between Dawenkou and Liangzhu at Huating, either in the form of friendly gift exchange or military conquest.

Sample selection for stable isotopic analysis

In order to further investigate the identity of the Huating population and the potential identities and origins of different individuals in the same burial, six individuals from the north cemetery, including two females, one male and three sex undetermined, were selected for stable isotopic analysis (Table 4.1). Most skeletons at Huating are very fragmentary and lack critical parts for sex and age identification. Identification of the sex of many individuals is based on the robustness of limb bones, which is problematic. I still listed the sex of individuals in Table 4.1 if provided by the excavation report. However, I will not attempt to compare male and female burials due to this limitation. Due to their poor preservation I did not attempt to extract DNA from these human remains.

The six individuals selected were from four burials— M42 (one female adult), M46 (one individual, sex and age undetermined), M60 (three adults, including the person the grave was prepared for and two sacrifices), and M61 (one female late adolescent). Both M42 and M46 have moderate number of grave goods and their tombs are moderate in size. The tomb of M42 is a simple pit, about 2.45×1.2 m in area (Figure 4.5). The female adult is in extended supine position, head oriented to the east. A pig skeleton was placed by her feet. Among 35 grave goods were eight jade artifacts, five stone tools, three bone awls, and nineteen pottery vessels. Most artifacts are Dawenkou style, except for one jade pendant (M42:1) and one stem cup (M42:17), which are Liangzhu style. Tomb M46 is similar to M42. It is a simple pit, about 2.2×1.7 m in area. The owner is in extended supine position, head oriented to the east. One pig mandible and some pig bones were placed by the left side. Among 39 grave goods recovered were 26 jade artifacts and thirteen pottery vessels. One jade pendant (M46:6) is Liangzhu style.

M60 and M61 are elaborate burials with human sacrifices. M60 is a simple pit, about 4.35×3 m in area (Figure 4.6). The central individual was identified as an adult male, about 30 years old at death, with his head oriented to the east. In addition to the the person the grave was prepared for, another male adult, one female adult, and three children were found at the northeast corner of the tomb. One pig skeleton and one dog skeleton were placed by the deceased's feet. A total of 149 grave goods were found in the burial, including pottery, jade artifacts, stone tools, bone tools, and one *zhangya gouxingqi* (a composite tool made of water deer canines and animal bone). One stem cup (M60:59) and one jade necklace (M60:12) are clearly Liangzhu style, one *he* (a pottery vessel with spout and handle, M60:116) has blended traits of Liangzhu and Dawenkou vessels.

Tomb M61 is also a simple pit, about 3.5×1.6 m in area (Figure 4.7). The central individual in this burial is identified as a young female; her head is oriented to the east. To her left side lies another child[1], with the distal ends of tibias tied. The young female in the center is in extended supine position, and the child lies on its right side facing her. Fifty grave goods were found in this burial, including pottery, jade artifacts, stone tools, and bone tools. One stem cup (M61:11) and one *huang* (a jade half disc, M61:10) are Liangzhu style.

Both Dawenkou and Liangzhu style artifacts are found in all four burials. Whether the the person the grave was prepared for and human sacrifices consumed the same or different food, and whether they may have chosen different staple foods to represent their identity will be investigated using stable isotope analysis in next chapter.

Liangwangcheng

Liangwangcheng is located at Pi County, Jiangsu Province, near the border of Jiangsu and Shandong (Nanjing Museum, Xuzhou Museum, and Pizhou Museum 2008, n. d.; Figure 3.3; Figure 4.8). The excavation report of Liangwangcheng is soon to be published (Nanjing Museum, Xuzhou Museum, and Pizhou Museum n. d.). The excavators have generously offered me access to the manuscript and allowed me to use these information in my dissertation[2]. Liangwangcheng is about one kilometer south of Liulin (early Dawenkou), and 15 kilometers southwest of Dadunzi (middle Dawenkou). Liangwangcheng has multiple components, including Neolithic Dawenkou and Longshan, and historic Western Zhou (ca. 1100 BC-771 BC), Eastern Zhou (770 BC-256 BC), and more recent dynasties. I will focus my discussion on the Dawenkou component.

Features dated to the Dawenkou era are mainly found near a platform, referred to as "*Jinluandian*" by local people, that was built during the Zhou Dynasty. The residential area is

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[1] The excavation report identified this child as female. However, it can be problematic due to the young age.

[2] Do not cite information on Liangwangcheng provided in this dissertation, including maps and photos, before getting permission from the excavators. The director of Liangwangcheng excavation is Liugen LIN, Nanjing Museum.

largely located on the northeast side of the platform and the cemetery is located west of this platform (Figure 4.9). However, there are a few exceptions: six temporary houses were found on the west side and some early phase child burials were found on the east. In order to preserve Zhou Dynasty features on the east side of the platform, some underlying Dawenkou residential features have been left for future excavations. Twelve houses, one road, one pottery workshop complex, five ditches, 70 pits, one large foundation (more than 300 m^2 in area) with functions unknown, and 139 burials that are dated to Dawenkou period have been excavated. The pottery workshop is located south of the residential area: two kilns, several ditches for water supply and drainage, one hearth, and one large house were found in the workshop area. I will briefly describe the houses below and focus my discussion on burials in the following section.

Most houses at Liangwangcheng are semi-subterranean (Figure 4.10), and two are at ground level. Postholes and pieces of burnt earth (*hongshao tukuai*) are commonly found in houses. Hearths, doorways, and pots are also found. The floor surface inside the house is usually flattened and covered with fine grained soil. Large numbers of pieces of burnt earth on the floors are supposedly the fallen walls and roofs; some walls are plastered on two opposing sides. A few pots were found in some houses: most of them are *ding* (tripod vessels) and a few serving vessels were also found. The houses are generally between 10 and 20 m^2 in floor area, one of them is 30 m^2. There is no discernible difference in wealth among houses.

Liangwangcheng burials

A total of 139 burials dated to the Dawenkou period have been excavated at Liangwangcheng (Figure 4.11). Most are primary burials, with heads oriented to the east; five burials are oriented to the west. These five burials have few or none grave goods and cannot be assigned to a specific pottery phase. Individual burials are dominant at the cemetery; nine contain more than one person. Most skeletons are in extended supine position (84 individuals), some are in extended side position (27 individuals) and two are in prone position. Six are flexed, five of which are urn burials. There are three types of burials: urn burials (two opposing pots holding the body as coffins) for infants, *taoguanzang* (broken pot sherds completely covering the body as coffins; Figure 4.12), mainly for children and adolescents, and pit burials, mostly for adults.

I would argue that the *taoguanzang* type burial was for people who died before reaching adulthood and pit burials were only for adults. Judging from the age at death, there are a few exceptions. For example, four individuals with the age of death around 20 and two individuals with the age of death around 30 were buried in *taoguanzang*, and seven adolescents were buried in pit burials. However, people at Liangwangcheng might have different definitions for adulthood other than the physical age as we define adulthood today. It is possible that only people that went through certain ceremonies were considered adults and could be buried in pit burials.

Based on pottery styles, burials are divided into nine occupational phases. Phase 1 is the earliest, and Phase 9 is the latest. One burial is assigned to Phase 8, and one is assigned to Phase 9. Samples from phases 8 and 9 were not included in radiocarbon dating. I grouped Phases 1 to 7 into three chronological phases based on my radiocarbon dates (see the dating section below, Phase A corresponds to phases 1 and 2, Phase B corresponds to phases 3 and 4, and Phase C corresponds to phases 5, 6, and 7): 27, 16, and 31 burials were dated to Phases A, B, and C, respectively. After excluding multiple burials with more than one individual, *taoguanzang* for preadult, and burials that have been disturbed by later features, I compared the number of grave goods in each phase and found no significant changes through time (Figure 4.13). However, there are other changes during later phases, such as the increasing use of *ercengtai* and *mingqi* (ceramics exclusively made for funerals instead for utilitarian purposes, Figure 4.14).

There are 28 burials with *ercengtai*, three of which date to Phase A, one to Phase B, and 19 to Phase C. Five cannot be assigned to a particular phase due to the absence of grave goods. Among these five, three probably also date to Phase C judging from their locations. The three burials dated to Phase A (M110, M118, and M154) are relative elaborate and have many grave goods (ranging from 15 to 28); red pigments were found in M110 and M118, and M110 has wooden coffins. I will discuss red pigment and wooden coffin in more detail in the following section. One burial (M126) with *ercengtai* dates to Phase B, and 10 grave goods were found. This burial was disturbed by later burial M90 and pit H419, and it could have had more grave goods originally. The construction of *ercengtai* in these earlier burials indicates that extra labor was involved in their construction and suggests a special status for their occupants.

More burials with *ercengtai* were found in Phase C (19 of 31). This change might indicate that more people embraced this practice later on. However, some of them have only a few grave goods, suggesting that some people of lower status tried to mimic the practice that was originally only for people of higher status. This proposition is also supported by the observation that *mingqi* (funerary ceramics) started to appear in Phase B, and were more extensively used in Phase C. *Mingqi* usually have shapes similar to utilitarian pottery, but are generally of lower quality. For example, *gaobingbei* (tall stemmed cup) usually has thin walls, and only highly skilled potters can make it. However, thick walled *gaobingbei* appeared in later phases, which requires less skill and probably could be produced faster in larger quantities. The increasing use of *ercengtai* and *mingqi* during later phases suggest more intense competition for social status and/or display of social obligations to ancestors.

Underhill (2002) suggests that people tend to show more respect to older individuals, at least at Xixiahou site, Dawenkou culture. After excluding multiple burials with more than one individual, *taoguanzang* for preadult, and burials that have been disturbed by later features, I grouped Liangwangcheng adult burials into two age groups—young adult (<40 years old) and older adult (⩾40 years old)—and compared their means. As you can see in Figure 4.15, there are much variation in each age group. However, older individuals have a significant larger number of grave goods comparing to younger individuals according to the Wilcoxon rank sum test ($p=0.001$). It seems people also show more respect to older individuals at Liangwangcheng site.

Liangwangcheng gender relationships

Gender relationships were discussed briefly in the excavation report (Nanjing Museum, Xuzhou Museum, and Pizhou Museum n. d.). Based on the observation of three instances of “couple” burials (one male and one female in the same burial) and three instances of “mother and child” burials (one female and one child in the same burial, Figure 4.16), the authors proposed that matrilineal clans and patriarchal monogamous families coexisted in this community. No cases of “father and child” burial (one male and one child in the same burial) were found. In two “couple” burials, the male lies in extended supine position, and the female in extended side position facing the male. The excavators claimed that females are subordinate to males in these two cases. However, “couple” burials are extremely rare (3 out of 139) in the cemetery, and we do not know if they were married couples or brothers and sisters. On the other hand, the extended side position does not seem to correlate with social status or gender. Both male (7 out of 20) and female burials (10 out of 34) occur in extended side position, some of which are elaborate and some are not. The patriarchal hypothesis is contradicted by observations suggesting that some females had a special status in the community.

The excavators noticed two uncommon attributes in some burials: the use of wooden coffins and the appearance of red pigments. It is interesting to note that more females had these special treatments than males. Nine burials were found with wooden coffins. Six of them are located at the south end of the cemetery and all date to later phases (Phases 5, 6, and 7); their spatial and temporal proximity suggest they may be related. Another burial (M110) dates to Phase 1, and two others (M128 and M141) cannot be assigned to a particular phase because no grave goods were found. In M128, two adult males were found in two separate coffins. In addition, this burial is oriented to the south, unlike most burials in the cemetery. In general, burials with wooden coffin are relative rich, with the number of grave goods ranging from 11 to 36. Six of these nine burials belong to females. The exceptions are: M110, sex undetermined; M242, male; and M128, two males with distinctive orientation.

Red pigment was found in five burials: M99, M106, M110, M118, and M140. For example, red pigment is found on the rim and body of one pottery jar in burial M99. It was also found on one pottery stem cup (*dou*) and one pottery jar in burial M110. In two cases, red pigment was found on the human remains. In burial M106, red pigment was found on the right elbow of the skeleton, and also on a jade awl. This jade awl is made of rare material possibly coming from thousands of kilometers away. In burial M118, red pigment was found on the right ribs of the skeleton (Figure 4.17), and also on a pottery jar. These five burials are relative rich, with large number of grave goods (ranging from 15 to 41); two of them have *ercengtai*, which generally involved more labor in construction. Burial M140 has the largest number of grave goods in the cemetery. The red pigment is assumed to be red ochre (Nanjing Museum, Xuzhou Museum, and Pizhou Museum n. d.). Because it is rare at Liangwangcheng and it is only found in rich burials, it is may be a marker of high status. The sex of one burial (M110) is undetermined, the other four all belong to females, possibly suggesting they also had special status.

In order to further understand gender relationship, I compared the number of grave goods in male and female adult burials (Figure 4.18). I excluded burials with multiple individuals, *taoguanzang* for preadults, adult burials with sex undetermined due to poor preservation, and burials that were disturbed by later features that could have originally had more grave goods. Here, I am making a robust comparison based on the total number of grave goods regardless of the quality of goods. I am prioritizing the quantity for two reasons. First, most grave goods at Liangwangcheng are pottery vessels. Very few stone tools, jade objects, or bone tools were found. Hence most grave goods are relative comparable in quality. Second, it is consistently found across late Dawenkou sites that the quantity of grave goods seems to correlate with the social status of the deceased (Underhill 2002). Figure 4.17 shows that more male burials have less than five grave goods. A few male burials are relative rich. However, no male burial has more than 30 grave goods. Some female burials are poor as well, yet more female burials are relative rich and have more than ten grave goods: four female burials have more than 30 grave goods. The mean number of grave goods in male burials is 8.7, and the mean number of grave goods in female burials is 13.5. The Wilcoxon rank sum test suggests that the mean number of grave goods of female burials is significantly higher than that of male burials ($p=0.045$). To further understand the change of gender relationship through time, I compared the number of grave goods in male and female burials in each phase. As you can see in Figure 4.19, the differences between male and female burials are more pronounced in Phase A, and more close together in Phases B and C. The Wilcoxon rank sum tests suggest that the mean number of grave goods in male and female burials are not significant different from each other in either of the three phases. Due to the small sample size in each phase, the results are just preliminary. A larger number of grave goods could indicate either the higher status of the deceased or the effort of mourners. In general, we could say that more females were given special treatment especially in Phase A, which suggests they had special status.

Sample selection for stable isotopic analysis

As discussed above, there are some signs of incipient social stratification at Liangwangcheng: some burials are rich and some are poor; some had exotic goods, some not; some involved more labor in tomb construction, some not. We also see some difference in male and female burial treatment. In order to further test whether some people had access to special foods (for example, meat and rice, which are more labor consuming in production) and whether males and females had different food consumption patterns, I selected 27 human remains for stable isotope analysis (Chapter 5). I tried to include a balanced sample of male and female adults, burials dated to different phases, and groups of burials defined on the basis of grave goods and grave type as indicators of differences in social ranking (Table 4.1). Selected samples include 12 males and 15 females; 13 burials from Phase A, five from Phase B, nine from Phase C. Various faunal remains have been found at Liangwangcheng, including mollusk, fish, amphibian, reptile, deer, pig, and other mammals (Song and Lin n. d.). Fourteen faunal remains were selected for isotopic analysis to build the foodweb baseline (Table 5.2). Unfortunately, no flotation was done at the site, and no plant remains are available for stable isotope analysis. I also tried to carry out ancient DNA analysis on these human remains to examine their geographic origin and kinship relationship (Chapter 6). However, their DNA preservation was marginal, and I could not get any reproducible sequences.

Dongjiaying and Fujia

Detailed excavation reports of Dongjiaying and Fujia have not been published. I only have access to the associated burial information that I have obtained samples from. Unfortunately no site map is available from either site. Dongjiaying is located in Wulian County, Shandong Province (Figure 2.3). It was excavated by Shandong Provincial Institute of Cultural Relics and Archaeology in 2000, directed by Mingkui Gao. Most Dongjiaying burials date to late Dawenkou by pottery styles (Mingkui Gao, personal communication). Twenty-one individuals were sampled from Dongjiaying. Due to poor preservation and the fact that only skulls were collected, individual sex and age were not determined, and I did not attempt to extract ancient DNA from these individuals. Pig mandibles are commonly found in burials. Nine pig mandible samples were also selected for stable isotope analysis to establish the foodweb baseline.

Fujia is located in Guangrao County, Shandong Province, and was excavated in 1985, 1988 and 1995 (SPICRA and Dongying Museum 2002). There were no observable wealth differences among burials in this cemetery. Unlike most Dawenkou mortuary sites, these burials were oriented to two major directions, northeast and southeast. No significant differences in burial treatment can be discerned between the NE and SE oriented groups. Twenty-three individuals, including ten males, twelve females, and one sex undetermined, were selected from Fujia (Table 4.1). Among these selected burials, most are primary burials in extended supine position, and five are secondary burials. Twelve burials are oriented to the southeast, nine to the northeast, and two are unknown. Nine pig samples were also selected for stable isotope analysis to build the foodweb baseline.

Radiocarbon Dating

Human collagen samples from each site were dated at the Radiocarbon Dating Laboratory, Illinois State Geological Survey, using accelerator mass spectrometry (AMS), to get better temporal control (Table 4.2). Preparation of collagen samples is described in more detail in Chapter 4. Online software OxCal was used for tree ring calibration (Reimer et al. 2009; Bronk

Ramsey 2009, 2012). Samples were selected mainly by two criteria. One is collagen preservation and purity. Samples considered suitable for dating are characterized by high collagen concentration in bone, high C and N concentrations in collagen, and C:N ratios like that of collagen (Ambrose 1990; Ambrose 1993). The second criterion was to sample each chronological phase. Relative chronology information based on pottery styles was available for Liangwangcheng and Dongjiaying; at least one sample was selected from each phase. If relative dating information was not available, samples were randomly selected. Human samples were used for direct radiocarbon dating in most cases. Because collagen preservation at Dongjiaying was poor, one pig bone sample (DWK43) associated with human skeleton M1 was selected for radiocarbon dating.

Radiocarbon dates are summarized in Table 4.2 and shown in Figure 4.18. Tree ring calibration shows that the occupations of Huating, Liangwangcheng, and Fujia overlapped with each other (Figure 4.20). Huating dates to 2800-2600 cal. BC, Liangwangcheng to 2800-2550 cal. BC, and Fujia to 2800-2500 cal. BC. Dongjiaying dates to a few centuries later (2600-2300 cal. BC). The overlapping timespans of these sites makes it possible to compare dietary custom among contemporary communities, and over five centuries.

Liangwangcheng and Dongjiaying have occupation phase divisions based on pottery styles that can be compared to radiocarbon phases. Bone samples were selected from seven burials dated to each phase (from Phase 1 to Phase 7) at Liangwangcheng (Table 4.2). Phases 8 and 9 were excluded because only one burial dates to each phase. Radiocarbon dates largely support the relative chronology. After tree ring calibration, the date range of Phase 1 overlaps with Phase 2, Phase 3 overlaps with Phase 4, and Phases 5, 6 and 7 overlap with each other. This suggests continuity between phases. Radiocarbon dates suggest that Liangwangcheng was probably occupied in three phases: Phase A dated to 2810-2750 cal. BC (pottery phases 1 and 2), Phase B dated to 2700-2620 cal. BC (pottery phases 3 and 4), and Phase C dated to 2640-2560 cal. BC (pottery phases 5, 6, and 7) (Figure 4.21).

Dongjiaying has three phases based on pottery styles (Mingkui Gao, personal communication). One collagen sample from Phase 1, two from Phase 2, and one from Phase 3 were selected for radiocarbon dating (Table 4.2). DWK3, from a Phase 2 burial, yielded a much younger age compared to other samples; this could result from either contamination or an actual younger age. The remaining samples had radiocarbon dates corresponding to their pottery-based relative chronology.

Due to the poor preservation of Dongjiaying samples, I was concerned that collagen was possibly contaminated by absorbed humic substances from the soil. Two samples (DWK11 and DWK43) were dated again with the pyrolysis method, which is designed to separate high molecular weight collagen and low molecular weight contaminants (Wang et al. 2010). The pyrolysis residue of both samples yielded dates closely similar to those on whole collagen (Table 4.2). This indicates that collagen was not contaminated and the dates are reliable.

Fujia was believed to have been occupied in both middle Dawenkou and late Dawenkou by associated pottery styles. However, the radiocarbon dates of human bone collagen belonging to five randomly selected individuals put them all in the range of late Dawenkou. It is possible that individuals dated to middle Dawenkou were present but were not selected, and that Fujia was occupied in both middle and late Dawenkou. It is also possible that Fujia was occupied only in late Dawenkou but maintained some pottery styles more similar to middle Dawenkou.

Summary

In this chapter, I have introduced the archaeological background of Huating, Liangwangcheng, Dongjiaying, and Fujia sites. These four sites all date to late Dawenkou according to radiocarbon dating results. Despite their contemporaneity, there are significant variations in the development of social ranking. Huating seems to be the most stratified with evidence of human sacrifice in some burials. Skeletal preservation made sex identification at Huating problematic, so I will not discuss gender relations at Huating. Liangwangcheng shows some signs of social ranking, including some burials with large numbers of grave goods, and exotic artifacts suggesting long distance trade. In addition, some females seem to have privilege over others in the community. There is no evidence supporting the proposed transition to patriarchal monogamous family organization. Unfortunately, the excavation reports of Dongjiaying and Fujia are not available. Based on the limited information available, the Fujia community seems quite egalitarian.

In the next chapter, I will present the isotopic analysis results of human and faunal remains from these four sites. I will discuss how everyday food consumption reflects one's social status and gender identity and how the introduction of rice might have facilitated the process of social stratification.

Tables

Table 4.1. Summary of Dawenkou burials that were sampled from Liangwangcheng, Fujia, and Huating sites, including the occupation phase determined by associated pottery styles, number of grave goods, grave type, skeleton position, body orientation, sex, and age, if such information is available. 21 human samples were also obtained from Dongjiaying site; however, the excavation report of Dongjiaying has not been published and the associated information is largely unknown, hence Dongjiaying individuals were not listed in this table.

Site Name	Feature Number	Pottery Phase	Number of Grave Goods	Grave Type	Skeleton Position	Body Orientation	Sex	Age
Liangwangcheng	M81*	2	5	simple pit	extended supine	east	male	35±
Liangwangcheng	M82*	2	5	simple pit	extended supine	east	female	30±
Liangwangcheng	M89*	4	23	simple pit	extended supine	east	male	40-44
Liangwangcheng	M97	2	5	simple pit	extended side	east	male	40-44
Liangwangcheng	M99*	3	18	simple pit	extended supine	east	female	29-30
Liangwangcheng	M104		0	simple pit	extended supine	east	female	20±
Liangwangcheng	M106*	7	16	simple pit	extended side	east	female	35±
Liangwangcheng	M120*	2	20	simple pit	extended supine	east	female	45-50
Liangwangcheng	M121*	4	16	simple pit	extended side	east	male	35±
Liangwangcheng	M125*	6	11	pit with *ercengtai*	extended supine	east	female	35±
Liangwangcheng	M129*	1	18	simple pit	extended side	east	male	45-50
Liangwangcheng	M146*	2	18	simple pit	extended side	east	female	45-50
Liangwangcheng	M154*	1	20	pit with *ercengtai*	extended side	east	male	25±
Liangwangcheng	M160	1	15	simple pit	extended side	east	female	40-44
Liangwangcheng	M223	5	5	simple pit	extended supine	east	male	35±
Liangwangcheng	M225*	7	26	simple pit	extended side	east	male	35-39
Liangwangcheng	M226*	6	17	simple pit	extended prone	east	male	24-26

Liangwangcheng	M238	5	10	simple pit	extended supine	east	female	50-60
Liangwangcheng	M248	6	7	simple pit	extended supine	east	female	30±
Liangwangcheng	M249	5	8	simple pit	extended supine	east	female	23±
Liangwangcheng	M251*	5	6	simple pit	extended supine	east	female	40～44
Liangwangcheng	M252*		1	pit with *ercengtai*	extended supine	east	female	19～23
Liangwangcheng	M253*		1	pit with *ercengtai*	extended supine	east	male	45～49
Liangwangcheng	M254*	5	12	pit with *ercengtai*	extended supine	east	male	40±
Liangwangcheng	M268*		1	simple pit	extended supine	east	female	25±
Liangwangcheng	M271*	4	16	simple pit	extended supine	east	female	40-44
Liangwangcheng	M272*	3	4	simple pit	extended side	east	male	40±
Fujia	M6*		3	simple pit	extended supine	southeast	female	adult
Fujia	M7		1	simple pit	unknown	northeast	male	adult
Fujia	M9*		1	simple pit	extended supine	southeast	male	adult
Fujia	M10*		1	pit with *ercengtai*	extended supine	northeast	male	adult
Fujia	M12*		2	simple pit	extended supine	southeast	female	adult
Fujia	M16*		3	pit with *ercengtai*	extended supine	northeast	undetermined	undetermined
Fujia	M17*		1	simple pit	extended supine	southeast	female	adult
Fujia	M21		1	simple pit	extended supine	northeast	female	adult
Fujia	M24*		2	simple pit	extended supine	northeast	female	adult
Fujia	M28*		0	simple pit	extended supine	southeast	male	adult
Fujia	M31*		0	simple pit	extended supine	southeast	female	adult
Fujia	M32*		0	simple pit	extended supine	northeast	male	adult
Fujia	M34*		2	simple pit	extended supine	northeast	female	adult
Fujia	M101*		1	simple pit	extended supine	northeast	female	adult
Fujia	M112*		5	simple pit	secondary burial	northeast	male	adult
Fujia	M117*		0	simple pit	secondary burial	unknown	male	adult
Fujia	M118*		0	simple pit	unknown	southeast	male	adult
Fujia	M128*		2	simple pit	secondary burial	southeast	female	late adolescent
Fujia	M133*		0	simple pit	extended supine	southeast	female	adult

Fujia	M140*	0	simple pit	secondary burial	southeast	male	adult
Fujia	M145	0	simple pit	secondary burial	unknown	male	adult
Fujia	M154	0	simple pit	extended supine	southeast	female	late adolescent
Fujia	M156	0	simple pit	extended supine	southeast	male	adult
Huating	M42	35	simple pit	extended supine	east	female	middle age adult
Huating	M46	39	simple pit	extended supine	southeast	undetermined	undetermined
Huating	M60	149	simple pit	extended supine	east	male	30±
Huating	M60(2)		simple pit	extended supine	northwest	male	middle age adult
Huating	M60(3)		simple pit	extended supine	northwest	female	middle age adult
Huating	M61	50	simple pit	extended supine	southeast	female	late adolescent

* Samples selected for ancient DNA analysis, including 20 teeth samples from Liangwangcheng and 18 bone samples from Fujia (Chapter 5).

Note: 1. Number of grave goods are the number of grave goods found in the excavation. Some of the burials had been disturbed before excavation; it is possible there were larger number of grave goods originally than found.

2. Pit with *ercengtai* refers to the pit with artificial earthen second-level ledges.

3. Skeleton position refers to individual position in the grave: when it is a primary burial, the skeleton position is provided; when it is a secondary burial with the original skeleton position unknown, it is listed as secondary burial instead.

4. Body orientation means, where discernible, the direction to which the head of the deceased pointed in a grave. Where possible, the orientation is recorded with one of the eight major directions of the compass, i.e. north, south, east, west, northeast, northwest, southeast, and southwest. Because not every body was orientated precisely on one of the directions, some orientations are approximate, and simply rounded off to the nearest major direction.

5. Sex identification is mostly based on morphology; the sex and age identification of Liangwangcheng, Fujia, and Huating individuals was done by Xiaoting Zhu (n. d.), Kangxin Han (unpublished data), and Xianghong Huang (2003a, b) respectively. However, one individual M118 from Fujia site, which is morphologically identified as male, was molecular identified as female (Chapter 5).

6. M60, M60(2), and M60(3) are three individuals from burial M60. The one labeled M60 is the supposed the person the grave was prepared for, M60(2). M60(3) and another three juveniles are arguably sacrifices (Nanjing Museum 2003: 66).

Table 4.2. Radiocarbon dating results of Dongjiaying, Fujia, Huating, and Liangwangcheng sites.

Site Name	Feature Number	Relative Chronology by Pottery	Lab ID	wt% collagen	N wt%	C wt%	C: N	ISGS ID	Radiocarbon Date, BP	Calibrated Age Range, BC, 1σ	Calibrated Age, BC, 1σ	Calibrated Age, BC, 2σ
Dongjiaying	M10	1 (earliest)	DWK11	1.93	13.49	37.29	3.22	A2086	4010±20	2568-2517	2540±30	2525±50
								A2373	3995±25	2565-2525	2545±20	2540±30
Dongjiaying	M1:13	2	DWK43	1.68	14.46	39.23	3.17	A2088	3935±20	2476-2350	2415±65	2415±75
								A2374	3895±20	2460-2347	2405±60	2400±65
Dongjiaying	M4	2	DWK3	1.41	12.65	35.71	3.29	A2085	3730±20	2086-2050	2070±20	2120±80
Dongjiaying	M16	3 (latest)	DWK17	0.34	12.15	32.91	3.16	A2087	3855±20	2348-2286	2315±35	2345±70
Fujia	M17		DWK173	4.51	15.65	43.40	3.24	A1990	4175±25	2810-2751	2780±30	2740±75
Fujia	M34		DWK185	6.23	16.73	45.02	3.14	A2091	4150±25	2763-2672	2720±50	2765±95
Fujia	M9		DWK165	10.47	16.75	46.61	3.25	A1989	4140±20	2757-2665	2710±50	2700±80
Fujia	M21		DWK175	10.59	15.00	41.82	3.25	A2090	4050±25	2620-2565	2590±30	2560±75
Fujia	M32		DWK183	4.87	16.83	45.28	3.14	A1991	4030±20	2536-2492	2515±25	2530±50
Huating	M61		DWK217	0.56	12.67	32.04	2.95	A2093	4140±25	2758-2663	2710±50	2750±125
Huating	M42		DWK207	0.65	14.53	39.96	3.21	A2092	4120±25	2697-2625	2660±40	2670±90
Liangwangcheng	M129	1 (earliest)	DWK107	11.23	16.34	44.26	3.16	A1982	4170±20	2810-2751	2780±30	2745±70
Liangwangcheng	M120	2	DWK101	12.03	16.02	43.20	3.15	A1983	4175±25	2810-2751	2780±30	2740±75
Liangwangcheng	M272	3	DWK139	3.89	15.46	42.63	3.22	A1984	4125±20	2698-2632	2665±35	2690±75
Liangwangcheng	M271	4	DWK137	2.29	14.95	40.84	3.19	A1985	4105±20	2677-2617	2647±30	2640±60
Liangwangcheng	M238	5	DWK121	5.72	15.56	42.71	3.20	A1986	4095±20	2637-2580	2610±30	2635±60
Liangwangcheng	M226	6	DWK119	3.95	15.00	40.66	3.16	A1987	4055±20	2620-2568	2595±30	2595±35
Liangwangcheng	M225	7 (latest)	DWK117	6.60	16.44	44.55	3.16	A2089	4090±20	2635-2579	2610±30	2635±65

Figures

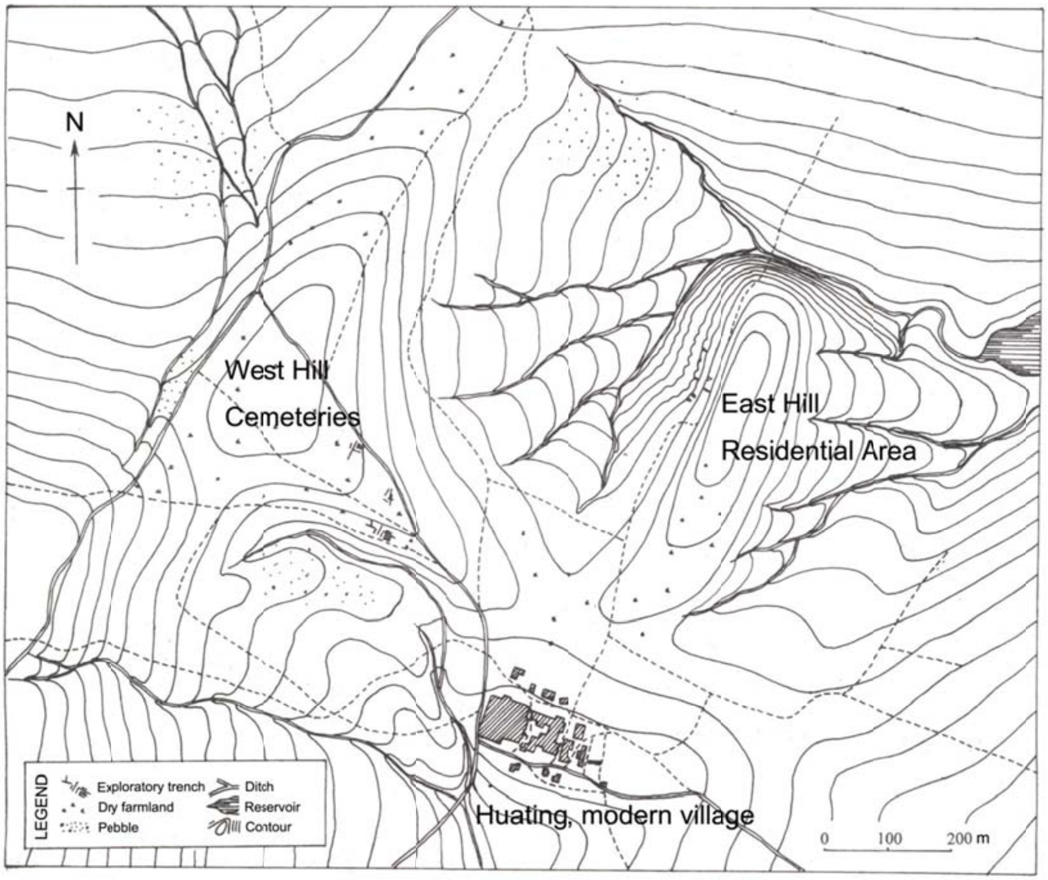

Figure 4.1. Topographic map of the Huating site, with the residential area in the eastern elevated area, and cemeteries in the western (modified from Nanjing Museum 2003: Figure 2).

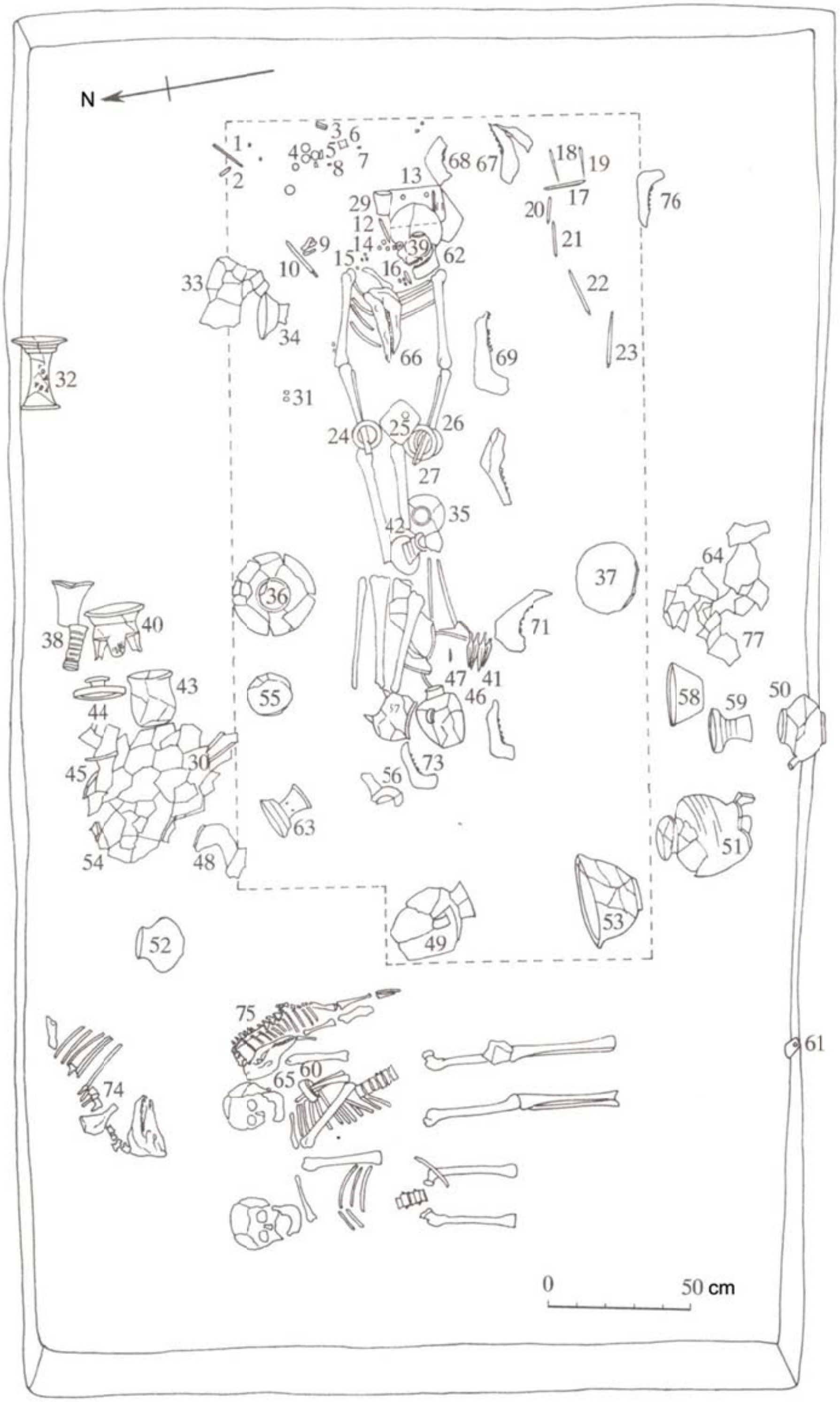

Figure 4.2. The layout of burial M20, Huating site (modified from Nanjing Museum 2003: Figure 44).

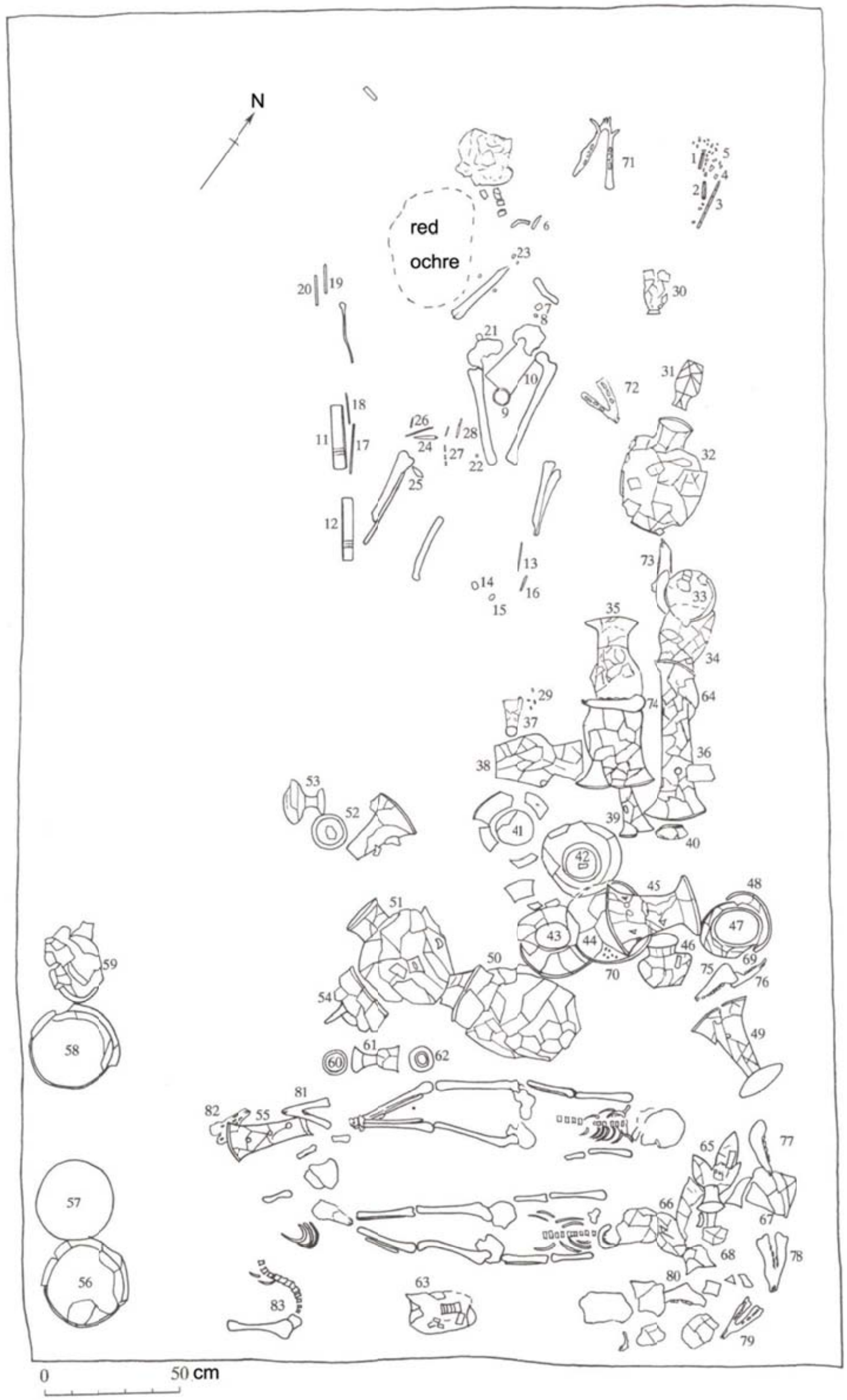

Figure 4.3. The layout of burial M50, Huating site (modified from Nanjing Museum 2003: Figure 49).

Figure 4.4. Field photo of two human sacrifices located at the south end of burial M50, Huating site (Nanjing Museum 2003: Color Figure 7).

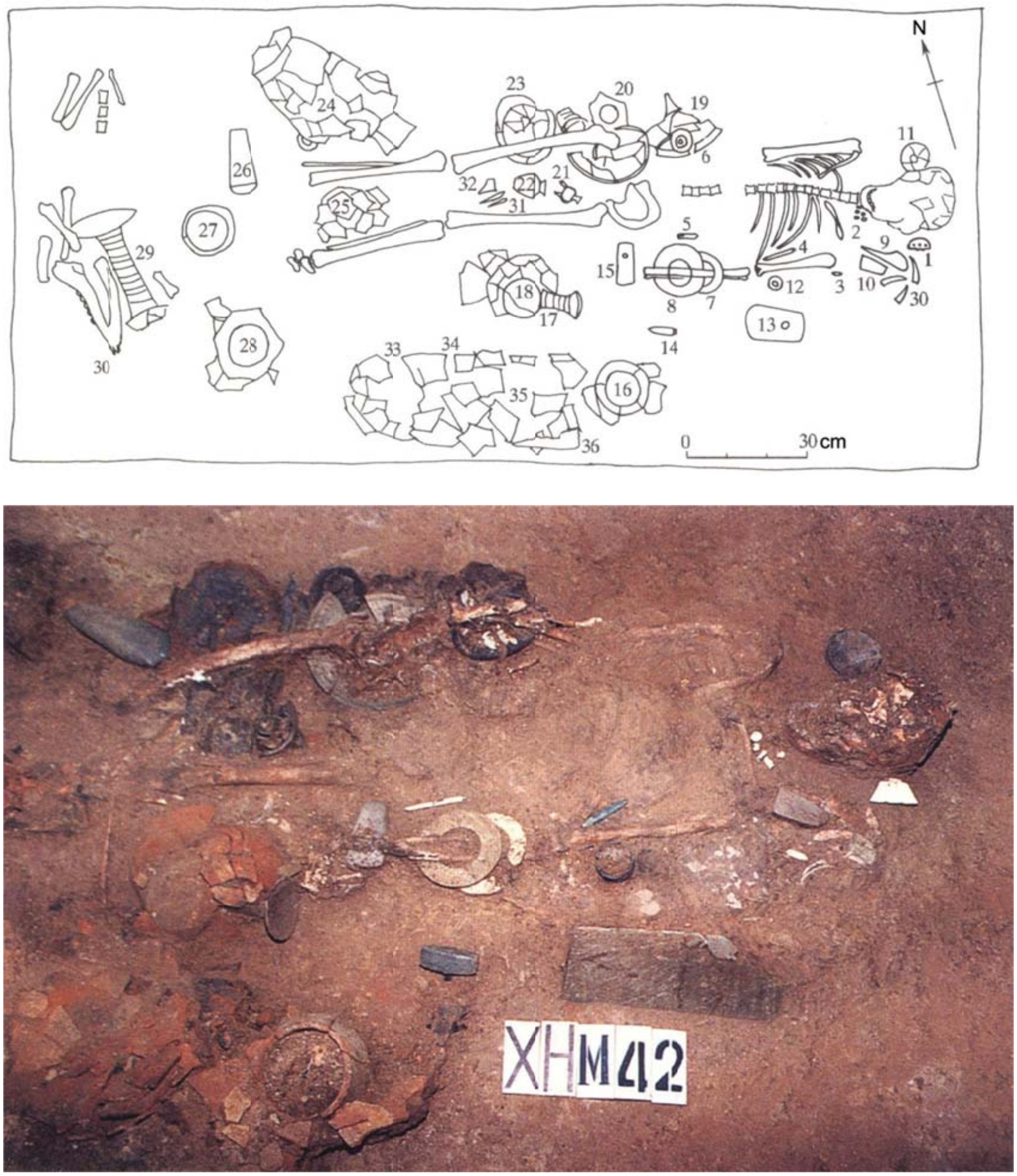

Figure 4.5. The layout and field photo of burial M42, Huating site (modified from Nanjing Museum 2003: Figure 76 and Color Figure 6).

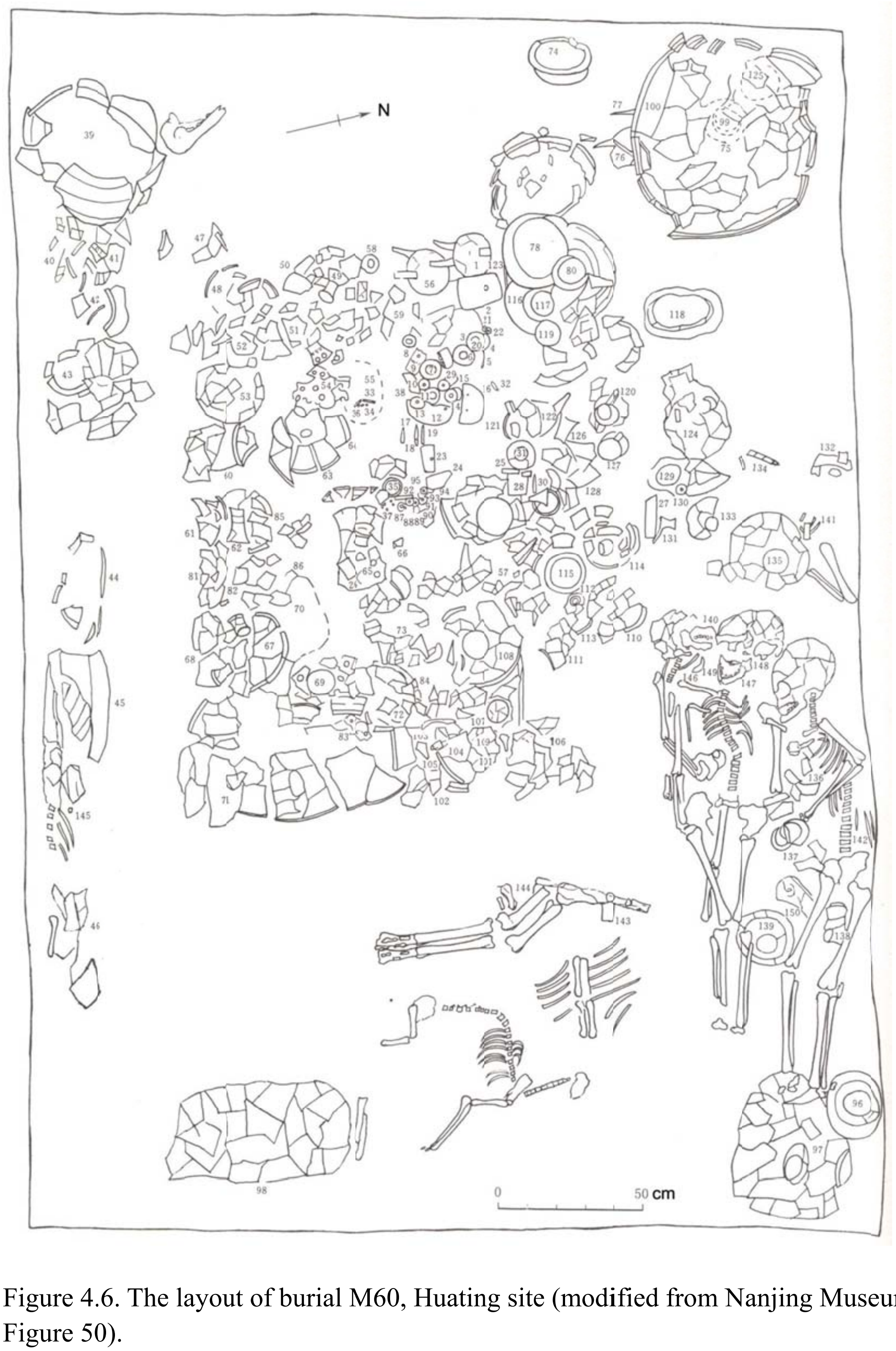

Figure 4.6. The layout of burial M60, Huating site (modified from Nanjing Museum 2003: Figure 50).

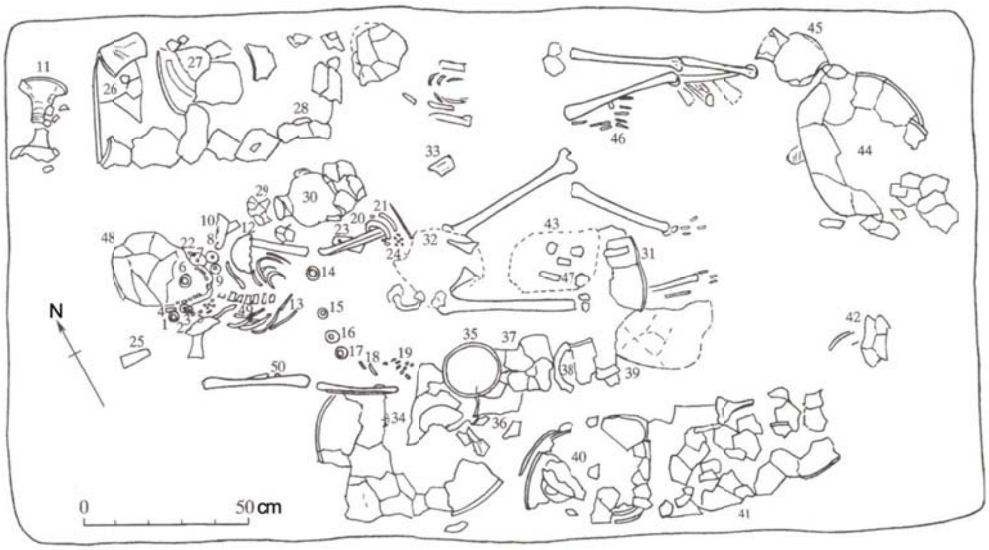

Figure 4.7. The layout of burial M61, Huating site (modified from Nanjing Museum 2003: Figure 51).

Figure 4.8. Excavation at Liangwangcheng site (photo provided by Liugen LIN[3]).

[3] Do not reproduce this photo before getting permission from Liugen LIN. The same rule applies to all photos provided by Liugen LIN in this dissertation.

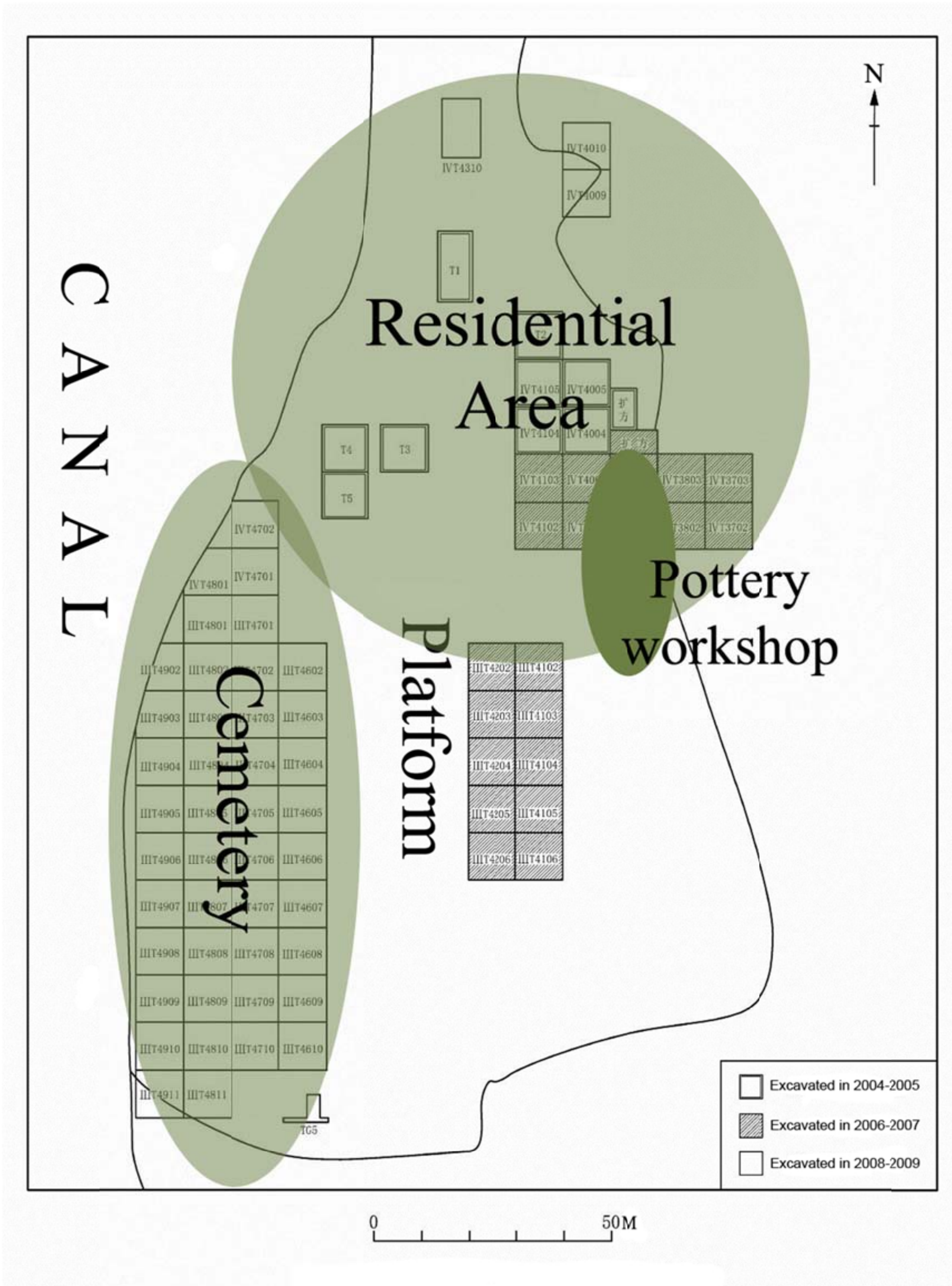

Figure 4.9. The site map of Liangwangcheng site (modified from Nanjing Museum, Xuzhou Museum, and Pizhou Museum n. d.: Figure 3). The platform is referred to as "Jinluandian" by local people, which was built during the Zhou Dynasty.

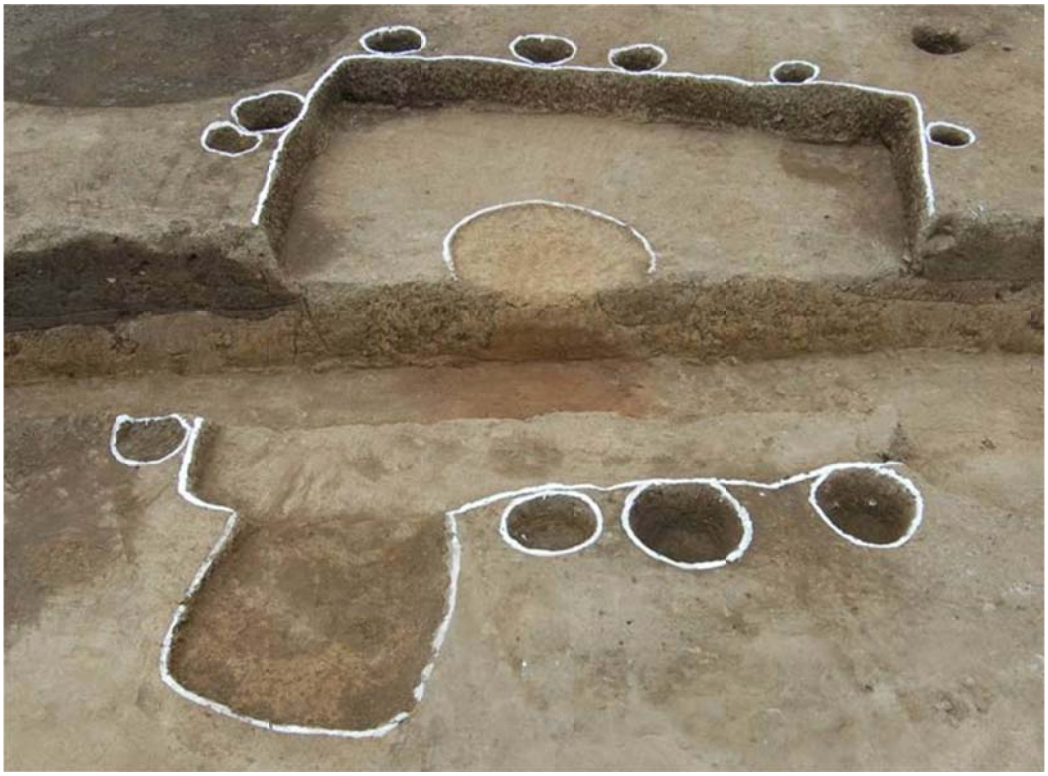

Figure 4.10. House F21 at Liangwangcheng site (photo provided by Liugen LIN).

Figure 4.11. Part of Liangwangcheng cemetery (photo provided by Liugen LIN).

Figure 4.12. Burial M230, a typical *taoguanzang*, Liangwangcheng site (photo provided by Liugen LIN).

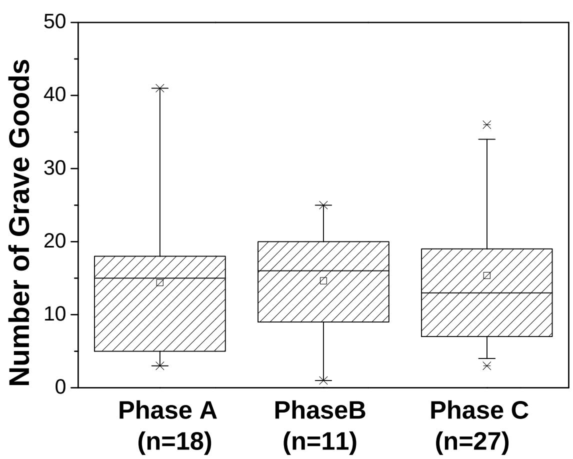

Figure 4.13. Box plot of number of grave goods in adult burials grouped by phase, Liangwangcheng site.

Figure 4.14. Grave goods in burial M225, Liangwangcheng site. The stemmed cups in the first row are likely *mingqi* considering their smaller size and lower quality. It is very likely that they were produced only for the purpose of the funeral (photo provided by Liugen LIN).

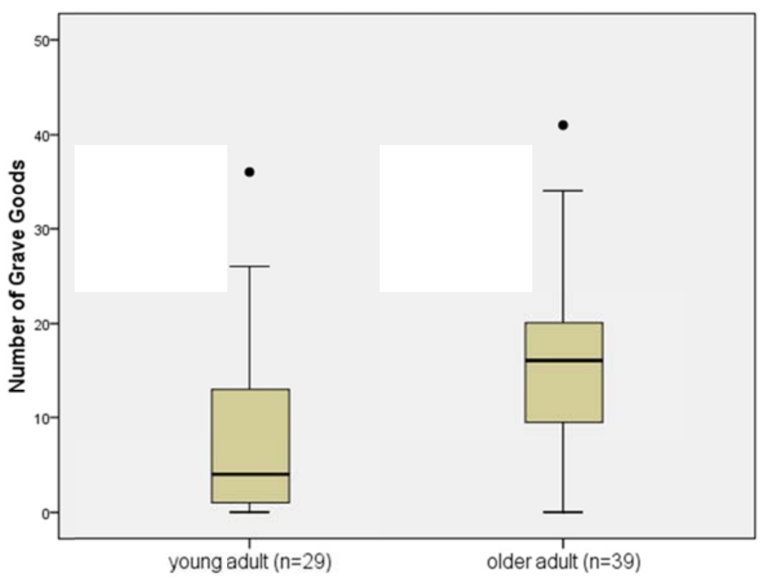

Figure 4.15. Box plot of number of grave goods in adult burials grouped by age groups, Liangwangcheng site. Young adults are individuals died before turning 40, older adults are individuals older than 40.

Figure 4.16. Burial M106, Liangwangcheng site, the assumed “mother and child” burial with one adult female and a child buried together (photo provided by Liugen LIN).

Figure 4.17. Red pigment found on the ribs of the human skeleton in burial M118, Liangwangcheng site (photo provided by Liugen LIN).

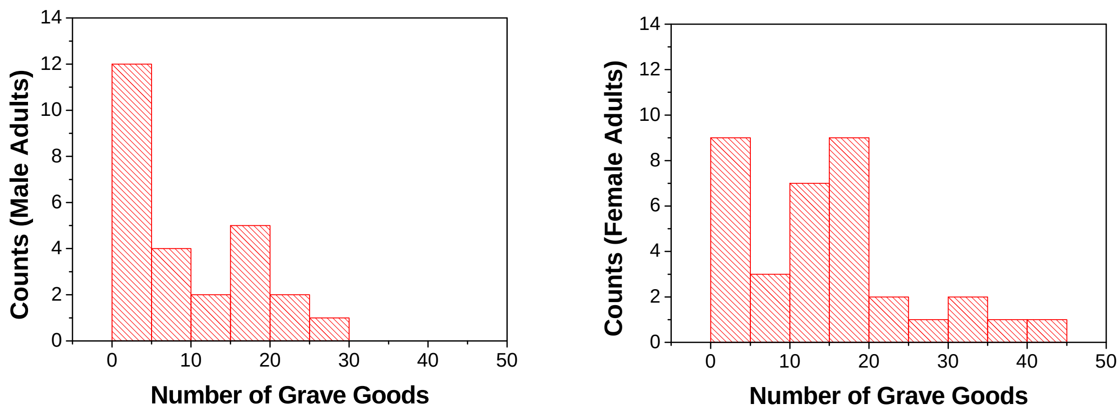

Figure 4.18. Histogram of number of grave goods in male and female adult burials, Liangwangcheng site.

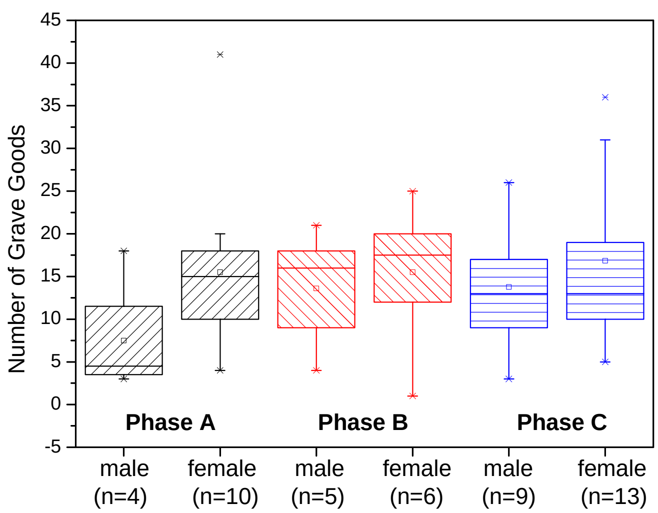

Figure 4.19. Box plot of number of grave goods in adult burials grouped by sex and phase, Liangwangcheng site.

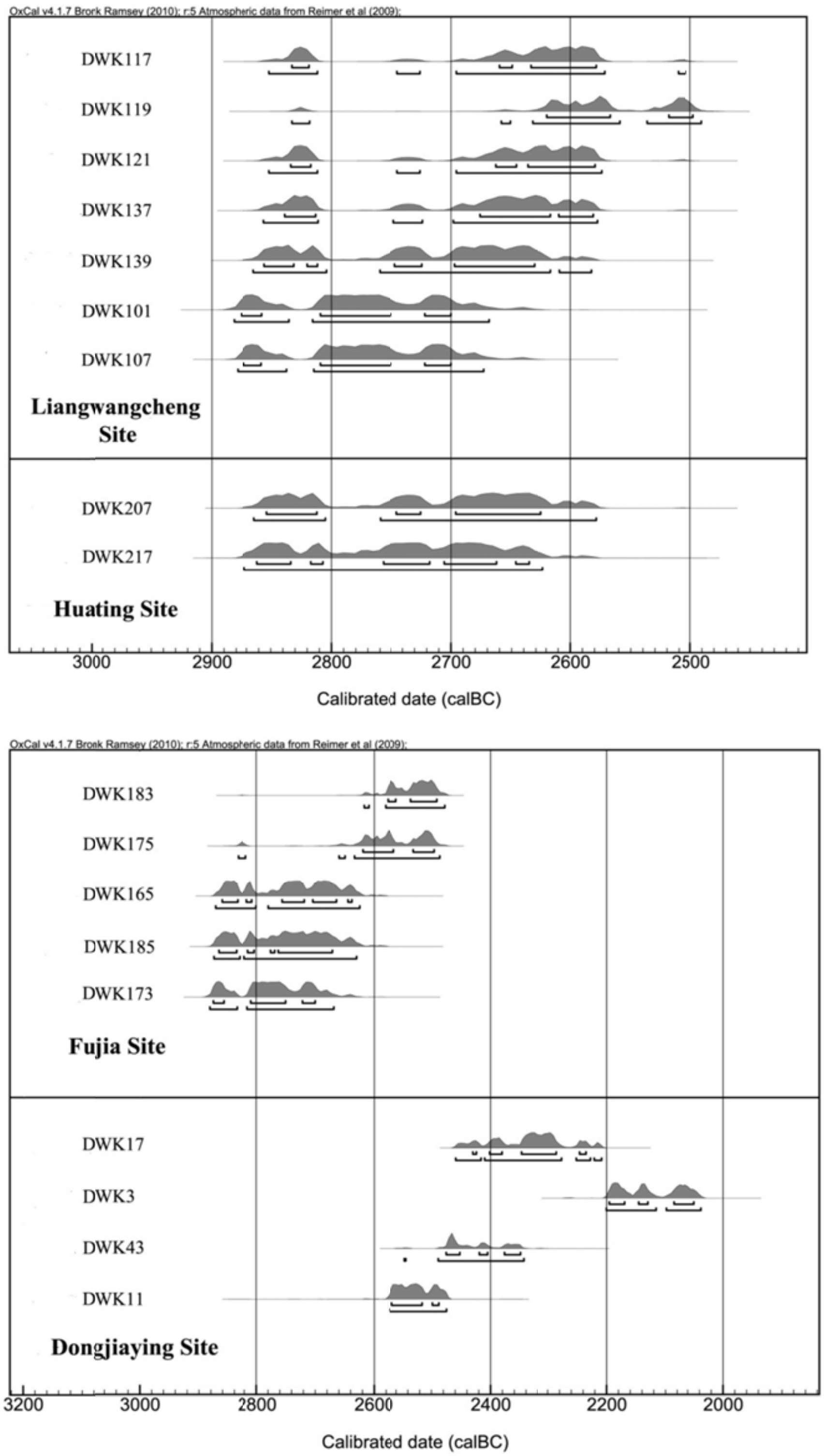

Figure 4.20. Radiocarbon dating results and calibrated date ranges of Dongjiaying, Fujia, Huating, and Liangwangcheng sites.

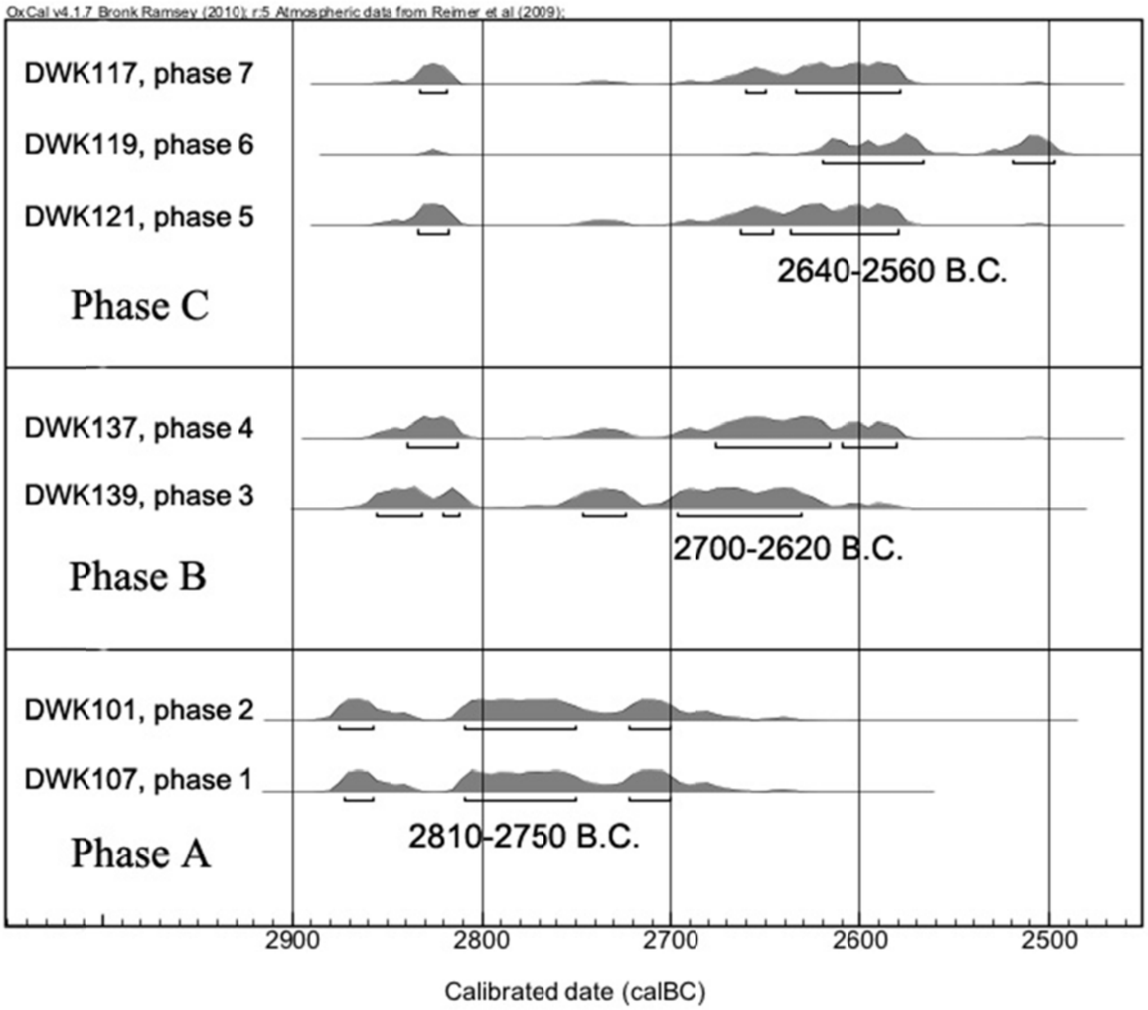

Figure 4.21. Radiocarbon dating results and calibrated date ranges of the seven groups and three phases at Liangwangcheng sites.

CHAPTER 5

FOOD CONSUMPTION AND ITS SOCIAL CONTEXT: STABLE ISOTOPE ANALYSIS

Food choices can often reflect one's identity on multiple levels, such as ethnicity, social status, and gender. Millet and rice, which were originally staples for earlier Neolithic northern and southern Chinese peoples, respectively, both appeared at Dawenkou sites and presented them with the option to either continue to consume their original food—millet, or accept the new food—rice. How people may have chosen millet or rice at Dawenkou sites to represent their identity, and how the introduction of rice may have facilitated the process of social stratification are discussed in this chapter. I will discuss the applicability of stable isotope analysis in dietary reconstruction at Dawenkou sites. Next, I will describe the methods and results of stable isotope analysis. I will then discuss the food consumption patterns at each site in their specific social context. Finally, I will discuss the significance of the finding and provide suggestions for future research.

As discussed in Chapter 3, the dietary staple at Dawenkou sites potentially includes millets and rice. The consumption of millets versus rice are potential ethnic identity markers for northern and southern China in antiquity. In addition, rice has a higher requirement for water than millets; water management projects were likely involved in rice production. Alternatively, if no water management projects were constructed, rice is likely to have much lower yield and makes it a rare food. In either case, rice is likely considered more valuable than millets due to the labor involved or the scarcity. In addition to crops, Dawenkou people probably also consumed some animal protein, such as pigs, deer, and maybe aquatic resources. Based on historical records, meat was probably a preferred food during the Shang dynasty and after (Underhill 2002: 82). It is very likely that meat was also preferred food at Dawenkou sites because the investment in raising pigs and hunting deer. We can expect that rice and meat were used as status markers and were only available to people of higher social status.

In this chapter, I will present the isotopic analysis results on food consumption at four Dawenkou sites. Since no flotation results are available for the four sites, my isotopic analysis provides valuable information about diet. What is more important, I will investigate food consumption differences among different sites and different individuals at the same site and discuss the social context of food consumption.

Diet Reconstruction with Stable Isotopes

Stable isotope ratios of samples are conventionally expressed using the δ (delta) notation as parts per thousand (‰, permil) difference from the ratios of standard reference materials. Diet reconstruction with stable isotopes is based on the assumption that the stable carbon and nitrogen isotope ratios ($^{13}C/^{12}C$, $^{15}N/^{14}N$) of animal tissues are direct and constant functions of those of the diet (DeNiro and Epstein 1978, 1981). Where these ratios differ significantly and consistently among dietary resources their amounts in the diet can be reconstructed.

Carbon isotopes

The different photosynthetic pathways of C_4 and C_3 plants cause a bimodal non-overlapping distribution of carbon isotope ratios (Van der Merwe and Vogel 1978). Tropical savanna grasses, which are adapted to strong sunlight, high temperatures and low CO_2 concentrations, use the C_4 pathway (Tieszen 1991). Trees, shrubs and most herbaceous dicots, and grasses adapted to the shaded forest understory, high elevation cold tropical alpine, and high latitude environments use the C_3 photosynthetic pathway (White et al. 2009). Many tropical succulent plant genera, including cactus and aloe, use the CAM (Crassulacean Acid Metabolism) photosynthetic pathway and have $\delta^{13}C$ values that are variable, nearly spanning the range from C_3 to C_4 plants, but usually much closer to the average for the latter (Osmond et al. 1973; P. L. Koch, Behrensmeyer, and Fogel 1991).

The mean $\delta^{13}C$ values for C_4 plants are around -12 to -14‰, and the mean values for C_3 plants are around -26 to -28‰. However, there are also significant variations within C_4 and C_3

plants: $\delta^{13}C$ values can range from -22‰ to -38‰ for C_3 plants, and -9 to -21‰ for C_4 plants (Medina et al. 1986; O'Leary 1988). Typical desert C_3 plants in northern China have $\delta^{13}C$ values from -23.2‰ to -30.0 ‰ (Chen et al. 2002). Herbaceous C_3 plants from the loess plateau area in northern China (n=367) have $\delta^{13}C$ values varying between −21.7‰ and −30.0‰, with a mean of −26.7‰ (Wang, Han, and Liu 2003).

A variety of environmental factors such as humidity and water stress can affect plant $\delta^{13}C$ values (Tieszen 1991). The $\delta^{13}C$ values of C_3 leaves can vary by up to 3-6‰ within species in response to water stress, and are generally highest in hot, dry environments. Closed canopy forests tend to trap ^{13}C-depleted biogenic CO_2 from C_3 plant decomposition and root respiration. High concentrations of ^{13}C-depleted biogenic CO_2 lowers plant $\delta^{13}C$ values near the forest floor and creates vertical stratification in plant and animal $\delta^{13}C$ values (van der Merwe and Medina 1991; Cerling, Harris, and Passey 2003).

Herbivores, omnivores, and carnivores should have $\delta^{13}C$ values that reflect those of the proportions of C_4 or C_3-based foods that they consume. Among the most widely used tissue types for reconstructing diets are bone collagen, and bone and tooth enamel and dentine apatite carbonate (bioapatite). Collagen and bioapatite have characteristic carbon isotope difference or spacing values relative to the diet. Differences in the isotopic composition of the major dietary macronutrients (proteins, carbohydrates and lipids) may influence the collagen-diet spacing, and digestive physiology may influence the apatite-diet difference. The causes of these systematic variations are explained in this section.

Controlled diet experiments show that collagen is synthesized mainly from dietary proteins, while bioapatite carbon reflects the whole diet $\delta^{13}C$ value (Ambrose and Norr 1993; Tieszen and Fagre 1993). Bioapatite carbon reflects the whole diet because it is formed from serum CO_2 and bicarbonate that are generated by metabolism of food. Because all digestible macronutrients are ultimately metabolized they all contribute equally to biopatite (Ambrose and Norr 1993).

The $\delta^{13}C$ value of collagen is typically enriched by 5‰ relative to that of the bulk diet ($\Delta^{13}C_{col\text{-}diet}$= +5‰) when the main dietary macronutrients all have the same $\delta^{13}C$ values. In other words for collagen, you are what you eat plus 5‰ (Vogel 1978; Ambrose 1993). This enrichment is consistent for all herbivores regardless of the proportions of C_3 and C_4 plants in their diets because the $\delta^{13}C$ values of the major dietary macronutrient fractions (proteins and carbohydrates) are usually closely similar. The controlled diet experiments noted above show that muscle is enriched by 1.5‰ relative to a mono-isotopic diet. Therefore the $\delta^{13}C$ value of carnivore collagen is enriched by 1.5‰ relative to the collagen of their prey, and by ~6.5‰ to 7‰ relative to the average of plants consumed by herbivores, as observed by Lee-Thorp et al. (1989).

Bioapatite-diet enrichment spacing varies among species depending on digestive physiology. The $\delta^{13}C$ value of ruminant herbivore bioapatite carbonate (bone, dentine and enamel) is enriched by approximately 14‰ relative to the diet (Cerling and Harris 1999; Balasse, Bocherens, and Mariotti 1999; Passey et al. 2005), while that of rodents and carnivores, and presumably other non-ruminants such as primates and suids, is enriched by 8.5‰~10‰ (Lee-Thorp, Sealy, and van der Merwe 1989; Ambrose and Norr 1993). The larger apatite-diet spacing of ruminant herbivores is apparently due to digestive tract microbial methanogenesis (Ambrose et al. 1997; Cerling and Harris 1999). Methanogenesis affects apatite $\delta^{13}C$ values because microbial methane is depleted by >40‰ relative to the diet ($\Delta^{13}C_{diet\text{-}methane}$= -40‰). Microbe simultaneously generate CO_2 that is enriched by ~13‰. This is diluted by the metabolic CO_2 of the host herbivore to ~+5‰ (Metges, Kempe, and Schmidt 2007). This enriched circulating CO_2 is thus responsible for the ~14‰ diet-apatite enrichment of herbivores compared to the ~9‰ enrichment of non-ruminants.

Pigs are omnivores, and wild and domestic pigs may have substantially different diets. Because methanogenesis in pigs increases significantly with a high fiber diet (Jensen 1996), the diet-bioapatite ^{13}C difference may vary depending on their diets. Foddering with crop residues (stalks and leaves) would be a high fiber diet, and scavenging within human settlements or provisioning with human food waste and feces, would be a lower fiber diet. As will be explained below, nitrogen isotope ratios can help differentiate low and high fiber diets.

As noted above, controlled diet experiments show that carbon isotope ratios of bone collagen reflect mainly those of dietary protein, while bone apatite carbonate (bioapatite) reflects whole diet composition regardless of the isotopic composition of the protein and non-protein components and their proportions in the diet (Ambrose and Norr 1993; Tieszen and Fagre 1993). Carnivores have smaller apatite-collagen spacing ($\Delta^{13}C_{ap\text{-}col}$) than herbivores in the same habitat (Lee-Thorp, Sealy, and van der Merwe 1989).

The interpretation of $\delta^{13}C$ values in omnivores are more complicated than herbivores and carnivores since their diet involved both protein and non-protein components, which can have different carbon isotope values. When protein and non-protein components (carbohydrates and fats) of the diet have the same carbon isotope ratios then bone collagen $\delta^{13}C$ is enriched by about 5‰ relative to the bulk diet for all digestive strategies ($\Delta^{13}C_{col\text{-}diet}$= +5‰), and the bioapatite-collagen difference value ($\Delta^{13}C_{ap\text{-}col}$) is approximately 4.5‰ for non-ruminants and ~9‰ for ruminants (Ambrose and Norr 1993).

When protein and non-protein dietary components have different carbon isotope ratios then the diet-collagen and collagen-bioapatite spacing (difference or enrichment) values will vary as follows: when the $\delta^{13}C$ value of dietary protein is less negative than that of the bulk diet (C_4 protein, C_3 non-protein) then $\Delta^{13}C_{col\text{-}diet}$ values are greater than 5‰ and $\Delta^{13}C_{ap\text{-}col}$ values are less than 4.5‰. Conversely, a diet with C_3 protein and C_4 non-protein shifts $\Delta^{13}C_{col\text{-}diet}$ values to less than 5‰ and $\Delta^{13}C_{ap\text{-}col}$ values higher than 4.5‰. These variations in bioapatite-collagen spacing can be used to determine the sources of protein and non-protein dietary components (Kellner and Schoeninger 2007).

The bulk collagen-to-diet spacing of omnivores, including humans, can vary depending on the carbon isotopic composition of the constituent biochemical macronutrients (Ambrose and Norr 1993). When the $\delta^{13}C$ value of the protein is lower than that of the bulk diet then the collagen-diet spacing will be less than 5‰. This can occur in Chinese human diets when the majority of the carbon may be obtained from ^{13}C-enriched C_4 millet carbohydrates but the protein may be obtained mainly from fish, deer, acorns and other C_3 foodweb-based resources. Conversely where the bulk diet is predominantly C_3, and the protein sources are derived from

C_4-fed animals such as pigs, or marine animals, then the collagen-diet difference will be greater than 5‰.

Nitrogen isotopes

Nitrogen enters foodwebs mainly via atmospheric nitrogen-fixing bacteria that have symbioses with plants or live independently in the soil. Volatilization of ammonia tends to increase soil $\delta^{15}N$ values through preferential volatilization of $^{14}NH_3$ (Mizutani, Kabaya, and Wada 1985a, 1985b; Mizutani and Wada 1988). Ammonia volatilization is greatly accelerated in dry soils, at high pH and at high temperatures (Stewart 1970; Aggarwal and Raina 1987). Therefore, cool and moist forest soils tend to have lower $\delta^{15}N$ values than hot, dry savanna and desert soils (Rennie, Paul, and Johns 1976; Mariotti et al. 1980; Ambrose 1991). Variation in $\delta^{15}N$ values within soil profiles, sediment fractions and chemical fractions have also been observed. Clays have higher $\delta^{15}N$ values than sands and silts (Shearer and Kohl 1986). Mature soils tend to have higher $\delta^{15}N$ values than young ones (Vitousek et al. 1989).

Plants obtain virtually all of their nitrogen from inorganic ammonium and nitrate (NH_4^+ and NO_3^-) in the soil, or through symbiosis with atmospheric N_2-fixing bacteria (Shearer and Kohl 1986). Although there is overlap with N_2-fixers, non-N_2-fixers usually have significantly higher $\delta^{15}N$ values (Delwiche et al. 1979; Shearer et al. 1983; Högberg 1986). In addition, there can be significant between-habitat and within-habitat variation in plant $\delta^{15}N$ values. Heaton (1987) observed a negative correlation between plant $\delta^{15}N$ values and rainfall. The highest plant $\delta^{15}N$ values appear to be associated with saline soils, arid environments, and marine coastal environments. The lowest non-leguminous plant $\delta^{15}N$ values are found in moist forest and montane areas (Virginia and Delwiche 1982; Heaton 1987). Heterogeneity within soil profiles associated with differences in depth, maturity, texture and distribution of nitrate and ammonium may contribute to within-habitat variation in plant $\delta^{15}N$ values. Plants that root at different depths or prefer substrates of different particle size may thus have different $\delta^{15}N$ values.

Controlled diet studies using rodents have demonstrated that the $\delta^{15}N$ values of animal tissues are systematically enriched relative to their diets (Gaebler, Vitti, and Vukmirovich 1966;

DeNiro and Epstein 1981; Ambrose 2000). A 3-4‰ step-wise enrichment in mean $\delta^{15}N$ values has been observed in each trophic step from plants to herbivores to carnivores in both marine and terrestrial ecosystems (Minagawa and Wada 1984; Schoeninger and DeNiro 1984; Schoeninger 1985; Sealy et al. 1987; Fry 1988). However, other researches have found a larger enrichment in $\delta^{15}N$ values between herbivores and carnivores. Koch, Behrensmeyer, and Fogel (1991) found a 5‰ trophic level fractionation between herbivores and carnivores. Bocherens and Drucker (2003) found that the prey-predator collagen enrichment values for nitrogen isotopes vary between 3-5‰.

In addition, the average 3-4‰ enrichment in $\delta^{15}N$ values from diet to animals' tissues can vary depending on the protein quantity and quality of the diet (Sponheimer et al. 2003; Pearson et al. 2003; Robbins, Felicetti, and Sponheimer 2005). Controlled diet experiments with herbivores and birds show that the enrichment in $\delta^{15}N$ values was found to be larger for the same species fed high protein diets compared to ones fed low protein diets (Sponheimer et al. 2003; Pearson et al. 2003). On the other hand, Robbins, Felicetti, and Sponheimer (2005) compiled published information and found that the $\delta^{15}N$ value of animals on high protein quality diets (such as fish and milk) was less enriched compared to the diet, while $\delta^{15}N$ values of animals on a low protein quality diets (such as grain and fruit) were usually more enriched compared to the diet. This discrepancy might be explained by the fact that the latter study was making comparisons across different species (Robbins, Felicetti, and Sponheimer 2005) while the two experiments compared the same species fed with different diets (Sponheimer et al. 2003; Pearson et al. 2003).

The $\delta^{15}N$ values of animal tissues can also be affected by environmental factors. Herbivores from arid regions tend to have higher $\delta^{15}N$ values than those from cooler ones (Heaton 1987; Sealy et al. 1987). A small part of this correlation may be explained by parallel variation in plant $\delta^{15}N$ values (Heaton 1987). Ambrose (1991) proposed that changes in rates of urea excretion in response to water stress have an effect upon nitrogen isotope mass balance, hence explained the much higher $\delta^{15}N$ values of herbivores. Balter and colleagues (2006) also argue that aridity could lead to higher $\delta^{15}N$ values in animal proteins due to the partial recycling of ^{15}N-enriched urea.

Estimation of human diet-tissue nitrogen isotope enrichment is even more complicated. First, the practice of manuring can significantly increase nitrogen isotope values (Bogaard et al. 2007). Second, O'Connell and colleagues (2012) tested 11 human individuals with a controlled diet and suggested a large $\Delta^{15}N_{diet\text{-}collagen}$ offset of up to 6‰ in humans instead of previously assumed 3~4‰. If this value holds generally, then many previous researchers may have overestimated the dietary importance of foods with higher nitrogen isotopic values, usually higher trophic level foods such as meat, milk and fish.

To accurately interpret isotopic signatures in human remains, associated plants and animals should also be analyzed to determine the foodweb baseline (Ambrose et al. 1997; Warinner, Garcia, and Tuross 2013). Diagenetic alteration of archaeological plant remains may complicate reconstruction of baseline values. For example, significant changes in C:N ratios, weight N%, and $\delta^{15}N$ values were observed on fresh plant remains under anaerobic, freshwater marsh environments during diagenesis (Fogel and Tuross 1999). Carbonized plants remains seem to retain isotope signatures in the archaeological record, hence reflect the original carbon and nitrogen isotope ratios (DeNiro and Hastorf 1985). If humans have higher $\delta^{15}N$ values due to hotter and drier climate, similar observations should also be found in plants and animals; if higher $\delta^{15}N$ values were found in both human and crops but not free ranging animals, it may indicate the impact of manuring; only if higher $\delta^{15}N$ values were found in humans, not in plants or animals, it then suggest the higher animal protein consumption in humans. Despite these complexities and uncertainties, bone collagen $\delta^{15}N$ values can be used to determine whether dietary protein came from predominantly plant or animal resources. It serves as a useful indicator of diet quality, and thus status (Ambrose, Buikstra, and Krueger 2003).

Oxygen isotopes and water intake

The oxygen isotope ratio of meteoric water controls that of food webs. Surface water $\delta^{18}O$ values are close to those of rainfall. Preferential evaporation of isotopic "light" water ($H_2{}^{16}O$) leads to isotopic enrichment of remaining liquid water in near-surface soils (Darling et al. 2005).

The oxygen in plant cellulose can come from groundwater and atmospheric carbon dioxide. However, DeNiro and Epstein (1979) demonstrated that atmospheric CO_2 has no isotopic influence on the oxygen isotopic composition of cellulose. Besides $\delta^{18}O$ values in ground water, temperature and humidity can also affect the $\delta^{18}O$ values in plants. Plants growing in hot and dry environment have higher $\delta^{18}O$ values than ones in cool and wet environment due to greater evapotranspiration (Yakir 1992). A canopy effect analogous to that in carbon isotope could also lower leaf $\delta^{18}O$ values near the humid forest floor, mainly in response to humidity effects on stomatal conductance (Sternberg 1989). In addition, $\delta^{18}O$ values can vary among different parts within the same plant. Plant stems have substantially lower $\delta^{18}O$ values than leaves because they have low evaporative surface areas (Yakir 1992; Helliker and Ehleringer 2002). Fruits, pith, roots and underground storage organs should also have lower $\delta^{18}O$ values than leaves.

Bioapatite $\delta^{18}O$ values of animals reflect that of ingested water, which includes drinking water, leaf water, and metabolic water formed from dietary carbohydrates, and proteins (Sponheimer and Lee-Thorp 1999; Schoeninger, Kohn, and Valley 2000). Dry grass cannot contribute significantly to animal water budgets, so grazers are generally (though not always) more water-dependent than browsers (Ambrose 1991). Water-independent browsing species such as deer and giraffe that obtain substantial amounts of ^{18}O-enriched water from green leaves should have higher bioapatite $\delta^{18}O$ values than grazing herbivores that drink more permanent surface water (Levin et al. 2006; Cerling et al. 2008; White et al. 2009). Water-dependent carnivores should have among the lowest values in an ecosystem (Sponheimer and Lee-Thorp 1999; Sponheimer and Lee-Thorp 2001; White et al. 2009). Frugivores and omnivores such as primates, root-eating suids and termite feeding insectivores should also have relatively low bioapatite $\delta^{18}O$ values due to the low $\delta^{18}O$ values in fruits and roots and the intake of surface water (Sponheimer and Lee-Thorp 2001; Iacumin et al. 2004; Tian et al. 2008).

Apatite $\delta^{18}O$ values can be useful in both monitoring environmental changes and identifying immigrants. Animals consuming water stressed plants in low-humidity environments will have higher $\delta^{18}O$ values. However, in more humid environments the difference between herbivores, omnivores and carnivores is reduced. Analysis of oxygen isotopes of a diverse community of large mammals from a humid sub-tropical environment in South Africa (Sponheimer and Lee-Thorp 1999) shows a much smaller difference between evaporation-sensitive herbivores and other species than is found in more arid environments (Levin et al. 2006). Therefore oxygen isotope analysis of faunal and human remains can be used in reconstructing paleoenvironments (Longinelli 1984; Sponheimer and Lee-Thorp 1999; Schoeninger, Kohn, and Valley 2000; Levin et al. 2006).

Human bioapatite $\delta^{18}O$ values can also be used to identify geographic origins because meteoric water (rainfall) $\delta^{18}O$ values in ecosystems vary depending on the geographic distance to ocean, humidity, source of drinking water, latitude, altitude and temperature. Combining evidence from oxygen and strontium isotope analyses, scholars have identified immigrants from an archaeological population (White et al. 1998; Price et al. 2010; Wright 2012).

Bone apatite is likely more susceptible to diagenetic alteration of carbonate oxygen isotope ratios compared to tooth enamel (Wang and Cerling 1994; Koch, Tuross, and Fogel 1997), so bone apatite oxygen isotope evidence for migration must be evaluated carefully. There are few unambiguous tests of the integrity of bone apatite oxygen isotope ratios. One potential test for preservation of oxygen isotope ratios in archaeological faunal skeletons is the presence of a systematic difference between herbivores that ingest significant amounts of ^{18}O-enriched leaf water, and species that ingest more drinking water (White et al. 2009). For example, pigs, dogs and water buffalo (*Bubalus sp.*) have systematically lower $\delta^{18}O$ values than sheep and deer at the Longshan Neolithic site of Kangjia (Pechenkina et al. 2005). Where such unambiguous differences in bone $\delta^{18}O$ values between non-human taxa with different water ingestion modes is evident, then it should be possible to use human bone $\delta^{18}O$ values to infer differences in areas of origin. However, human bone and tooth oxygen isotope variation could also reflect dietary rather than geographic variation. Therefore tooth enamel $^{87}Sr/^{86}Sr$ isotopic evidence should be used to confirm identifications of immigrants.

Applicability of stable isotope analysis for Dawenkou sites

Stable carbon isotope analysis is suitable for my purpose of identifying millet versus rice consumption in Dawenkou sites. Millets use the C_4 photosynthetic pathway to assimilate atmospheric CO_2 and transform it into organic matter. They tolerate strong sunlight, high temperatures, low water availability, and low air CO_2 concentrations (Ehleringer, Cerling, and Helliker 1997; Ehleringer 2005). They are well adapted to the climatic stresses of the often unpredictably variable warm and dry onset of the spring planting season in the temperate zone of northern China (Theisen, Knox, and Mann 1978; Baltensperger 1996). Most leafy plants and many non-tropical grasses adapted to cold, high elevations, higher soil water availability and shade, use the C_3 pathway, as does rice.

Northern Chinese Neolithic agriculture was initially based on ^{13}C-enriched millets (*Setaria italica* and *Panicum miliaceum*), which are grains with relatively low protein contents (10-11%). All other foods in this region are C_3 plants or C_3-feeding animals that have low $\delta^{13}C$ values, and most have higher protein contents, particularly terrestrial mammals and freshwater fish. Because collagen is derived mainly from dietary protein, its isotopic composition will underestimate the consumption of millets. Conversely, apatite carbon is derived equally from all dietary macronutrients (Ambrose and Norr 1993). Therefore in this study I used the isotopic composition of both collagen and apatite for more accurate reconstruction of Dawenkou Neolithic individuals' diets.

For prehistoric northern China, candidates for the C_4 component in the diet include millet and millet-fed pigs and dogs (Pechenkina et al. 2005; Barton et al. 2009). The C_3 component could include grain and legume crops such as rice, wheat, and soybean, wild plants (Pyankov et al. 2000; Wang 2003), and wild mammals, fish and birds. Wheat was not introduced into this region until the Longshan era (Crawford et al. 2005), and soybean was not domesticated until Longshan (Lee et al. 2011), so rice would be the most likely Dawenkou C_3 staple crop. Because agriculture had already been well established in the region for several thousand years, wild plants likely did not contribute significantly to Dawenkou people's diets. The main challenge is distinguishing the isotopic signature of rice consumption from wild animal consumption, which can be done by combining collagen carbon and nitrogen isotope and apatite carbon isotope values. Wild pigs and herbivores generally have $\delta^{15}N$ values lower than domestic pigs and higher than millets and rice in Neolithic China (Pechenkina et al. 2005; Guan et al. 2007; Barton et al. 2009; Dong, Ambrose, et al. n. d.). The consumption of C_3-fed wild animals and freshwater fish usually leads to relative high nitrogen isotope values and lower carbon isotope values in collagen (Schoeninger and DeNiro 1984; Katzenberg 1989; Dufour, Bocherens, and Mariotti 1999). Wild animals were generally not the dominant component of Dawenkou diets (as noted in Chapter 3 and below), but could be over-represented in collagen carbon isotopes. Carbon isotope values in apatite would not be biased toward protein sources. Rice consumption, however, would lead to lower collagen and apatite carbon isotope values. These expectations will serve as the criteria in distinguishing a typical C_4 diet of millet and millet fed pigs, a mixed diet of millet and wild animals, a mixed diet of rice and millet and maybe some animals, or a typical C_3 diet of rice and wild plants and animals.

Stable isotope analysis has been applied in dietary reconstruction at six Dawenkou sites (Chapter 3). The results suggest that some individuals had a typical C_4 diet, while others had a more C_3-based diet. As I discussed above, the C_4 component is probably millet and millet-fed pigs. However, no isotopic data for apatite are available, so it is hard to further determine the source of the C_3 component. Isotopic analysis of humans from the early Dawenkou site of Beiqian suggests substantial consumption of marine resources and millet (Wang et al. 2012). The authors used a three component iso-source model to calculate that millet, marine resources and terrestrial animals constituted 34%, 44%, and 22% of the diet, respectively. However, this estimation might be biased. First, the isotope values of the marine resources from the site were not available; they used values from coastal Japan for reference, which could be different from eastern China. Second, and more importantly, they only analyzed collagen, which reflects mainly the values of dietary protein. Because millet is a low protein food it is probably underrepresented in collagen. Hence, the contribution of millet to the whole diet could be seriously underestimated.

Third, the average $\delta^{15}N$ value of Beiqian humans is only 8.1‰, which is lower than expected for a diet with large amount of marine protein.

In general, more isotopic research is needed to reconstruct dietary consumption patterns among Dawenkou sites and among individuals within sites. In order to properly interpret human diet by isotopic analysis, we must have a comprehensive understanding of the isotopic composition of their potential dietary classes. Due to the variability of carbon and nitrogen isotope values in an ecosystem (Medina et al. 1986; O'Leary 1988; Ambrose 1991), possible manuring effect on nitrogen isotope values (Bogaard et al. 2007), and a variety of environmental effects such as humidity and water stress on plant and animal carbon and nitrogen isotopic values (Heaton 1987; Tieszen 1991), it is critical to analyzed associated animal and plant remains (DeNiro and Hastorf 1985; Ambrose et al. 1997; Warinner, Garcia, and Tuross 2013) to build the baseline foodweb isotopic composition of the human diet. In addition, both apatite and collagen should be analyzed for accurate dietary interpretation.

Materials and Methods

Samples selected

Human remains were obtained from four Dawenkou Culture sites, Huating, Fujia, Dongjiaying, and Liangwangcheng (Figure 3.3). Detailed information of these burials including occupation phase, number of grave goods, grave type, skeleton position, body orientation, sex, and age, are summarized in Table 4.1. Unfortunately, no macrobotanical remains are available from these sites. Carbonized broomcorn millet remains were obtained from Beiqian (5 samples). Associated pig bones from Dongjiaying and Fujia (9 samples from each site), and various faunal remains from Liangwangchen (14 samples) were also obtained for isotopic analysis.

Methods

Collagen was prepared at the Ministry of Education Key Laboratory of Cultural Relics Conservation, Northwest University, Xi'an for isotopic analysis using variations of methods described previously (Ambrose 1990; Ambrose et al. 1997; Hu, Ambrose, and Wang 2006). To purify collagen, 1.5~2 g of ground bone (sieved size fraction between 0.28 mm and 1 mm) was demineralized with 0.2 M HCl (2-3 days). Humic acids were removed by treatment with 0.125 M NaOH (20 hours). Collagen was solubulized in 10^{-3} M HCl at 95°C (10 hours), filtered and freeze-dried. Carbonized plant remains were not treated before isotopic analysis.

Apatite was prepared using the more intensive "vacuum milling" technique developed by Krueger (1991) to remove excess carbonate from bone. Organic matter was removed from bone samples (50 mg of ground bone sieved size fraction between 0.063 mm and 0.111 mm) by treatment with NaOCl (50% Clorox bleach, 20 hours), twice. Adsorbed carbonate was removed with 0.1 M acetic acid for 4-6 hours, with periodic evacuation with a vacuum pump, followed by repressurization with N_2 gas. The vacuum removes trapped CO_2 from microscopic pores, thus minimizing the potential for isotopic exchange with structural carbonate in bioapatite. Repressurization permits more complete wetting and acid reaction within the microscopic pores. Treatment was considered complete when effervescence ceased under vacuum. Samples were then rinsed and freeze-dried.

Isotopic analysis of collagen and carbonized plant remains was accomplished by combustion in tin foil capsules and purification of N_2 and CO_2 in a Carlo-Erba NC2500 elemental analyzer connected to a Finnegan MAT 252 isotope ratio mass spectrometer at Environmental Isotope Paleobiogeochemistry Laboratory, University of Illinois at Urbana-Champaign. Apatite carbonate was analyzed by reaction with 100% phosphoric acid at 70° C and measured by Thermo Scientific™ DELTA V Plus isotope ratio mass spectrometer at Isotech Laboratories Inc. Results are reported with reference to the AIR (atmospheric N_2) standard for nitrogen, the PDB (Pee Dee Formation *Belemnitella*) standard for carbon and the SMOW (Standard Mean Ocean Water) standard for oxygen.

The effects of diagenesis on collagen isotopic composition were evaluated in three ways: by the collagen concentration in bone; C and N concentrations in collagen; and its atomic C:N ratio (Ambrose 1990). Modern bone is approximately 20-25% collagen by weight. Archaeological specimens usually produce reliable results when concentrations are greater than 1-2%. Collagen is approximately 42% C and 17% N by weight, and has an atomic C:N of 3.21 (Ambrose 1993; Ambrose 1990). The acceptable range for atomic C:N ratios of well-preserved collagen is conventionally considered to be 2.9-3.6 (DeNiro 1985).

Modern bone and tooth enamel have carbonate carbon contents of 0.9-1.2% by weight (Ambrose and Norr 1993; Ambrose 1993). If soil and groundwater carbonates accumulate on bone apatite mineral surfaces and voids, bone may have a significant excess of carbonate carbon. Effective pretreatment to remove excess carbonate should reduce carbonate carbon content and shift carbon isotope ratios away from that of the exogenous carbonate (Lee-Thorp 2000).

Results

Plant and collagen carbon and nitrogen isotopes

Carbonized broomcorn millet remains from Beiqian were analyzed (n=5); the results are presented in Table 5.1. The mean δ^{15}N and δ^{13}C values are 3.0‰ and -10.3‰ respectively. This low δ^{15}N value is typical for most plants, and the high δ^{13}C value is expected for C_4 plants.

Collagen was extracted from 77 human and 32 animal bones (pig, deer, dog, cattle, fish, and turtle) from four Dawenkou sites. Most samples are well preserved, with C:N ratios within the range of 2.9-3.6 (DeNiro 1985; Ambrose 1990) (Table 5.2). However, seven human (DWK21, DWK27, DWK29, DWK31, DWK33, DWK35, and DWK219) and two pig samples (DWK51 and DWK53) from Dongjiaying, one pig sample from Fujia (DWK233), and four human samples from Huating (DWK209, DWK211, DWK213, and DWK215) have atomic C:N ratios outside of the acceptable range; they are excluded from further analysis. The remaining 95 samples have collagen concentrations ranging from 0.16% to 14.29%, with a mean of 5.24% (Table 5.3).

Collagen concentrations are generally lower in Dongjiaying and Huating, with means of 1.33% and 0.61% respectively. Collagen preservation at Fujia and Liangwangcheng is generally better, with mean collagen concentrations of 9.64% and 4.21%, respectively. The weight %C and %N in collagen average 40.4% (range: 15.9-46.6%) and 15.0% (range: 5.6-17.4%), respectively, which are close to the concentrations in modern bone (Ambrose 1990). Thus, while our samples have clearly lost some organic matter, their C:N ratios and high C and N concentrations demonstrate that the organic matter recovered retains its *in-vivo* composition.

Nitrogen and carbon isotope values of human and fauna collagen samples are plotted in Figure 5.1. It is clear that human samples from sites located further north, Dongjiaying and Fujia (Figure 3.3), have higher $\delta^{13}C_{coll}$ values, indicating a predominantly C_4 diet. Human samples from Huating and Liangwangcheng, located further south, had lower $\delta^{13}C_{coll}$ values, indicating some intake of C_3-based terrestrial and/or aquatic foods. The statistics in Table 5.3 demonstrate a similar pattern: the $\delta^{13}C_{coll}$ values of Dongjiaying individuals ranged from -10.3‰ to -6.4‰, with a mean of -7.6‰. The $\delta^{13}C_{coll}$ values of Fujia individuals range from -8.5‰ to -6.6 ‰, with a mean of -7.6‰. Only two individuals from Huating yielded usable results, with $\delta^{13}C_{coll}$ values of -14.7‰ and -14.0‰ respectively. The $\delta^{13}C_{coll}$ values of Liangwangcheng individuals have a wider range, from -16.6‰ to -7.9‰, with a mean of -11.3‰. This means Liangwangcheng individuals had a diverse diet: some of them have consumed more millet, others might have consumed more rice. I will examine how and why they had different food choices in more detail in the discussion section below.

Collagen $\delta^{13}C$ values of pigs from Dongjiaying and Fujia indicate a typical C_4 diet similar to that of humans at their respective sites. Those of faunal remains from Liangwangcheng sites are more variable (Tables 5.2 and 5.3). Pigs from Dongjiaying and Fujia have collagen $\delta^{13}C$ values ranging from -12.2‰ to -6.6‰, with means of -9.5% and -10.2% respectively. The $\delta^{13}C$ values of faunal collagen samples from Liangwangcheng have a wider range, from -20.8‰ to -7.8‰. The species represented in the assemblage include deer (*Cervus nippon*, n = 5), domestic pig (*Sus scrofa*, n = 3), bovini (*Bos sp.*, n = 2), turtles (one Geoemydidae and one Trionychidae), dog (*Canis familiaris*, n = 1), and fish (*Mylopharyngodon piceus*, n = 1). Wild species, such as deer, fish, and turtle, generally have $\delta^{13}C_{coll}$ values lower than -17‰, reflecting predominantly C_3-based diets. Whether the bovines found at Liangwangcheng represent domestic or wild species are unknown. According to Lyu (2010), cattle were not domesticated until the terminal Neolithic (ca. 2500~2000 BC) in China. The two bovines had higher $\delta^{13}C_{coll}$ values than deer (-13.2‰ and -7.8‰), which indicates feeding in C_4 pastures or consumption of millet fodder. Domestic species had diverse $\delta^{13}C_{coll}$ values: the only dog sample (DWK75) had a very low $\delta^{13}C_{coll}$ value (-17.2‰); one pig (DWK63) had a very high $\delta^{13}C_{coll}$ value (-7.8‰), and two pigs from Liangwangcheng (DWK69 and DWK77) had relatively low $\delta^{13}C_{coll}$ values (-15.6.‰ and -14.2‰). The domestic species consumed mixed diets of varying proportions of C_3- and C_4-based foods.

The $\delta^{15}N$ values of Fujia, Huating, and Liangwangcheng humans are similar, with means of 9.1‰, 8.7‰ and 8.9‰, respectively (Figure 5.1, Table 5.3). These individuals probably all had mixed diets of plants and animals. However, Dongjiaying individuals have lower $\delta^{15}N$ values compared to those from other sites, ranging from 5.2‰ to 9.8‰, with a mean of 7.3‰. The t-test suggests that there is significant difference ($p<0.001$) in the mean $\delta^{15}N$ values of people from Dongjiaying and Fujia (Table 5.4). This could mean that Dongjiaying individuals ate less animal protein. However, the $\delta^{15}N$ values of associated faunal remains (Table 5.3) suggest an alternative interpretation: Pigs from Dongjiaying and Fujia have fairly similar $\delta^{13}C$ values but Dongjiaying pigs have $\delta^{15}N$ values ranging from 1.1‰ to 7.4‰, with a mean of 4.6‰; Fujia pigs have $\delta^{15}N$ values ranging from 5.6‰ to 7.5‰, with a mean of 6.9‰. The t-test suggests that there is significant difference ($p=0.007$) in the mean $\delta^{15}N$ values of pigs from Dongjiaying and Fujia (Table 5.4). Lower $\delta^{15}N$ values of pigs at Dongjiaying could indicate less access to leftovers or human feces and more reliance on millet fodder. Lower $\delta^{15}N$ values of pigs from Dongjiaying may partly explain the lower $\delta^{15}N$ values of Dongjiaying humans.

The faunal collagen samples from Liangwangcheng site have more diverse $\delta^{15}N$ and $\delta^{13}C$ values, as expected for this taxonomically and ecologically diverse sample set. Their $\delta^{15}N$ values range from 1.9‰ to 7.9‰ (Tables 5.2 and 5.3). Aquatic species generally have higher $\delta^{15}N$ values: A turtle (Trionychidae) has a $\delta^{15}N$ value of 7.3‰, and a fish (*Mylopharyngodon piceus*, black carp) has a $\delta^{15}N$ value of 6.5‰. Terrestrial carnivores and omnivores also have relatively high δ^{15}N values: the dog (DWK75) is 7.9 ‰, and a pig (DWK63) is 7.0‰. Terrestrial herbivores generally have lower δ^{15}N values: deer and cattle have averages of 4.1‰ and 5.1‰ respectively. Note that one deer (DWK73) has a δ^{15}N value of 7.1‰, which is higher than those of other herbivores. This might be due to the fact that this individual is a juvenile, as indicated by its unfused distal metapodial. The Geoemydid turtle (DWK79) also has a low δ^{15}N value (3.3‰), which indicates an herbivorous diet.

Apatite carbon and oxygen isotopes

The factors affecting the preservation of the *in-vivo* isotopic composition of collagen and apatite differ, and there are few conclusive ways to evaluate the preservation condition of apatite. The fourteen samples excluded due to poor collagen preservation collagen analysis were also excluded in apatite analysis, on the assumption that when collagen is poorly preserved, bone porosity increases and the apatite is more exposed to diagenetic processes. The remaining 95 samples had weight percent apatite ranging from 33.9% to 84.6%, with a mean of 54.7% after pretreatment with sodium hypochlorite and 0.1 M acetic acid under vacuum (Table 5.3). Apatite yields after pretreatment can vary depending on bone preservation, starting particle size, carbonate content and duration of treatment with acetic acid (Balasse et al. 2002).

One criterion for assessing apatite carbonate isotopic integrity is the correlation of apatite and collagen δ^{13}C. Figure 5.2 shows significant correlations for human and pig apatite and collagen δ^{13}C. However, the correlation is far from 1:1. Apatite δ^{13}C values span less than half the range of collagen, so the slope of the regression equation for humans is 0.473 and that for pigs is 0.346. Although the range of apatite δ^{13}C values is compressed, the pattern of differences among humans and other species is still preserved. Reduction in the apatite δ^{13}C range could result from diagenesis, which would shift all samples toward the δ^{13}C values of the contaminant. However, apatite records whole diet δ^{13}C, while collagen reflects mainly the δ^{13}C value of dietary protein (Ambrose and Norr 1993). Therefore the larger range of collagen δ^{13}C could indicate that the dietary protein had a wider range of δ^{13}C values than the bulk diet.

The second criterion is the pattern of $\Delta^{13}C_{ap\text{-}coll}$ ($\Delta^{13}C_{ap\text{-}coll} = \delta^{13}C_{ap} - \delta^{13}C_{coll}$) expected for ruminants versus non-ruminants. Figure 5.3 shows that ruminant herbivores (cows and deer) have generally higher $\Delta^{13}C_{ap\text{-}coll}$ than pigs, dogs and humans, as observed in modern taxa. Therefore mammal apatite $\delta^{13}C$ values are likely reliable. Aquatic animals have extremely high values. There are few studies of aquatic vertebrate $\Delta^{13}C_{ap\text{-}coll}$, so the reasons for such large difference values are poorly understood.

Oxygen isotopes can also be used to identify apatite diagenesis. In modern ecosystems, fish and other aquatic organisms have the lowest $\delta^{18}O$ values because surface waters have the least amount of evaporative enrichment relative to meteoric water. Conversely, herbivores tend to have the highest $\delta^{18}O$ values because leaf water is highly enriched by evaporation (Levin et al. 2006; White et al. 2009). Figure 5.4 shows a plot of apatite carbon and oxygen isotopes for all Dawenkou samples. Deer have higher $\delta^{18}O$ values, while fish and turtles have lower values. Bovines, pigs and humans have low to intermediate values. Although these results are in the relative order expected for their water use and diet selection, the range of $\delta^{18}O$ values is relatively small compared to modern semi-arid habitats. The small difference between deer and water-dependent species could reflect high rainfall and humidity. However, more data on modern foodwebs in temperate environments is needed to determine whether greater separation between aquatic, omnivorous and herbivorous species is expected in temperate mid-latitude environments such as northern China.

Carbon and oxygen isotopes of human and fauna apatite samples are plotted in Figure 5.4. There is clear difference in $\delta^{13}C_{ap}$ values of humans from sites located further north (Dongjiaying and Fujia) and those from sites further south (Huating and Liangwangcheng). The $\delta^{13}C_{ap}$ values of Dongjiaying humans range from -4.4‰ to -2.6‰, with a mean value of -3.5‰ (Table 5.3), and Fujia $\delta^{13}C_{ap}$ values range from -4.0‰ to -2.1‰, with a mean of -3.2‰. Two humans from Huating had $\delta^{13}C_{ap}$ values of -7.1‰ and -6.6‰ respectively. Liangwangcheng $\delta^{13}C_{ap}$ values range from -7.3‰ to -4.2‰, with a mean value of -5.7‰. This means that individuals from northern sites generally had consumed more C_4 dietary staple (such as millets), while individuals from southern sites had more C_3 component in the diet (such as rice).

The apatite $\delta^{13}C$ values of faunal samples support the conclusions drawn from collagen $\delta^{13}C$ values. Pig apatite samples from Dongjiaying and Fujia have $\delta^{13}C$ values ranging from -3.2 to -5.8, with means of -5.2‰ and -4.4‰, respectively (Table 5.3), which suggest a typical C_4 diet similar to that of humans from these sites. Faunal apatite samples from Liangwangcheng had diverse $\delta^{13}C_{ap}$ values ranging from -10.9‰ to -3.2‰ (Tables 5.2 and 5.3). Most wild species (deer, fish, and turtle) have lower $\delta^{13}C_{ap}$ values, with a mean of -8.3‰. Cattle had higher $\delta^{13}C_{ap}$ values (-6.3‰ and -3.2‰). These high values suggest provisioning with C_4 fodder, perhaps millet crop wastes. Domestic pigs and the dog have diverse $\delta^{13}C_{ap}$ values, ranging from -10.9 to -4.8‰, again indicating mixed diets of C_4 and C_3 foods.

The oxygen isotope values of humans from all four sites are roughly in the same range, from 22.6‰ to 24.4‰, with a mean of 23.8‰ (Figure 5.4, Table 5.3). People from Fujia and Liangwangcheng had a wider range of $\delta^{18}O$ values that those from Dongjiaying. The $\delta^{18}O$ values of Dongjiaying humans range from 23.7‰ to 24.3‰, with a standard deviation of 0.16‰. Human $\delta^{18}O$ values at Fujia and Liangwangcheng range from 22.6‰ to 24.4‰, with standard deviations of 0.42‰ and 0.32‰, respectively. According to the result of Levene's test (p=0.001) and t-test (p=0.018), both the variance and mean of $\delta^{18}O$ values in Dongjiaying differ from Fujia population (Table 5.4). Liangwangcheng has two outliers (Figure 5.5): a male with the lowest value (M97, 22.7‰) and a female with the highest (M99, 24.4‰). Fujia has one outlier: a female with a low value (M128, 22.6‰). Collagen preservation is very good in all of these outliers (Table 5.2), so these samples are unlikely to be affected by to apatite diagenesis.

A similar trend is found in the $\delta^{18}O$ values of faunal remains (Tables 5.2 and 5.3). The range and standard deviation of $\delta^{18}O$ values of Dongjiaying site (23.4 ~ 24.1‰, SD = 0.24‰) are narrower than those of Fujia (22.6 ~ 24.2‰, SD=0.50‰; Figure 5.4). However, Levene's test does not indicate significant differences in the variance of $\delta^{18}O$ values between pigs from Dongjiaying and Fujia (Table 5.4). More species are represented in the Liangwangcheng assemblage. Both oxygen and carbon isotopes have a wider range ($\delta^{18}O$: 23.0 ~ 24.9‰, SD = 0.51‰; $\delta^{13}C$: -10.9 ~ -3.2‰, SD = 2.2‰). Terrestrial herbivores (deer and bovines) generally have higher $\delta^{18}O$ values, averaging 24.0‰. However, one bovine has a much lower $\delta^{18}O$ value, suggesting it obtained more water by drinking rather than from green plants. Terrestrial omnivores and carnivores (pigs and dogs) have lower $\delta^{18}O$ values, averaging 23.4‰. Aquatic species (fish and turtle) also have low $\delta^{18}O$ values, averaging 23.2‰. As noted above, the difference among herbivores, omnivores and aquatic species is consistent with their habitat and dietary adaptations.

Discussion

Foodweb at Dawenkou sites

Food consumption varied among Dawenkou culture sites and among individuals within sites. As noted earlier, millet, rice, and various faunal remains were found at several Dawenkou culture sites. The proportional contributions of these food groups to people's diets can only be characterized in a limited way from the isotopic composition of their bones. According to our stable isotope analysis results, Dawenkou people generally had balanced diets with both plants and animals.

Collagen $\delta^{13}C$ values show that people from sites located further north generally had C_4 based diets. People from southern Dawenkou sites of Liangwangcheng and Huating consumed less millet and more C_3-based foods that could have include deer, rice, leafy plants, nuts and aquatic species, such as fish and turtles. Liangwangcheng people have the widest range of $\delta^{13}C$ values, and thus the most varied proportions of C_3- and C_4-based food sources. The negative correlation between $\delta^{15}N$ and $\delta^{13}C$ values at this site indicates that those with the highest $\delta^{13}C$ values consumed more millet rather than more meat from millet-fed pigs and cows (Figure 5.6). Because only two individuals from Huating had well-preserved collagen we cannot be certain whether their low $\delta^{13}C$ values represent the average diet at this site.

The $\delta^{15}N$ values of pigs at Dongjiaying are lower than that of pigs at Fujia. Consequently, Dongjiaying humans consuming these pigs also had lower $\delta^{15}N$ values than humans at Fujia. Lower $\delta^{15}N$ values of Dongjiaying pigs suggest that they probably had less access to leftovers or human feces and more reliance on millet fodder. Foodweb $\delta^{15}N$ values can also vary due to environmental factors, with lower $\delta^{15}N$ in humid cooler environments (Ambrose 1991). However, the $\delta^{18}O$ values of Dongjiaying and Fujia pigs are not significantly different from each other ($p=0.704$), the environments at both sites were probably comparable.

I will discuss the food consumption in the social context at each site below, starting with the site located in the north and then moving south.

Fujia

Fujia is located in the northern periphery of the Dawenkou culture area (Figure 3.3). It is dated to late Dawenkou by pottery style, and directly radiocarbon dated to 2800~2500 cal. BC (Table 4.2). The excavation report of Fujia has not been published. However, the published report of a contemporary site, Wucun, with 75 burials, located less than three km from Fujia (SPICRA and Guangrao Museum 1989) can serve as a provisional analog for the findings from Fujia. More than half of the burials at Wucun had no grave goods at all; the richest burial had only four grave goods. This is similar to Fujia (Table 4.1), where nine out of the 23 burials that I sampled from had no grave goods. The remaining individuals had one to five associated mortuary artifacts. Because no burials had large numbers of mortuary offerings it is likely that the Fujia community was as egalitarian as Wucun.

Isotopic analysis of human and pig remains suggests that both human and pigs consumed significant amount of C_4-based foods, such as millet (Tables 5.2 and 5.3). Millet remains had been found at Fujia (SPICRA and Guangrao Museum 1985) further supporting this proposition. Humans probably consumed millet fed pigs, and high $\delta^{15}N$ for pigs suggests that they also scavenged on human waste and leftovers, as was found at Yangshao sites (Pechenkina et al. 2005). The results of faunal analysis are not available at Fujia. The Wucun faunal assemblage includes pigs and deer, fish and shellfish were also common (Kong 1989). These wild species were probably also available at Fujia, but the high human collagen $\delta^{13}C$ values indicate that they probably did not contribute much to the diets. Isotopic analysis was performed only on pigs from Fujia. However the wild species probably all had lower $\delta^{13}C$ values as at Liangwangcheng (Table

5.2). If species other than pig were a significant component of human's diet, we would expect to see lower $\delta^{13}C$ values in Fujia human bones.

Most Dawenkou sites that had uniform body orientations, but both Fujia and Wucun cemeteries had two major body orientation directions (southeast and northeast). Body orientation did not seem to correlate with sex, grave location, grave type, or number of grave goods. Mitochondrial DNA sequencing results suggest that despite the different body orientations, individuals oriented towards northeast or southeast all belong to the same maternal lineage (Chapter 6). Students t-tests of stable isotope values between the individuals oriented towards northeast and the ones oriented towards southeast, resulted in near to significant ($p=0.053$) differences only in apatite $\delta^{18}O$ values (Table 5.4, Figure 5.7). This means that the diets of two groups of people that had different body orientations were probably quite similar. However, their source of drinking water might be different. For example, one group was drinking surface water while the other group was drinking from wells. This could relate to their residential patterns that one group was adjacent to a river, while the other is next to a well. Burial orientation may correlate to different factors in different communities. According to a cross-cultural survey by Carr (1995), burial orientation was found most commonly to reflect society's beliefs about the afterlife, universal orders, and the soul's journey to the afterlife. Unfortunately we do not know the beliefs about afterlife at Fujia or Wucun; however, the act of orienting the body to a specific direction probably reaffirmed their affiliation based on residential patterns and created social bond (Binford 1971; Parker Pearson 1999).

In order to discern if there is any statistical difference in food consumption between males and females, I did a series of t-test of various stable isotope values grouped by sex (Table 5.4). The results show that no statistical differences existed in the stable isotope values between males and females, indicating that there was probably not much difference in food consumption between males and females. Because the Fujia excavation report is not available, differences in burial treatment between males and females at Wucun site can serve provisionally as an analog instead. After excluding burials with multiple individuals and burials of undetermined sex due to poor preservation of diagnostic skeletal parts or young age, the Wilcoxon rank sum test of Wucun burials (instead of t-test, since the number of grave goods is not normally distributed) suggests that the number of grave goods in male burials is not significantly different from the number in female burials. Again I am prioritizing the quantity versus quality of grave goods as I did for Liangwangcheng (Chapter 4). There do not seem to be major differences in the quality of grave goods at Wucun. No exotic or labor intensive objects were found. Hence, we can probably say that neither males nor females had any significant privilege over food consumption or personal belongings at Fujia or Wucun.

Dongjiaying

Dongjiaying is located in Wulian County, Shandong Province (Figure 3.3), dated to late Dawenkou by pottery style analysis, and directly radiocarbon dated to 2600~2300 cal. BC, slightly later than the other three sites analyzed in this study (Table 4.2). Bone preservation is not ideal: 14 out of 21 human samples yielded usable results. Stable carbon isotope analysis results suggest that both human and pigs consumed significant amount of C_4 food, such as millet (Tables 5.2 and 5.3). Similar to Fujia, humans probably also consumed millet-fed pigs, and pigs probably scavenged on human waste and leftovers.

In addition, there seem to be some variation in food consumption among different individuals within this site (Figure 5.6). The individual from burial M4 (DWK3) had a higher $\delta^{15}N$ value (9.8‰, compared to the site mean of 7.3‰) and a lower collagen $\delta^{13}C$ value (-10.3‰, compared to the site mean of -7.6‰) compared to other individuals from the site. On the other hand, this individual's apatite $\delta^{13}C$ value was relatively high (-2.9‰, compared to the site mean of -3.5‰). The isotopic composition of collagen of DWK3 indicates that this individual consumed more C_3 or aquatic protein than other individuals at Dongjiaying, while that of apatite suggests the whole diet was C_4 over all. This sample also yielded a much younger radiocarbon age compared to other samples; this could result from either contamination or an actual younger age (Table 4.2). One stone "battle axe" was found in this burial, which is generally believed to be a highly symbolic tool, possibly suggesting the special social status of this individual (Mingkui

Gao, personal communication; Cunnar 2007).

Unfortunately, the excavation report for Dongjiaying has not yet been published. In order to get a sense of the social organization in the region during late Dawenkou, I draw on evidence from the sites of Dazhujiacun, Xiaozhujiacun and Lingyanghe, which are located 40 kilometers away from Dongjiaying (to the southwest). All sites are dated to the same period as Dongjiaying (Figure 3.3). Dazhujiacun and Lingyanghe have published excavation reports (Wang 1987; Su et al. 1989; SPICRA and Juxian Museum 1991). Most burials at Dazhujiacun and Lingyanghe are individual primary burials with the body in the extended supine position oriented to southeast. Pig mandibles and large numbers of pottery vessels used for drinking alcoholic beverages are the most frequent types of grave goods. Pottery fragments with carved proto-writing were also found in both sites. Moreover, both Dazhujiacun and Lingyanghe had a wide range of elaboration of burials. For example, the most elaborate burial at Lingyanghe (79M6) had more than 160 grave goods and a huge grave pit (4.55m x 3.8m), while the contemporary burial 79M2 had only 6 grave goods and a simple pit barely fit the body (1.77m x 0.43m). A similar situation is found at Dazhujiacun, the most elaborate burial M02 had 148 grave goods, while the poorest burial had no grave goods at all.

Carbon isotope data are available for one individual from Lingyanghe and one from Xiaozhujiacun, which is located five kilometers away from Dazhujiacun (Cai and Qiu 1984; Qi et al. 2004). The Lingyanghe individual was from a moderately endowed burial (M12) and had collagen carbon isotope value of -16.8‰, suggesting a diet with significant amounts of C_3 or aquatic foods. The Xiaozhujiacun individual was from a poor burial with no grave goods, and had a $\delta^{13}C$ value of -12.4‰, suggesting a largely C_4 diet. Combining evidence from Dongjiaying, it seems there were variations in food consumption among different individuals during late Dawenkou, possibly correlated with their different social status. While the majority of the population consumed a mainly C_4 diet (millet and millet fed pigs), some individuals had more access to aquatic or C_3 foods, which could be wild animals (like DWK3 from Dongjiaying) or rice. Unfortunately, neither collagen nitrogen nor apatite carbon isotope values are available from

Lingyanghe or Xiaozhujiacun individuals, so dietary comparisons are limited. Paleoethnobotanical analysis results are not available from contemporary sites in this region. However, the flotation (Crawford et al. 2005) and stable isotope analysis (Lanehart et al. 2008) at nearby Liangchengzhen (30 miles SE from Dongjiaying) suggested that rice was an important crop and was consumed by both human and pigs in the region during the Longshan period (ca. 2400-2200 BC). Systematic flotation is needed to determine if rice was available in this region (southeast of Tai Mountain) during late Dawenkou.

Huating

Huating is located in Xinyi, northern Jiangsu Province, on the southern periphery of the Dawenkou culture (Figure 3.3). Two human collagen samples from Huating were directly radiocarbon dated to 2800~2600 cal. BC (Table 4.2). Due to the constraints of preservation I can only briefly discuss the diets of the two individuals that yielded usable results.

Collagen and apatite $\delta^{13}C$ values show that both individuals consumed a mixed diet of C_3, C_4 and possibly aquatic foods (Tables 5.2 and 5.3). They have lower $\delta^{13}C$ than most humans from Liangwangcheng, Fujia and Dongjiaying. Pig mandibles were commonly found as grave goods at Huating, so the C_4 component of the diet is very likely to be millet and millet fed pigs. Because some of the grave goods from Huating resemble those of the southern Liangzhu culture, it is possible that the C_3 component of their diet included rice, which could have been introduced into the area through exchange from southern China or grown locally by the immigrants. Although, we cannot exclude the possible contributions from C_3 wild animals in their diets, their $\delta^{15}N$ values show that, compared to humans from Liangwangcheng that had similarly low $\delta^{13}C$, the two Huating individuals had lower $\delta^{15}N$ values, suggesting more reliance on C_3 plants than on C_3-fed animals and fish. One individual is from a moderately endowed burial (M42); the other is the tomb owner from an elaborate burial (M61). Burial M61 had one female youth in the center and one juvenile on the side with tied distal ends of its tibias, who is possibly human sacrifice. One stem cup (M61:11) and one *huang* (a jade half disc, M61:10) are Liangzhu style. In burial M42, one jade pendant (M42:1) and one stem cup (M42:17) are Liangzhu style. The small difference in $\delta^{13}C$ values between M42 and M61 suggests that rice was probably available to relative high status people. Whether rice was available to members of this population interred in less elaborate burials needs to be tested in future research.

Food consumption and its social context at Liangwangcheng

Liangwangcheng is located in Pizhou, northern Jiangsu Province (Figure 3.3). It dates to the late Dawenkou by pottery style analysis, and directly radiocarbon dated to 2800~2500 cal. BC (Table 4.2). In addition, the occupation at Liangwangcheng can be further divided into three phases based on radiocarbon dating results (Chapter 4): Phase A (2810-2750 cal. BC), Phase B (2700-2620 cal. BC), and Phase C (2640-2560 cal. BC). I have more background information and a more representative sample set from Liangwangcheng. Therefore I will discuss food consumption in its social context, including patterns among different social groups, such as males versus females, and through time.

Stable isotope analysis shows that some individuals consumed more C_4 food while others consumed more C_3 and/or aquatic resources. The strong negative correlation of $\delta^{15}N$ and $\delta^{13}C$ values (Figure 5.6) indicates that individuals with high $\delta^{15}N$ ate more animal protein that was not derived from millet-fed pigs. Conversely individuals with high collagen $\delta^{13}C$ values had relatively low $\delta^{15}N$ values, indicating diets with more millet and millet-fed pigs.

Environmental changes and food consumption through time

Before dealing with social factors that could cause diversity in food consumption, we need to first exclude environmental factors that could lead to differences in food consumption. The excavators assigned each burial to one pottery phase if possible (Table 4.1). Because the radiocarbon chronology is not as precise, with dates that overlap some pottery phases (Table 4.2), I grouped seven pottery phases into three radiocarbon phases. I did analysis of variance (ANOVA) of oxygen isotope values among individuals, using the radiocarbon phases to categorize individuals (Tables 5.5 and 5.6). The results show that there are no significant differences (p=0.088) in $\delta^{18}O$ values among individuals of different phases. Figure 5.8a shows the differences in $\delta^{18}O$ values of individuals from Phase A, B, and C with box plots. We can see a slight trend of increasing $\delta^{18}O$ values through time. However, the differences between chronological periods might be too small to be biologically or culturally significant.

ANOVA of carbon and nitrogen isotope values of individuals from different phases also shows no significant differences (Tables 5.5 and 5.6). Figure 5.8c illustrates the differences in collagen carbon isotope values of individuals from Phase A, B, and C by box plot. We can see that the distributions of $\delta^{13}C_{co}$ values in Phase A and B are relatively constrained, while the distribution of $\delta^{13}C_{co}$ values in Phase C is wider. The $\delta^{13}C_{co}$ values decrease from Phase A to B, while the $\delta^{15}N$ values increased slightly (Table 5.5, Figures 5.8c and 5.8d); however, no observable trend can be found in $\delta^{13}C_{ap}$ values (Figure 5.8b). Due to the small sample size of each phase and significant overlap in carbon and nitrogen isotope values among phases, the change in $\delta^{13}C_{co}$ values from Phase A to B may not be biologically or culturally significant.

Hint on geographic origin from oxygen isotope values

Many studies have used oxygen isotope values of tooth and bone as a proxy to effectively detect individual's geographical origin (White et al. 1998; Price et al. 2010; Wright 2012). Bone is more susceptible to diagenesis than tooth enamel (Wang and Cerling 1994), so as noted above, the bone $\delta^{18}O$ values obtained in this study likely underestimate the range and differences within and among populations. Here I assume that the majority were local people. I use means and standard deviations of $\delta^{18}O$ values to define the range of local people at Liangwangcheng. Four individuals emerge as outliers (Figure 5.9). M97 and M120 had much lower $\delta^{18}O$, while M99 and M226 had much higher $\delta^{18}O$ than the rest of this population (Figure 5.9, Table 5.2). These individuals all have excellent bone collagen preservation so they are unlikely to be affected by diagenesis. Because apatite in human bones has a slow turnover rate, the distinctive $\delta^{18}O$ values of these four individuals could be attributed either to their lifetime distinctive drinking habits compared to the rest of the population or to regular consumption of foods and liquids with different oxygen isotope compositions. In other words, even though they were buried at Liangwangcheng, they could have originated from at least two geographic regions, and the distinctive oxygen isotope signals may not have been fully replaced by the local signal after they moved to Liangwangcheng.

Both M97 and M120 date to Phase A (2810-2750 cal. BC; Chapter 4). M97 is male and had five grave goods; M120 is female and had 20 grave goods. The male (M97) had relatively high $\delta^{13}C_{ap}$ (-4.6‰, compared to the mean of -5.6‰) and $\delta^{13}C_{co}$ values (-8.8‰, compared to the mean of -11.3‰), indicating a diet based on more millet and millet-fed pigs than most individuals from this site. The female (M120) had a relatively low $\delta^{13}C_{ap}$ value (-7.3‰, compared to the mean of -5.6‰) and an average $\delta^{13}C_{co}$ value (-11.9‰, compared to the mean of -11.3‰) suggesting the intake of low protein C_3 food, such as rice. M99 dates to Phase B (2700-2620 cal. BC; Chapter 4). One pot found in the grave had a large amount of red ochre painted on the rim and body, which is rare at this site (Chapter 4). This individual was a female adult and had much lower $\delta^{13}C_{co}$ values (-16.6‰, compared to the mean of -11.3‰) and slightly lower $\delta^{13}C_{ap}$ values (-6.6‰, compared to the mean of -5.6‰) suggesting the intake of protein rich C_3 foods such as deer and/or aquatic food such as fish and turtle (Table 5.2). However, domestic species such as pig and dog at Liangwangcheng also had relative low $\delta^{13}C_{co}$ and $\delta^{13}C_{ap}$ values (Table 5.2). Consumption of those domestic animals could also lead to the lower $\delta^{13}C_{co}$ values in humans. M226 is a young adult male dated to Phase C (2640-2560 cal. BC; Chapter 4), and is the only individual in an extended prone position in this cemetery (Nanjing Museum, Xuzhou Museum and Pizhou Museum n. d.). He (M226) had relatively high $\delta^{13}C_{co}$ (-9.5‰, compared to the mean of -11.3‰) and average $\delta^{13}C_{ap}$ values (-5.2‰, compared to the mean of -5.6‰) indicating a diet based on more millet-fed pigs.

In other words, the four individuals (M97, M120, M99, and M226) with abnormal $\delta^{18}O$ values have consumed diverse diets: some are similar to other individuals at Liangwangcheng, some have consumed more millet (M97), some have consumed more rice (M120), and some have consumed more animal protein (M99), some have consumed more millet-fed pigs. Their different diets could potentially relate to their different geographic origins. Oxygen and strontium analyses of tooth enamel are needed to find out their geographic origins.

Food consumption and identity

One of the primary objectives of this research is to determine if changes in gender relationships occurred during the late Dawenkou Neolithic era. As discussed above, there were no significant differences between males and females in diet and burial treatment at Fujia and Wucun. Here I will test whether there were any differences in food consumption between males and females at Liangwangcheng that could be attributed to differences in social status. ANOVA tests of differences in isotope values between males and females found significant differences in apatite carbon isotope values ($p=0.028$, Table 5.4). Figure 5.10 illustrates the differences in $\delta^{13}C$ and $\delta^{15}N$ values of males and females by box plot. Apatite $\delta^{13}C$ values of females span a larger range than those of males. A similar trend is also found in collagen $\delta^{13}C$ and $\delta^{15}N$ values. This could mean that some females in the community had more flexibility in food choices (discussed below), possibly related to their higher social status. The mean $\delta^{13}C$ values of apatite and collagen of females are lower than males suggesting diets with more C_3 and/or aquatic foods. This difference between males and females can be partly explained by a few female individuals that stand out compared to the rest of the Liangwangcheng population.

The individuals from burials M99, M106, M125, and M248 are all females and had much lower collagen $\delta^{13}C$ values and higher $\delta^{15}N$ values than the rest population (Figure 5.6). M99, M106, M125, and M248 also had lower apatite $\delta^{13}C$ values (Figure 5.5). Two females (M82 and M120) have lower apatite $\delta^{13}C$ values than the rest of this population (Figure 5.5). It seems that C_4 foods with higher $\delta^{13}C$ values (millets and millet-fed pigs) were available to the majority of the population, while the availability of C_3 or aquatic foods with lower $\delta^{13}C$ values was more restricted. Apparently, these six females enjoyed the privilege of access to C_3 and/or aquatic foods. The low $\delta^{13}C$ component in the diets of M82 and M120 was probably rice because both individual had lower $\delta^{13}C_{ap}$ values and moderate $\delta^{13}C_{co}$ values; the C_3 component in the diet of M99, M106, M125, and M248 were likely to be a mixture of rice and animal protein, since these individuals had lower both $\delta^{13}C_{ap}$ and $\delta^{13}C_{co}$ values, plus higher $\delta^{15}N$ values (Table 5.2, Figures 5.5 and 5.6).

If we have a closer look at those six special females, we were able to find some hint on changes through time. Of the six special females, M82 and M120 dated to Phase A, M99 dated to Phase B, the rest three dated to Phase C. Meanwhile, M120 had lower $\delta^{18}O$ values and M99 had higher $\delta^{18}O$ values, suggesting both were possibly originally from other regions; M82, M106, M125, and M248 had $\delta^{18}O$ values within one standard deviation and were probably locals. It is possible that during the early phases (Phase A and B) individuals like M120 and M99 were originally from another community, and they introduced C_3 or aquatic resources into the Liangwangcheng community. Even though aquatic resources are generally available at most Dawenkou sites, how they are exploited could vary site to site. For example, stable isotope analysis of human remains at Dongjiaying and Fujia suggest that aquatic resources were not a significant component of their diets (discussed above). During those early days, few local people (M82) at Liangwangcheng accepted the new food. During Phase C, more people (M106, M125, and M248) accepted the new food. It is worth noting that a jade awl was found in M106, possibly originally from a distant geographic region in northwestern China (Nanjing Museum, Xuzhou Museum and Pizhou Museum n. d.). In addition, similar red mineral pigment that was found on the pottery from M99 was also found on the human bones and the jade awl in M106 (Nanjing Museum, Xuzhou Museum and Pizhou Museum n. d.). If M106 was not originally from another geographic region, it seems that she had special access to some exotic artifacts.

The “special six” all had moderate or large numbers of grave goods, which means their social and economic status gave them some flexibility in food choices. However, they were not necessarily from the most elaborate burials in each phase in the cemetery. For example, among all Phase A burials, M82 and M120, with signals of rice consumption, had 5 and 20 grave goods respectively, and both are simple pit burials. M154 also dates to Phase A, which had 20 grave goods in a pit with *ercengtai*. This burial was disturbed by later features and could have had more grave goods originally. The same observation holds in Phase B and C as well. This means that other individuals in the community such as M154 could have had access to rice but chose not to. It was the “special six” who apparently took the lead and accepted the new staple—rice.

Rice was first domesticated and practiced in southern China, including Liangzhu region (Chapter 3). We do not know who Liangwangcheng people were interacting with and where the rice was originally introduced. Rice was also available at contemporary late Dawenkou site—Yuchisi (Zhao 2006), and probably also at Huating (discussed above). It is possible that Liangwangcheng people acquired the knowledge of rice agriculture from Huating or Yuchisi instead from southern Liangzhu people directly.

Food choices were apparently intertwined with various social identities at Liangwangcheng. Most of the population kept their traditional millet dominant diet and thus reaffirmed their group identity, but some individuals (M99 and M120) may have consumed more rice, possibly as an expression of their southern origin. We do not know the post-marital residence pattern at Liangwangcheng. It is possible that M99 and M120 were married into this community. In addition to these two, some local females also consumed significant amount of rice, perhaps conveying a somewhat different identity from the rest population.

It is hard to know exactly how rice was accepted by local people and under what circumstances rice was consumed. During the early phases, it is possible that rice was regarded as a prestigious food derived from "foreign" areas of exchange partners, and people wanted to serve it at feasts—either in the form of food or to convert to a fermented beverage. Residue analysis of pottery found in Liangwangcheng burials has the potential of revealing what kind of food was served during the funeral and before and what kind of role rice played during graveside feasting. At this point, very few local people (M82) consumed significant amount of rice in their daily diet. During Phase C, more local people (M106, M125, and M248) accepted the new food and possibly invested labor in diverting water to fields, either with a system that was large or small in scale. It is possible that more people with southern origins and having rice as their traditional diet were married into the community during later phases. However, our limited oxygen isotope analysis results do not support this proposition. Oxygen isotope analysis results of Liangwangcheng human remains suggest that all rice consumers dated to Phase C are local people. It is more likely that some local people deliberately adopted rice because they felt it was a prestigious food. It is also possible that only those who had agricultural fields close to water resources or those who had the power to manage people to control water supplies succeeded in growing rice.

Food consumption reflects everyday choices by each individual, and it is argued to be one of the critical factors in the development of complexity (Smith 2012). I understand complexity as societies became more horizontally diversified or more stratified. The introduction of rice provided Dawenkou people with both diversified food consumption choices and probably also diversified food production choices. Even though I only have evidence on food consumption, it is very likely that staple food (millet and rice) was produced locally. It is hard to imagine that large quantity of staple food was obtained through exchange for these not so complex societies. If agricultural fields can be revealed in future excavations at Liangwangcheng, it can help confirm this proposition. Diversified farming practices grant the possibility that some individuals were more successful than others. In addition, potential water management projects were involved for rice production. These practices would provide "aggrandizers" (Hayden 1995) great opportunities to differentiate oneself from another, hence leading to further social stratification and complexity. Identity declarations (ethnicity, gender, and social status) by differential food consumption and other means might have triggered the initial social stratification and eventually led to the more stratified societies in Longshan culture.

Summary

Stable isotopic analysis of human and faunal remains from four contemporary Dawenkou sites suggests that food consumption varied across the landscape and even among different individuals within the same site. Populations from Fujia and Dongjiaying had diets dominated by millets and millet-fed pigs, while the populations from Huating and Liangwangcheng had more diverse diets, including significant amount of C_3 plants such as rice and C_3-feeding animals and/or aquatic resources. Fujia and Dongjiaying are located further north, and Huating and Liangwangcheng are further south. Dietary reconstruction with stable isotopes, combined with archaeological evidence, supports a model of a late Dawenkou population with well-established millet agriculture that gradually adopted rice that was introduced from the southern Liangzhu culture or other southern area and gradually spread north. The observation that more individuals consumed rice during the last phase of occupation at Liangwangcheng supports this proposition. None of the individuals from Dongjiaying consumed significant amounts of rice. However, rice may have been available in the region judging from the collagen $\delta^{13}C$ value of one individual from Lingyanghe that was tested in previous research (Cai and Qiu 1984). A larger sample set from other contemporary Dawenkou sites in the region could reveal to what extent rice was available in the northern Dawenkou region.

Social and political transformations are often accompanied by changes in cuisine practices (Hastorf 1990; Costin and Earle 1989; Crown 2000). Change in food practices could also facilitate social and political transformation. The evidence from Liangwangcheng suggests that the introduction of rice provided a new venue for social diversification and identity reaffirmation. The majority of the individuals tested (21/27) retained the traditional millet-dominated diet, while some women started to accept the new staple food. Women generally had more special status than men at Liangwangcheng, as expressed by exotic and larger quantity of grave goods (Chapter 4). The consumption of rice could be one of the privileges that women enjoying at the community. Meanwhile, these women could have actively utilized this new venue to differentiate themselves from the rest population, which might have eventually led to further stratification. This study provides a new dimension to a model for the initial development of social stratification among Dawenkou communities. It complements the theory of social stratification emerging from graveside competitive feasting (Fung 2000; Underhill 2002). This model can be further tested using materials from other Dawenkou community to see if rice played a critical role in the process of social stratification.

The introduction of rice into northern China had influences beyond the Dawenkou period. Due to higher water requirements, and labor for paddy field preparation, maintenance and irrigation, growing rice generally requires more labor. As a consequence, rice may have become more valuable compared to millet, and only used by elites or only for ritual purposes (Lanehart et al. 2008). Both millet and rice agriculture were practiced at Liangchengzhen (Longshan Culture), however, chemical analysis of pottery indicates the fermented beverage was exclusively made from rice (McGovern et al. 2005), suggesting possible social and/or symbolic roles and meanings for rice. Rice also has nutritional advantages that could have made rice more attractive to population in northern China. Milled rice has lower crude fiber content than any other cereal, making boiled rice gruel an ideal infant food (Chang 2000). In addition to being a good source of carbohydrate, rice is also a good source of protein. For laboring adults, milled rice alone could meet the daily carbohydrate and protein needs for sustenance (Hegsted 1969).

Analysis of oxygen isotopes of human and animal bones in this study demonstrated the potential for providing insights into dietary variation that may reflect regional dietary differences between local residents and possible immigrants. However, further research on natural variation in bone apatite oxygen isotope ratios of aquatic and terrestrial herbivores and omnivores within modern ecosystems is needed to fully evaluate archaeological bone apatite diagenesis. Oxygen isotope analysis of human remains from Fujia suggests an interesting interpretation for the two distinctive body orientations in the same cemetery. Body orientation did not seem to correlate with sex, grave location, grave type, or number of grave goods. However, people with different orientations had different oxygen isotope values. It is likely that they had different source of drinking water, possibly related to different residential locations. Oxygen isotope analysis of human remains suggests different geographic origins for two males and two females from Liangwangcheng.

In next chapter, I attempted to extract DNA from human remains of Liangwangcheng and Fujia sites in order to address two questions. First, I intend to use genetic markers to pin point possible immigrants and test whether the consumption of rice is related to their geographic origins. Second, I try to use ancient DNA to reconstruct social organization at these two sites, especially aspects of kinship and marital residence, and test the long held hypothesis in China that social organization has changed from matrilineal descent to patrilineal descent.

Tables

Table 5.1. Carbon and nitrogen concentration and isotope values in broomcorn millet from Beiqian site.

Site Name	Feature No.	Species	Lab Identifier	wt% N	wt% C	$\delta^{15}N$‰	$\delta^{13}C$‰
Beiqian	09JB T1415 D87	broomcorn millet	DWK361	2.61	43.78	3.443	-10.180
Beiqian	09JB T1315 D34	broomcorn millet	DWK362	3.03	49.08	4.712	-10.625
Beiqian	09JB T1416 ZK10	broomcorn millet	DWK363	2.55	46.71	2.299	-10.328
Beiqian	09JB T1416 H318	broomcorn millet	DWK364	1.93	41.72	2.118	-10.677
Beiqian	09JB T1518 ZK14	broomcorn millet	DWK365	2.63	50.19	2.626	-9.509

Table 5.2. Collagen concentration in bone, C and N concentration in collagen, and isotopic composition of human and faunal collagen and apatite samples from Dongjiaying, Fujia, Huating, and Liangwangcheng.

Site Name	Feature No.	Species	Collagen Identifier	wt% collagen	wt% N	wt% C	C:N	$\delta^{15}N$ ‰	$\delta^{13}C_{co}$ ‰	Apatite Identifier	wt% Apatite	$\delta^{13}C_{ap}$ ‰	$\delta^{18}O$ ‰	$\Delta^{13}C_{ap-co}$ ‰
Dongjiaying	M1	human	DWK1	0.25	12.83	35.62	3.24	8.131	-7.557	DWK251	60.96	-3.802	23.788	3.755
Dongjiaying	M4	human	DWK3	1.41	12.65	35.71	3.29	9.778	-10.264	DWK252	62.67	-2.954	23.926	7.310
Dongjiaying	M5	human	DWK5	0.94	13.59	37.37	3.21	7.686	-7.653	DWK253	55.56	-4.447	24.104	3.206
Dongjiaying	M7	human	DWK7	0.87	5.57	15.87	3.32	5.766	-9.295	DWK254	64.80	-3.357	23.941	5.938
Dongjiaying	M8	human	DWK9	0.61	12.40	31.32	2.95	5.226	-7.512	DWK255	62.64	-3.504	23.977	4.008
Dongjiaying	M10	human	DWK11	1.93	13.49	37.29	3.22	8.394	-7.149	DWK256	57.02	-4.385	24.106	2.764
Dongjiaying	M11	human	DWK13	1.22	10.68	28.39	3.10	7.992	-7.471	DWK257	67.46	-3.409	24.046	4.062
Dongjiaying	M13	human	DWK15	0.20	10.14	26.80	3.08	5.492	-8.856	DWK258	60.74	-4.402	24.260	4.454
Dongjiaying	M16	human	DWK17	0.34	12.15	32.91	3.16	6.661	-6.991	DWK259	61.94	-2.570	23.926	4.421
Dongjiaying	M17	human	DWK19	0.96	14.20	38.58	3.17	7.987	-6.743	DWK260	52.22	-3.303	24.026	3.440
Dongjiaying	M21	human	DWK21	0.36	12.95	30.57	2.75	6.975	-7.206	DWK261	55.19	-2.680	24.076	4.526
Dongjiaying	M24	human	DWK23	0.93	13.70	37.54	3.20	7.440	-6.773	DWK262	67.47	-2.813	24.168	3.960
Dongjiaying	M25	human	DWK25	6.42	15.80	43.10	3.18	7.370	-6.389	DWK263	60.24	-3.163	23.742	3.226
Dongjiaying	M29	human	DWK27	0.32	6.96	15.78	2.65	-0.766	-11.005	DWK264	61.61	-4.067	24.617	6.938
Dongjiaying	M30	human	DWK29	0.00	5.33	5.69	1.25	-15.737	-21.940	DWK265	69.54	-3.422	24.040	18.518
Dongjiaying	M36	human	DWK31	0.30	1.81	4.29	2.77	0.971	-12.107	DWK266	59.27	-3.566	23.082	8.541
Dongjiaying	M37	human	DWK33	0.00	2.16	4.76	2.57	2.685	-18.569	DWK267	63.58	-10.243	24.205	8.326
Dongjiaying	M38	human	DWK35	0.51	1.57	2.91	2.16	-14.101	-24.853	DWK268	60.45	-6.083	24.037	18.770
Dongjiaying	M42	human	DWK219	0.00	9.11	15.98	2.05	-1.306	-15.760	DWK269	57.83	-4.211	24.177	11.549
Dongjiaying	M44	human	DWK221	0.19	10.61	26.67	2.93	6.550	-7.470	DWK270	56.37	-2.859	23.662	4.611
Dongjiaying	M45	human	DWK41	2.40	15.04	41.12	3.19	7.138	-6.814	DWK271	62.54	-4.167	23.976	2.647
Dongjiaying	M1:13	pig	DWK43	1.68	14.46	39.23	3.17	5.733	-7.299	DWK272	54.60	-5.402	23.887	1.897
Dongjiaying	M8:7	pig	DWK45	0.16	11.02	28.53	3.02	1.061	-9.478	DWK273	57.74	-4.783	23.669	4.695
Dongjiaying	M8:8	pig	DWK47	0.42	11.95	32.57	3.18	3.714	-9.333	DWK274	57.08	-5.118	23.932	4.215
Dongjiaying	M13:21	pig	DWK49	0.57	11.08	29.72	3.13	4.635	-7.783	DWK275	53.69	-5.475	24.116	2.308

Dongjiaying	M13:22	pig	DWK51	0.17	10.44	24.18	2.70	0.889	-10.363	DWK276	56.86	-5.828	23.941	4.535
Dongjiaying	M13:25	pig	DWK53	0.00	8.82	20.37	2.69	1.265	-11.477	DWK277	47.64	-5.630	23.957	5.847
Dongjiaying	M20:22	pig	DWK55	0.96	14.05	35.93	2.98	4.777	-8.747	DWK278	64.50	-4.991	23.647	3.756
Dongjiaying	M24:20	pig	DWK57	2.30	14.45	38.27	3.09	7.454	-12.156	DWK279	66.38	-5.770	23.405	6.386
Dongjiaying	M24:21	pig	DWK59	1.02	15.14	39.84	3.07	5.071	-11.518	DWK280	61.71	-4.668	23.599	6.850
Liangwangcheng	H86	deer	DWK61	3.64	16.47	41.11	2.91	1.945	-20.829	DWK281	59.02	-9.002	23.950	11.827
Liangwangcheng	H394	pig	DWK63	9.12	17.19	45.33	3.08	7.035	-7.843	DWK282	49.11	-4.790	23.229	3.053
Liangwangcheng	H394	deer	DWK65	11.02	17.29	45.85	3.09	3.046	-19.706	DWK283	43.26	-10.219	24.929	9.487
Liangwangcheng	H394	fish	DWK67	2.26	14.88	38.47	3.02	6.545	-20.743	DWK284	53.64	-6.106	23.674	14.637
Liangwangcheng	H420	pig	DWK69	4.16	16.02	44.16	3.22	6.922	-15.620	DWK285	55.69	-7.209	23.450	8.411
Liangwangcheng	H420	cattle	DWK71	12.39	16.49	43.64	3.09	5.322	-13.242	DWK286	40.28	-6.325	23.268	6.917
Liangwangcheng	H536	deer	DWK73	9.94	17.42	45.72	3.06	7.148	-18.101	DWK287	33.92	-10.517	24.162	7.584
Liangwangcheng	T4701[9]	dog	DWK75	12.72	17.42	45.85	3.07	7.879	-17.240	DWK288	43.41	-10.868	23.230	6.372
Liangwangcheng	T4701[9]	pig	DWK77	7.89	16.96	44.43	3.06	4.924	-14.185	DWK289	47.41	-9.677	23.528	4.508
Liangwangcheng	T4708[9]	Geoemydidae	DWK79	0.72	11.63	30.48	3.06	3.272	-18.448	DWK290	66.47	-8.532	23.037	9.916
Liangwangcheng	T4708[9]	deer antler	DWK227	2.52	14.41	38.55	3.12	2.772	-17.159	DWK291	69.28	-6.678	24.011	10.481
Liangwangcheng	T4804[9]	Trionychidae	DWK83	0.20	12.34	31.10	2.94	7.320	-20.253	DWK292	62.72	-7.476	23.411	12.777
Liangwangcheng	H394	cattle	DWK85	8.06	17.28	46.10	3.11	4.940	-9.403	DWK293	40.41	-3.248	24.113	6.155
Liangwangcheng	T4804[9]	deer	DWK229	3.23	14.74	39.61	3.14	5.615	-18.414	DWK294	64.56	-7.481	23.840	10.933
Liangwangcheng	M81	human	DWK87	3.04	16.61	43.14	3.03	8.355	-10.293	DWK295	63.20	-4.460	23.734	5.833
Liangwangcheng	M82	human	DWK89	1.73	15.67	40.85	3.04	8.876	-12.250	DWK296	64.11	-6.892	23.598	5.358
Liangwangcheng	M89	human	DWK91	0.17	14.20	36.65	3.01	8.780	-11.248	DWK297	66.25	-5.932	23.448	5.316
Liangwangcheng	M97	human	DWK93	9.46	16.46	43.31	3.07	9.072	-8.814	DWK298	49.70	-4.593	22.715	4.221
Liangwangcheng	M99	human	DWK95	2.89	16.07	42.25	3.07	10.007	-16.572	DWK299	59.76	-6.608	24.432	9.964
Liangwangcheng	M104	human	DWK97	11.05	17.23	45.80	3.10	8.720	-8.852	DWK300	52.14	-4.711	23.763	4.141
Liangwangcheng	M106	human	DWK99	2.33	15.15	40.53	3.12	9.955	-15.010	DWK301	70.19	-6.658	23.967	8.352
Liangwangcheng	M120	human	DWK101	12.03	16.02	43.20	3.15	9.143	-11.898	DWK302	45.83	-7.302	23.355	4.596
Liangwangcheng	M121	human	DWK103	1.95	15.29	41.02	3.13	9.509	-13.335	DWK303	64.52	-5.560	23.838	7.775
Liangwangcheng	M125	human	DWK105	3.44	16.08	43.48	3.15	10.888	-15.064	DWK304	62.55	-7.238	23.872	7.826

Liangwangcheng	M129	human	DWK107	11.23	16.34	44.26	3.16	9.673	-10.519	DWK305	46.48	-6.060	23.625	4.459
Liangwangcheng	M146	human	DWK109	3.20	15.83	42.69	3.15	8.579	-10.939	DWK306	51.65	-5.600	23.668	5.339
Liangwangcheng	M154	human	DWK111	3.31	15.87	42.03	3.09	8.202	-11.018	DWK307	55.58	-5.886	23.935	5.132
Liangwangcheng	M160	human	DWK231	2.26	13.34	35.30	3.09	8.114	-7.896	DWK308	84.62	-5.114	23.769	2.782
Liangwangcheng	M223	human	DWK115	3.17	15.58	41.76	3.13	8.591	-8.182	DWK309	61.98	-4.566	23.559	3.616
Liangwangcheng	M225	human	DWK117	6.60	16.44	44.55	3.16	9.517	-11.897	DWK310	54.69	-6.112	23.819	5.785
Liangwangcheng	M226	human	DWK119	3.95	15.00	40.66	3.16	8.361	-9.530	DWK311	60.94	-5.218	24.242	4.312
Liangwangcheng	M238	human	DWK121	5.72	15.56	42.71	3.20	8.576	-10.729	DWK312	61.79	-5.936	23.908	4.793
Liangwangcheng	M248	human	DWK123	3.05	15.32	42.03	3.20	9.792	-15.819	DWK313	65.26	-6.499	24.041	9.320
Liangwangcheng	M249	human	DWK125	3.04	14.21	38.62	3.17	8.888	-9.993	DWK314	62.67	-5.939	23.953	4.054
Liangwangcheng	M251	human	DWK127	3.91	15.36	41.88	3.18	9.394	-13.402	DWK315	62.12	-5.744	23.696	7.658
Liangwangcheng	M252	human	DWK129	2.56	15.08	40.93	3.17	7.555	-10.191	DWK316	58.90	-5.631	24.088	4.560
Liangwangcheng	M253	human	DWK131	1.53	14.09	37.60	3.11	7.747	-9.513	DWK317	70.28	-4.707	23.495	4.806
Liangwangcheng	M254	human	DWK133	1.68	14.80	40.43	3.19	8.691	-10.146	DWK318	64.18	-5.149	23.666	4.997
Liangwangcheng	M268	human	DWK135	3.88	15.66	43.04	3.21	8.278	-9.108	DWK319	62.28	-4.189	24.071	4.919
Liangwangcheng	M271	human	DWK137	2.29	14.95	40.84	3.19	8.593	-11.353	DWK320	61.02	-5.498	23.787	5.855
Liangwangcheng	M272	human	DWK139	3.89	15.46	42.63	3.22	9.161	-11.576	DWK321	57.77	-4.808	23.710	6.768
Fujia	TG1:H11	pig	DWK143	9.58	15.61	43.50	3.25	7.340	-9.960	DWK323	43.66	-5.359	23.737	4.601
Fujia	T3267H370	pig	DWK145	1.31	14.09	38.06	3.15	7.191	-6.571	DWK324	62.08	-3.156	23.677	3.415
Fujia	T3367[6]	pig	DWK147	5.49	15.22	42.02	3.22	6.667	-12.239	DWK325	57.69	-5.682	23.317	6.557
Fujia	T3369[5]	pig	DWK149	7.22	16.01	44.28	3.23	5.626	-11.178	DWK326	49.22	-4.108	23.795	7.070
Fujia	T3370[6]	pig	DWK151	6.37	15.04	41.67	3.23	7.507	-7.623	DWK327	42.64	-4.406	24.161	3.217
Fujia	T3371[6]	pig	DWK153	4.53	15.05	41.59	3.22	6.905	-11.776	DWK328	50.10	-4.464	24.118	7.312
Fujia	T3372[4]	pig	DWK155	6.12	15.23	42.20	3.23	7.295	-11.177	DWK329	42.66	-3.632	22.634	7.545
Fujia	T3373[6]	pig	DWK157	7.39	15.36	42.01	3.19	7.076	-11.230	DWK330	52.30	-4.783	23.925	6.447
Fujia	T3373[6]	pig	DWK233	0.00	6.01	8.88	1.72	5.878	-13.184	DWK331	75.44	-3.858	23.738	9.326
Fujia	M6	human	DWK161	7.02	15.86	43.64	3.21	9.098	-7.805	DWK332	47.88	-3.289	24.051	4.516
Fujia	M7	human	DWK163	9.17	15.84	43.96	3.24	8.760	-7.990	DWK333	50.20	-3.523	23.842	4.467
Fujia	M9	human	DWK165	10.47	16.75	46.61	3.25	9.153	-7.028	DWK334	42.16	-2.701	23.593	4.327

Fujia	M10	human	DWK167	8.99	15.91	43.97	3.22	9.191	-7.401	DWK335	48.19	-3.048	24.307	4.353
Fujia	M12	human	DWK169	9.35	15.49	42.67	3.21	9.015	-7.233	DWK336	54.04	-2.947	24.017	4.286
Fujia	M16	human	DWK171	9.69	15.50	42.65	3.21	9.845	-7.820	DWK337	43.59	-3.037	24.166	4.783
Fujia	M17	human	DWK173	4.51	15.65	43.40	3.24	8.075	-8.115	DWK338	44.38	-2.996	23.311	5.119
Fujia	M21	human	DWK175	10.59	15.00	41.82	3.25	8.657	-7.588	DWK339	38.52	-3.175	23.247	4.413
Fujia	M24	human	DWK177	10.25	15.32	42.26	3.22	8.815	-7.556	DWK340	50.29	-3.112	23.634	4.444
Fujia	M28	human	DWK179	9.62	16.60	44.51	3.13	9.630	-7.347	DWK341	44.62	-2.927	23.291	4.420
Fujia	M31	human	DWK181	6.01	16.94	45.74	3.15	9.116	-7.267	DWK342	45.36	-3.225	24.181	4.042
Fujia	M32	human	DWK183	4.87	16.83	45.28	3.14	8.955	-6.995	DWK343	47.35	-4.015	24.197	2.980
Fujia	M34	human	DWK185	6.23	16.73	45.02	3.14	9.297	-7.952	DWK344	44.44	-3.396	24.034	4.556
Fujia	M101	human	DWK187	9.91	16.72	45.50	3.17	9.654	-6.567	DWK345	45.29	-2.098	23.975	4.469
Fujia	M112	human	DWK235	11.40	16.02	44.04	3.21	8.529	-8.472	DWK346	37.67	-3.317	23.860	5.155
Fujia	M117	human	DWK237	9.98	15.65	43.14	3.22	9.533	-7.229	DWK347	40.53	-2.995	23.698	4.234
Fujia	M118	human	DWK193	8.16	16.94	45.80	3.15	8.688	-8.118	DWK348	41.51	-3.574	23.582	4.544
Fujia	M128	human	DWK195	11.14	15.96	43.08	3.15	9.353	-7.552	DWK349	39.26	-3.432	22.593	4.120
Fujia	M133	human	DWK197	13.73	16.58	44.74	3.15	9.478	-8.217	DWK350	46.77	-3.822	23.959	4.395
Fujia	M140	human	DWK199	14.29	16.39	43.87	3.12	8.882	-7.324	DWK351	34.55	-3.110	23.228	4.214
Fujia	M145	human	DWK201	13.33	16.63	45.03	3.16	9.481	-7.979	DWK352	39.78	-2.949	24.150	5.030
Fujia	M154	human	DWK203	11.83	16.20	43.42	3.13	9.386	-7.571	DWK353	47.75	-3.585	23.430	3.986
Fujia	M156	human	DWK205	11.18	16.87	45.46	3.14	9.789	-7.708	DWK354	49.80	-3.349	23.398	4.359
Huating	M42	human	DWK207	0.65	14.53	39.96	3.21	8.368	-14.004	DWK355	58.35	-7.105	24.272	6.899
Huating	M46	human	DWK209	0.00	7.11	3.87	0.64	-2.709	-24.826	DWK356	84.08	-7.017	24.832	17.809
Huating	M60	human	DWK211	0.00	3.96	3.78	1.11	-6.028	-25.012	DWK357	62.78	-10.906	24.159	14.106
Huating	M60(2)	human	DWK213	0.00	12.86	28.64	2.60	4.684	-17.176	DWK358	80.12	-10.065	24.158	7.111
Huating	M60(3)	human	DWK215	0.00	9.91	19.90	2.34	2.336	-18.906	DWK359	80.83	-9.398	24.422	9.508
Huating	M61	human	DWK217	0.56	12.67	32.04	2.95	8.950	-14.698	DWK360	77.16	-6.636	23.839	8.062

Note: 1. Except that DWK227 is a deer antler, all other samples are bone samples.

2. The identification of faunal samples was done by Yu Dong. The fauna identification results of Liangwangcheng site were confirmed by an independent zooarchaeological analysis (Song and Lin n. d.). All pig samples from Dongjiaying are mandibles; Fujia pig samples include mandibles, scapula, and humerus.

All the pig samples are assumed domestic pigs since pig has been domesticated long ago and domestic pigs are commonly found in northern China (Yuan and Flad, 2002). No further effort was made to discern if they were domestic or wild pigs.

Table 5.3. Summary descriptive statistics of the composition of well-preserved bone collagen and apatite samples.

		wt% collagen	wt% N	wt% C	C:N	$\delta^{15}N$‰	$\delta^{13}C_{co}$‰	wt% apatite	$\delta^{13}C_{ap}$‰	$\delta^{18}O$‰	$\Delta^{13}C_{ap-co}$‰
Humans and fauna: all sites	Minimum	0.16	5.57	15.87	2.91	1.061	-20.829	33.92	-10.868	22.593	1.897
	Maximum	14.29	17.42	46.61	3.32	10.888	-6.389	84.62	-2.098	24.929	14.637
	Average	5.24	14.99	40.40	3.14	7.716	-10.472	54.71	-4.937	23.776	5.535
	Standard deviation	4.14	1.94	5.37	0.08	1.943	3.705	9.98	1.870	0.377	2.333
	Number of samples	95	95	95	95	95	95	95	95	95	95
Humans: Dongjiaying	Minimum	0.19	5.57	15.87	2.93	5.226	-10.264	52.22	-4.447	23.662	2.647
	Maximum	6.42	15.80	43.10	3.32	9.778	-6.389	67.47	-2.570	24.260	7.310
	Average	1.33	12.35	33.45	3.16	7.258	-7.638	60.90	-3.510	23.975	4.129
	Standard deviation	1.60	2.55	7.15	0.11	1.242	1.097	4.40	0.636	0.165	1.247
	Number of samples	14	14	14	14	14	14	14	14	14	14
Humans: Fujia	Minimum	4.51	15.00	41.82	3.12	8.075	-8.472	34.55	-4.015	22.593	2.980
	Maximum	14.29	16.94	46.61	3.25	9.845	-6.567	54.04	-2.098	24.307	5.155
	Average	9.64	16.19	44.16	3.18	9.147	-7.601	44.52	-3.201	23.728	4.401
	Standard deviation	2.61	0.59	1.27	0.04	0.440	0.454	4.76	0.393	0.423	0.436
	Number of samples	23	23	23	23	23	23	23	23	23	23
Humans: Huating	Minimum	0.56	12.67	32.04	2.95	8.368	-14.698	58.35	-7.105	23.839	6.899
	Maximum	0.65	14.53	39.96	3.21	8.950	-14.004	77.16	-6.636	24.272	8.062
	Average	0.61	13.60	36.00	3.08	8.659	-14.351	67.76	-6.871	24.055	7.481
	Standard deviation	0.06	1.32	5.60	0.18	0.412	0.491	13.30	0.332	0.306	0.822
	Number of samples	2	2	2	2	2	2	2	2	2	2
Humans: Liangwangcheng	Minimum	0.17	13.34	35.30	3.01	7.555	-16.572	45.83	-7.302	22.715	2.782
	Maximum	12.03	17.23	45.80	3.22	10.888	-7.896	84.62	-4.189	24.432	9.964
	Average	4.20	15.47	41.56	3.13	8.927	-11.302	60.76	-5.652	23.769	5.650
	Standard deviation	3.15	0.86	2.37	0.06	0.747	2.299	7.94	0.860	0.319	1.773
	Number of samples	27	27	27	27	27	27	27	27	27	27

Pigs: Dongjiaying	Minimum	0.16	11.02	28.53	2.98	1.061	-12.156	53.69	-5.770	23.405	1.897
	Maximum	2.30	15.14	39.84	3.18	7.454	-7.299	66.38	-4.668	24.116	6.850
	Average	1.01	13.16	34.87	3.09	4.635	-9.473	59.39	-5.172	23.751	4.301
	Standard deviation	0.75	1.75	4.63	0.07	1.957	1.803	4.90	0.397	0.240	1.873
	Number of samples	7	7	7	7	7	7	7	7	7	7
Pigs: Fujia	Minimum	1.31	14.09	38.06	3.15	5.626	-12.239	42.64	-5.682	22.634	3.217
	Maximum	9.58	16.01	44.28	3.25	7.507	-6.571	62.08	-3.156	24.161	7.545
	Average	6.00	15.20	41.92	3.22	6.951	-10.219	50.04	-4.449	23.670	5.771
	Standard deviation	2.41	0.55	1.82	0.03	0.596	2.052	7.16	0.838	0.496	1.762
	Number of samples	8	8	8	8	8	8	8	8	8	8
Fauna: Liangwangcheng	Minimum	0.20	11.63	30.48	2.91	1.945	-20.829	33.92	-10.868	23.037	3.053
	Maximum	12.72	17.42	46.10	3.22	7.879	-7.843	69.28	-3.248	24.929	14.637
	Average	6.28	15.75	41.46	3.07	5.335	-16.513	52.08	-7.723	23.702	8.790
	Standard deviation	4.36	1.904	5.28	0.08	1.932	4.059	11.18	2.231	0.505	3.254
	Number of samples	14	14	14	14	14	14	14	14	14	14

Table 5.4. The results of independent sample t-test of stable isotope values between different groups.

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
Comparing $\delta^{15}N$ values of human samples from Fujia and Dongjiaying	Equal variances assumed	13.139	0.001	6.688	35	0
	Equal variances not assumed			5.486	15.008	0
Comparing $\delta^{15}N$ values of pig samples from Fujia and Dongjiaying	Equal variances assumed	2.929	0.111	3.197	13	0.007
	Equal variances not assumed			3.011	6.975	0.020
Comparing $\delta^{18}O$ values of human samples from Fujia and Dongjiaying	Equal variances assumed	11.906	0.001	-2.08	35	0.045
	Equal variances not assumed			-2.504	31.069	0.018
Comparing $\delta^{18}O$ values of pig samples from Fujia and Dongjiaying	Equal variances assumed	1.346	0.267	-0.388	13	0.704
	Equal variances not assumed			-0.406	10.37	0.693
Comparing $\delta^{13}C_{co}$ values of individuals oriented to SE and NE from Fujia	Equal variances assumed	0.566	0.461	0.065	19	0.948
	Equal variances not assumed			0.062	13.506	0.951
Comparing $\delta^{15}N$ values of individuals oriented to SE and NE from Fujia	Equal variances assumed	0.144	0.708	-0.301	19	0.767
	Equal variances not assumed			-0.301	17.477	0.767
Comparing $\delta^{18}O$ values of individuals oriented to SE and NE from Fujia	Equal variances assumed	0.917	0.350	2.062	19	0.053
	Equal variances not assumed			2.16	18.993	0.044
Comparing $\delta^{13}C_{ap}$ values of individuals oriented to SE and NE from Fujia	Equal variances assumed	0.311	0.583	0.302	19	0.766
	Equal variances not assumed			0.283	12.764	0.781

Comparing $\delta^{13}C_{co}$ values of male and female individuals from Fujia	Equal variances assumed	0.168	0.686	0.402	20	0.692
	Equal variances not assumed			0.401	19.11	0.693
Comparing $\delta^{15}N$ values of male and female individuals from Fujia	Equal variances assumed	0	0.992	0.753	20	0.460
	Equal variances not assumed			0.758	19.667	0.458
Comparing $\delta^{18}O$ values of male and female individuals from Fujia	Equal variances assumed	0.291	0.596	0.481	20	0.636
	Equal variances not assumed			0.490	20	0.629
Comparing $\delta^{13}C_{ap}$ values of male and female individuals from Fujia	Equal variances assumed	0.007	0.933	0.157	20	0.877
	Equal variances not assumed			0.159	19.971	0.875
Comparing $\delta^{13}C_{co}$ values of male and female individuals from Liangwangcheng	Equal variances assumed	5.51	0.027	1.662	25	0.109
	Equal variances not assumed			1.774	22.06	0.090
Comparing $\delta^{15}N$ values of male and female individuals from Liangwangcheng	Equal variances assumed	1.259	0.273	-0.750	25	0.460
	Equal variances not assumed			-0.781	24.585	0.442
Comparing $\delta^{18}O$ values of male and female individuals from Liangwangcheng	Equal variances assumed	0.292	0.594	-1.819	25	0.081
	Equal variances not assumed			-1.747	18.887	0.097
Comparing $\delta^{13}C_{ap}$ values of male and female individuals from Liangwangcheng	Equal variances assumed	1.066	0.312	2.327	25	0.028
	Equal variances not assumed			2.420	24.636	0.023

Table 5.5. Summary statistics of stable isotope values of human collagen and apatite samples from Liangwangcheng, grouped by occupation phase, sex, or skeleton position. One individual was in the extended prone position (M226) and was not included in this table.

	Collagen $\delta^{15}N$			Collagen $\delta^{13}C_{co}$			Apatite $\delta^{13}C_{ap}$			Apatite $\delta^{18}O$		
Phase	A	B	C	A	B	C	A	B	C	A	B	C
N	8	5	10	8	5	10	8	5	10	8	5	10
Mean (‰)	8.752	9.210	9.265	-10.453	-12.817	-11.977	-5.738	-5.681	-5.906	23.550	23.843	23.872
Std. (‰)	0.537	0.568	0.795	1.470	2.265	2.683	1.018	0.658	0.789	0.376	0.362	0.199
	male	female		male	Female		male	female		male	female	
N	12	15		12	15		12	15		12	15	
Mean (‰)	8.805	9.024		-10.506	-11.938		-5.254	-5.971		23.649	23.865	
Std. (‰)	0.595	0.858		1.423	2.693		0.632	0.903		0.364	0.252	
	extended supine	extended side		extended supine	extended side		extended supine	extended side		extended supine	extended side	
N	17	9		17	9		17	9		17	9	
Mean (‰)	8.875	9.087		-11.448	-11.223		-5.706	-5.599		23.792	23.672	
Std. (‰)	0.809	0.657		2.462	2.147		0.981	0.667		0.274	0.377	

Table 5.6. Analysis of variance (ANOVA) of stable isotope values of human collagen and apatite samples from Liangwangcheng, grouped by radiocarbon occupation phase.

	Sum of Squares	df	Mean Square	F	Sig.
Apatite $\delta^{18}O$					
Between Groups	0.513	2	0.256	2.746	0.088
Within Groups	1.867	20	0.093		
Total	2.38	22			
Collagen $\delta^{13}C_{co}$					
Between Groups	19.324	2	9.662	1.925	0.172
Within Groups	100.403	20	5.02		
Total	119.727	22			
Collagen $\delta^{15}N$					
Between Groups	1.289	2	0.645	1.433	0.262
Within Groups	8.994	20	0.45		
Total	10.284	22			
Apatite $\delta^{13}C_{ap}$					
Between Groups	0.213	2	0.107	0.146	0.865
Within Groups	14.593	20	0.73		
Total	14.806	22			

Figures

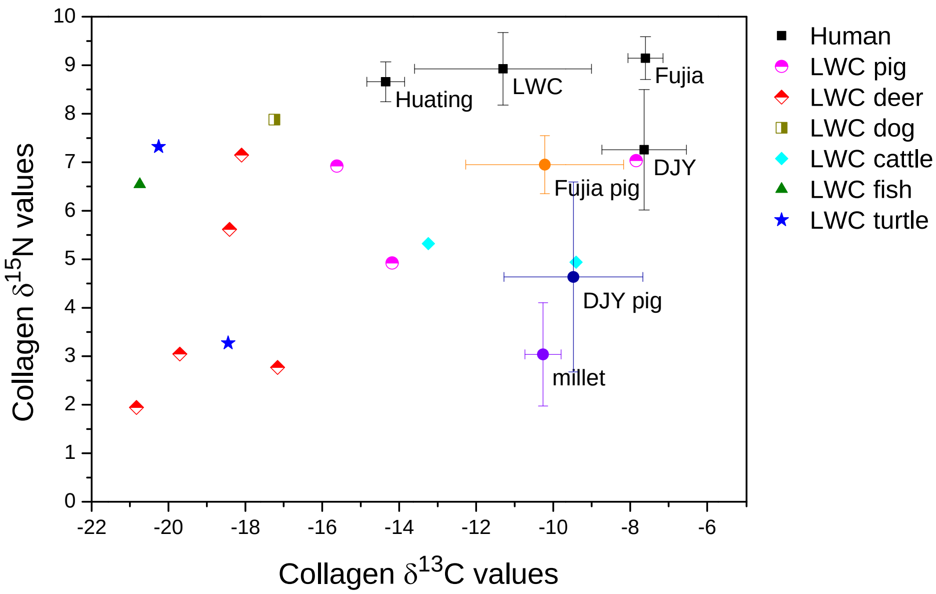

Figure 5.1. Bivariate plot of human and fauna bone collagen $\delta^{15}N$ and $\delta^{13}C$ values from Dongjiaying (DJY), Fujia, Huating, and Liangwangcheng (LWC) sites, and $\delta^{15}N$ and $\delta^{13}C$ values of carbonized broomcorn millet remains from Beiqian.

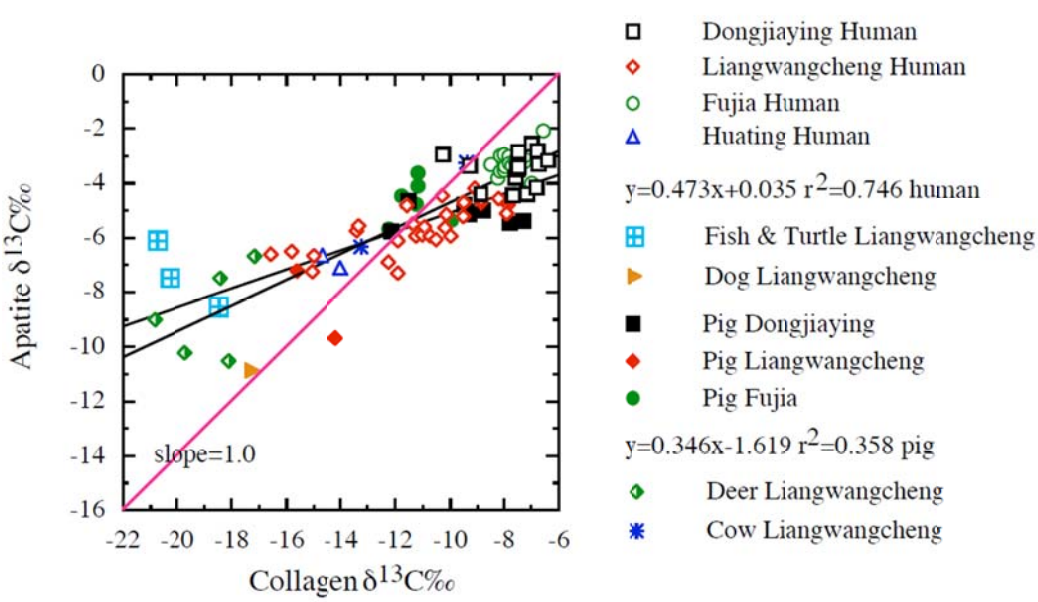

Figure 5.2. Bivariate plot of human and fauna collagen and apatite $\delta^{13}C$ values from Dongjiaying, Fujia, Huating, and Liangwangcheng.

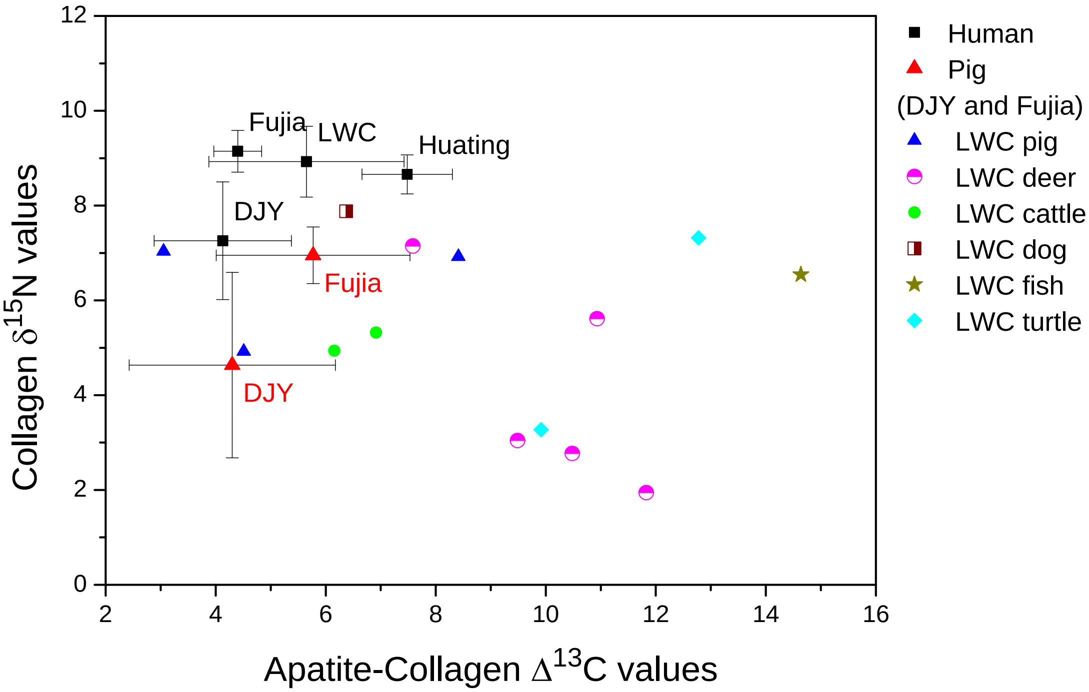

Figure 5.3. Bivariate plot of human and fauna collagen δ^{15}N and Apatite-Collagen $\Delta^{13}C_{ap\text{-}coll}$ values from Dongjiaying (DJY), Fujia, Huating, and Liangwangcheng (LWC).

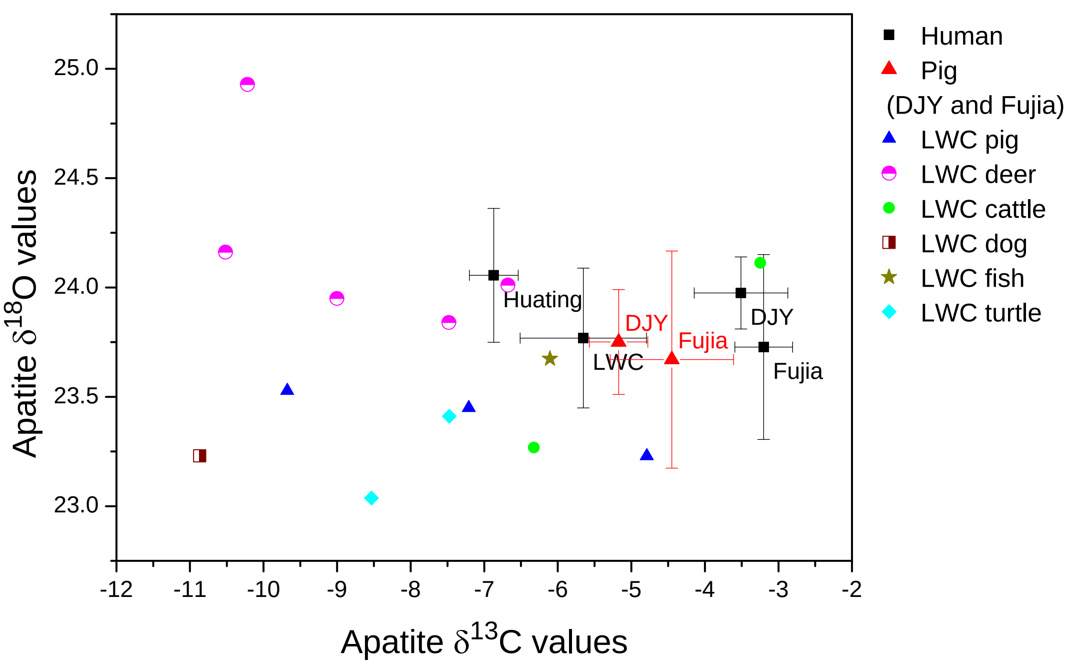

Figure 5.4. Bivariate plot of human and fauna bone apatite δ^{18}O and δ^{13}C values from Dongjiaying (DJY), Fujia, Huating, and Liangwangcheng (LWC).

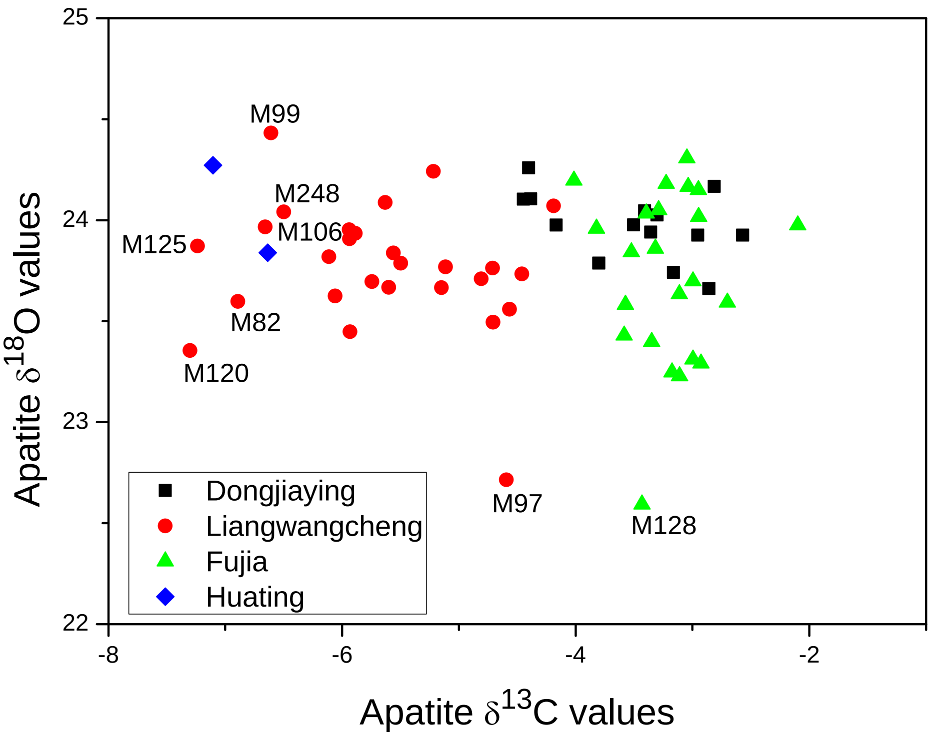

Figure 5.5. Scatter plot of human apatite δ^{18}O and δ^{13}C values from Dongjiaying, Fujia, Huating, and Liangwangcheng.

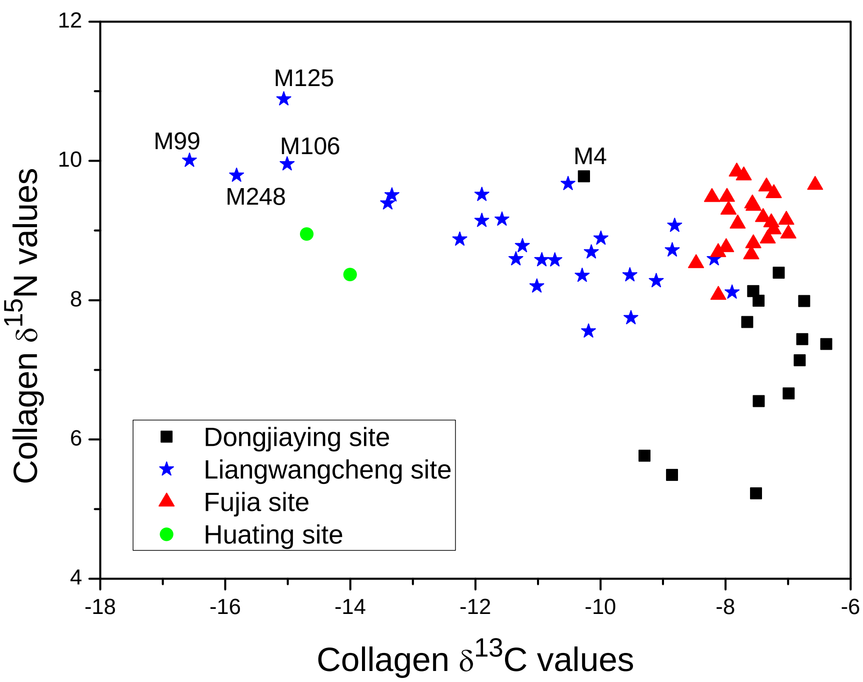

Figure 5.6. Scatter plot of human collagen δ^{15}N and δ^{13}C values from Dongjiaying, Fujia, Huating, and Liangwangcheng.

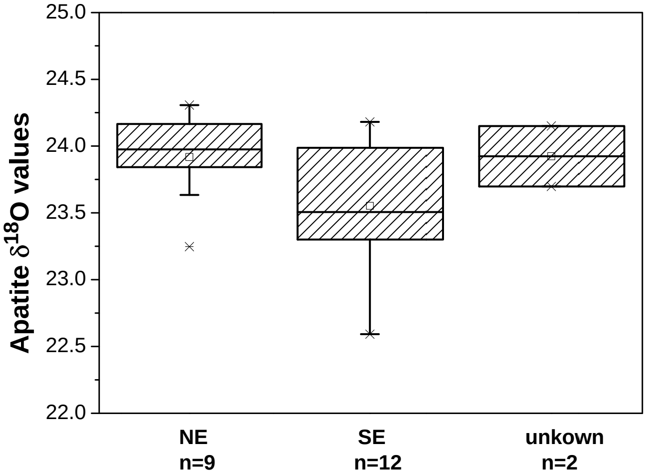

Figure 5.7. Box plot of apatite oxygen isotope values of Fujia human remains, grouped by burial orientation.

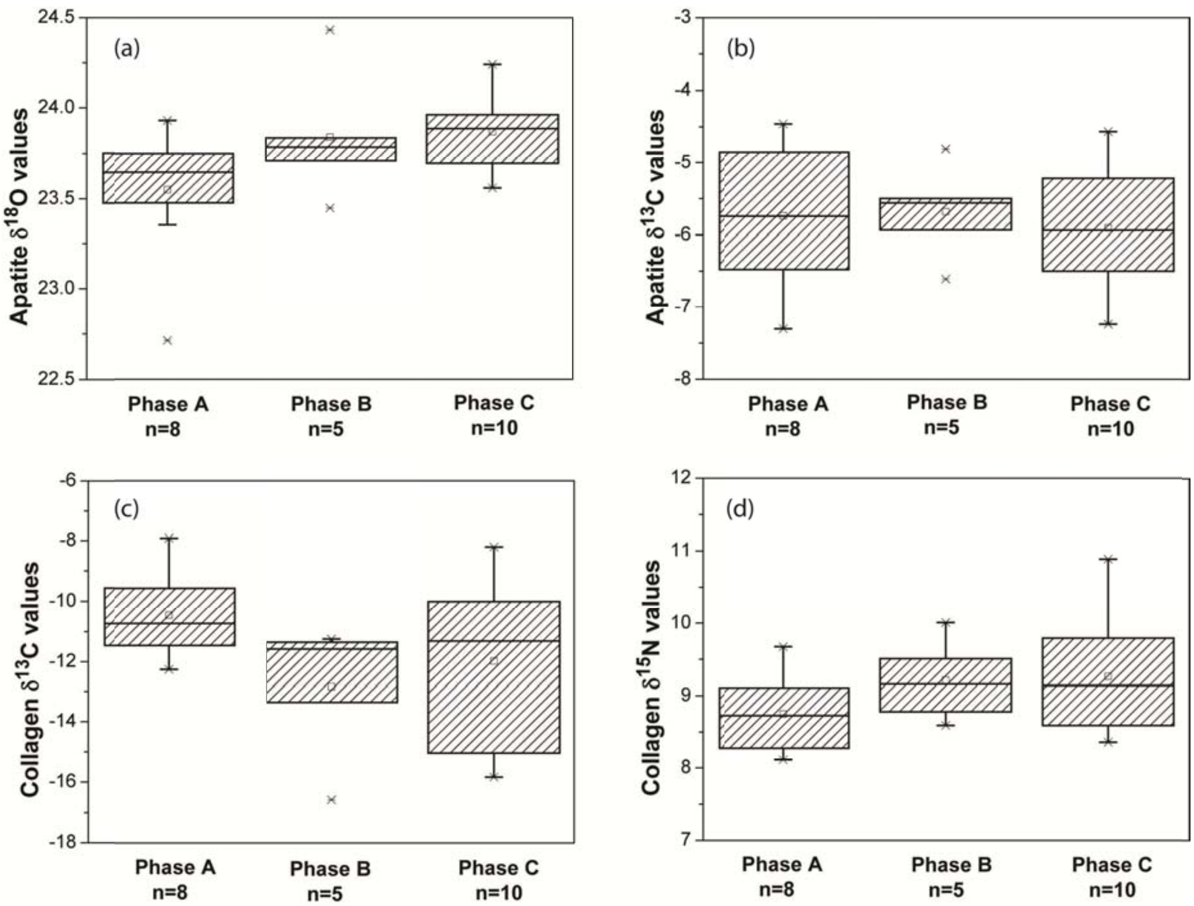

Figure 5.8. Box plot of apatite and collagen isotope values of Liangwangcheng human remains, grouped by chronology: (a) apatite oxygen, (b) apatite carbon, (c) collagen carbon, and (d) collagen nitrogen.

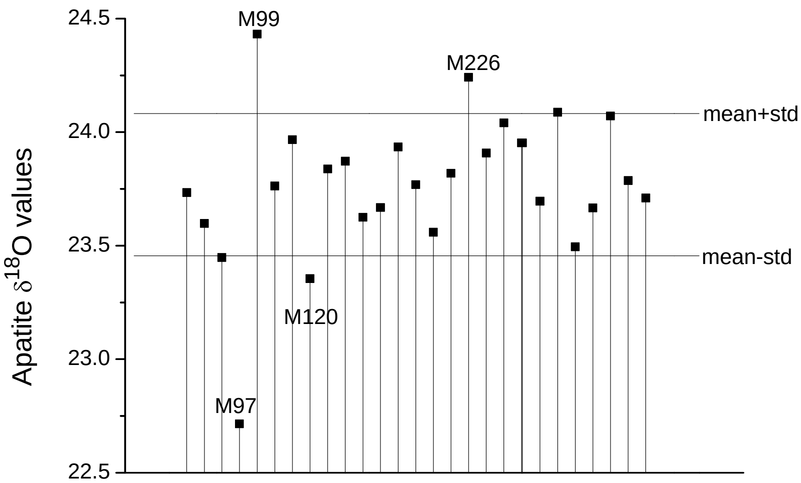

Figure 5.9. Oxygen isotope values of human apatite samples from Liangwangcheng.

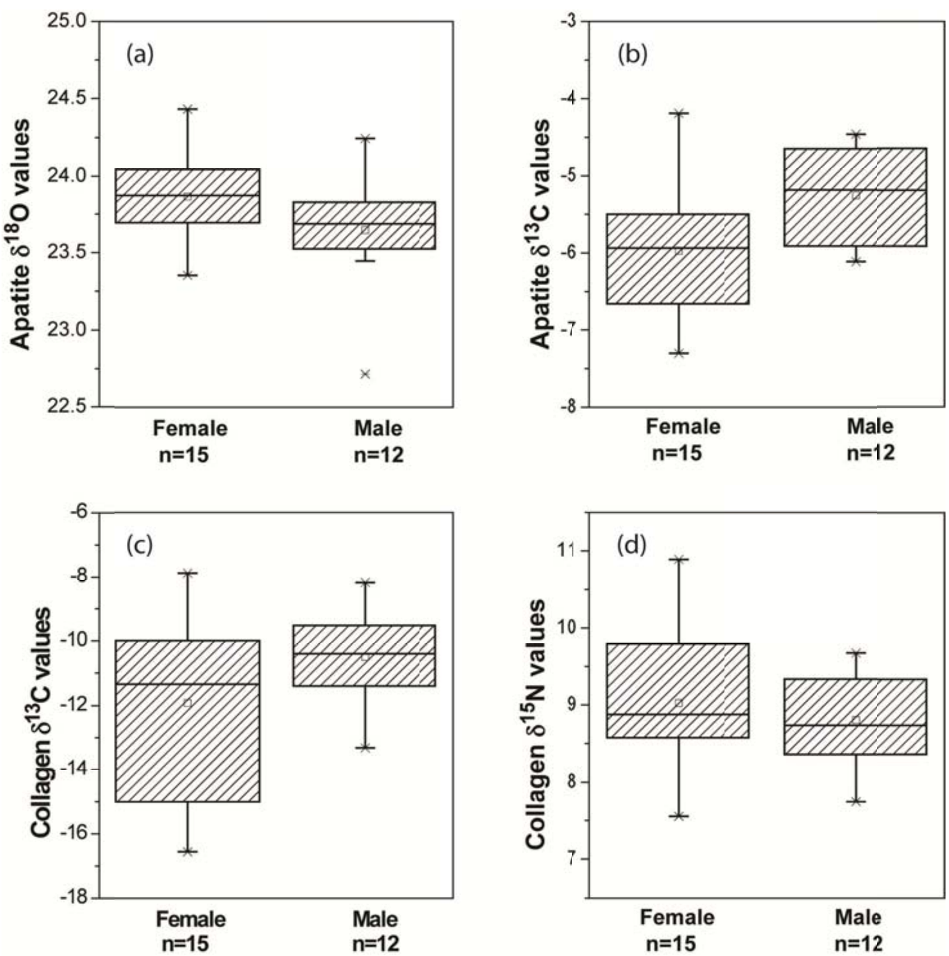

Figure 5.10. Box plot of apatite and collagen isotope values of Liangwangcheng human remains, grouped by sex: (a) apatite oxygen, (b) apatite carbon, (c) collagen carbon, and (d) collagen nitrogen.

CHAPTER 6
RECONSTRUCTING SOCIAL ORGANIZATION WITH ANCIENT DNA ANALYSIS

Stable isotope analyses of human remains suggest that some individuals at Liangwangcheng site consumed large amount of rice (Chapter 5). I have proposed the hypothesis that some of them originally came from southern China and retained their staple food preference for rice. I attempted to test the hypothesis whether people consumed large amount of rice were originally from southern China by analysis of DNA from human remains from two Dawenkou Neolithic sites that I sampled for stable isotope analysis. Dawenkou is the assumed transitional period during which social organization changed from matrilineal clans to patriarchal monogamous families (Chapter 3). I will use ancient DNA analysis to reconstruct the social organization at Liangwangcheng and Fujia. Below I will describe the methods and results of ancient DNA analysis, followed by discussion and conclusions.

Materials and Methods

Samples

Well-preserved samples of dense long bone shafts were selected from the Fujia site, Shandong Province, and tooth samples were selected from Liangwangcheng site, Jiangsu Province for ancient DNA analysis (Table 4.1, marked with asterisk). Information on individual sex, age, burial position, accompanying artifacts, and burial orientation is given in Table 4.1.

DNA Extraction

DNA extraction, amplification, and sequencing were carried out at the Ancient DNA Laboratory, Research Center for Chinese Frontier Archaeology, Jilin University (Fu et al. 2007; Li et al. 2011; Xie et al. 2007; Li et al. 2010; Cui et al. 2010; Gao et al. 2007). Bone samples were first abraded using a Strong 90 Micro Motor (Saeshin Precision Co.) with a carbide drill bit to remove the possibly contaminated outer layers and also the porous inner layers. Bone and tooth samples were then soaked in NaClO (bleach) solution (~5% effective Cl^-) for 15 minutes, rinsed with ethanol, and then put under UV light overnight. Each tooth or bone was powdered in a 6750 or 6850 SPEX Freezer Mill. Powered samples were digested in 0.5M EDTA (pH=8) for 24 hrs on a rotator, and 100μl of 20mg/mL proteinase K was then added on rotator 50℃ overnight. The supernatant from digested samples was condensed using Amicon® Ultra-4 centrifugal filter units (Millipore) to about 100μl. Each sample was then treated with a QIAquick® PCR Purification Kit (QIAGEN) following the manufacture's protocol, except using smaller amount of Elution Buffer (60μl) for elution at the end. We performed two or more independent extractions per sample.

Amplification and Sequencing

The first hypervariable region (HVSI) of mtDNA was amplified and sequenced in two overlapping fragments using primers listed in Table 6.1. To further confirm the mitochondrial haplogroup, each sample was tested by amplified product-length polymorphisms (APLP; Shinoda et al., 2006). In addition, the amelogenin (AMG gene) fragment was amplified for sex confirmation (Stone et al. 1996) for morphologically assigned male individuals, and confirmed samples were chosen for further analysis. We screened all male samples with three bi-allelic markers (M89-F, M9-K, and M214-NO) that define the major branches on the Eurasian haplogroup tree (Karafet et al. 2008; Consortium 2002). Subsequent analysis was restricted to markers (M231-N, M175-O) on the appropriate sub-branch of the haplogroup tree (Karafet et al. 2008; Hui Li et al. 2007). Polymerase chain reaction (PCR) amplification was carried out in 12.5μl reactions containing 3μl template, 1 unit Taq polymerase (Promega), 1 reaction buffer, 2.5 mM $MgCl_2$, 0.2 mM dNTPs, 2 mg/ml bovine serum albumin and 2μM of each primer. Amplification products were checked on a 2% agarose gel and purified with QIAquick Gel Extraction Kit (QIAGEN). PCR products were sequenced using the ABI 310 Terminator Sequencing kit (PE Applied Biosystems) and were analyzed on the ABI PRISM 3100 automatic sequencer (PE Applied Biosystems). DNA sequences were analyzed using Sequencher 4.7 (Gene Codes Corporation). A minimum of two amplifications per sample were conducted. If no consensus sequencing results were obtained by two amplifications and sequencing, additional extraction and amplification were carried out.

Contamination Precautions

Ancient DNA is usually degraded and fragmented, and sometimes modified, mainly due to hydrolytic and oxidative forces (Kaestle and Horsburgh 2002; Svante Pääbo et al. 2004). It is critical to take every precaution to avoid contamination from modern DNA and also to tease out the false signals within ancient samples due to postmortem modifications (Cooper and Poinar 2000). Direct PCR usually yields the same sequences as consensus cloning sequences, and PCRs are more time and cost-effective, so cloning was not performed in this study (Winters et al. 2011). Dedicated preparation rooms for ancient samples were used, located in a building away from any amplification activities. Strict procedures, multiple independent extractions and amplifications, and inclusion of negative controls were practiced. All staff wore sterilized laboratory coats, face masks, and gloves (which were frequently changed), and strict cleaning procedures were performed by regular treatment with DNA-OFF^{TM} (Q-Biogene) and UV light (254 nm). Laboratory staff were limited in their movements between the ancient DNA laboratory and post-PCR area, and PCR products were never brought into the Ancient DNA Laboratory. The DNA of all people involved in processing the samples was genetically typed and then compared to results obtained from the ancient samples. In addition, only female researchers were involved in the pre-PCR procedures in Y-SNP analysis, reducing possible contamination from modern Y-chromosome DNA. Negative controls occasionally turned up positive and were subsequently sequenced. In all cases, the sequencing results of negative controls were random and did not match the sequences of any lab member. Randomly selected samples (DWK171, DWK187, DWK193, and DWK199) were sent to a second ancient DNA laboratory for independent replication and authentication.

Results

All the samples from Liangwangcheng failed to yield reproducible sequences. Only Fujia samples are discussed below. Of the 18 burials sampled from Fujia, 16 yielded reproducible mtDNA sequences (Table 6.2). All individuals shared the same HVSI sequences and coding region Single Nucleotide Polymorphisms (SNPs); they all belong to haplogroup D5 or D6. This sequence differs from those of all researchers present in the laboratory. Haplogroup D is common in modern China (Kivisild et al. 2002; Wen et al. 2004). Haplogroup D5/D6 individuals were present in a 2000 year old population (Yixi site, 9%, about 30 miles to the southwest of Fujia, Yao et al., 2003) and are still present in modern Shandong Province: 8% at Tai'an City, 10% at Qingdao City, 6% at Zibo City (Yao et al. 2002; Yao et al. 2003) .

Eight morphological assigned males at Fujia were further tested using the AMG gene for sex confirmation, seven were confirmed to be male, and one (DWK193) was found to be female. The confirmed males were screened for Y chromosome haplogroups. Three failed to yield reproducible sequences. The remaining four males all belong to macrohaplogroup K. Within macrohaplogroup K, DWK167 and DWK199 are further assigned to haplogroup N, and DWK237 is assigned to haplogroup O. Both haplogroup O and N were present at Dadianzi site (ca. 3600 BP), northeastern China (Hongjie Li et al. 2011). Haplogroup N has a wide geographic distribution throughout northern Eurasia and is found in modern northern and southern China (Tatiana Karafet et al. 2001; Derenko et al. 2007; Zhong et al. 2011). On the other hand, haplogroup O is dominant among populations of East Asia and Southeast Asia, especially in the Chinese Han population (the major ethnic group in China), with an average frequency of 52.3% (Ke et al. 2001). Y-SNPs analysis of prehistoric people (6400–3100 BP) along the Yangtze River showed that all individuals belonged to haplogroup O (Hui Li et al. 2007).

Discussion

There are numerous variations of social organization in modern and ancient communities (Murdock 1967; Morgan 1871; Haviland 1996). Bilateral, neolocal unilateral, patrilocal matrilineal, and matrilocal patrilineal societies are very complicated to reconstruct by mtDNA and Y-chromosome data. Here I will focus my discussion on three kinds of communities based on kinship and post-marital residence: matrilineal community without married-in males, matrilineal community with married-in males, and patrilineal community with or without married-in females, the reasoning is provided below (Table 6.3).

I define two dimensions of gender-related social organization patterns: one is how descent is traced, either matrilineal or patrilineal. In a matrilineal community, because descent is traced maternally, I expect all females to be maternally closely related and have similar mtDNA sequences (excluding patrilocal ones). Conversely, in a patrilineal community, I expect all males to be paternally closely related and have similar Y-chromosome sequences (excluding matrilocal ones). The second dimension is whether the husband or wife is incorporated into the affinal group or stays with their own descent group after marriage. For matrilineal communities, if the husbands are not incorporated into their wives' descent group but stay with their own matrilineal descent group, I expect males to have diverse paternal origins but shared maternal origins. On the other hand, if the husbands are incorporated into their wives' descent groups, I expect males not only have diverse paternal origins and also diverse maternal origins. For ancient patrilineal communities, it is not possible to discern whether women were married into their husbands' descent group or if they continued to live with their own patrilineal descent group because I cannot trace females' paternal origins with genetic markers that I have. Therefore, patrilineal communities with or without married-in females were lumped together.

Based on my ancient DNA analyses, the Fujia community conforms to the pattern expected for a 'matrilineal community without married-in males'. First, all male and female individuals tested from Fujia cemetery (9 females, 8 males, one sex unknown; 15 adults, 3 adolescents) shared the same maternal lines. This means that maternal ties were considered very important, and it is very likely only maternally closely related individuals were buried together. The alternative explanation for finding the same maternal line in all 16 individuals is that there was a large population bottleneck that reduced mtDNA diversity to only this single sequence. A population bottleneck could be caused by pandemic disease with massive death, dramatic environmental change resulting in massive mortality due to severe famine, large scale wars killing or driving people away, or a founder effect resulting from the expansion of a small colonizing population in a new setting. No available archaeological or paleoenvironmental evidence suggests the existence of a severe bottleneck during early Holocene in the region.

Fujia was a moderate sized community with at least 343 burials that was occupied for least 300 years (Chapter 4). The number of individuals tested here is very limited. How well this pattern holds across the cemetery is not known. However, the chance of finding 16 maternally closely related individuals in a patrilineal society is slim. In typical patrilineal and patrilocal communities in modern traditional rural China, only siblings within one family are maternally closely related. Individuals that I tested span a period of 300 years, and were probably not siblings. I would argue that Fujia was very likely a matrilineal community; analysis of DNA of more individuals from this cemetery could confirm this proposition.

In addition, it seems that the bond of marriage was de-emphasized compared to the bonds of descent at death at Fujia. Whether Fujia was a matrilineal community with married-in males largely depends on whether the husband lived with and made contributions to the wife's descent group or his own descent group. Unfortunately, I do not have the relevant information to show where they lived. One can only judge from what was emphasized in the burial arrangement. If we assume exogamy, the "husbands" of a matrilineal community would have come from other communities, hence are expected to have diverse paternal and maternal origins. No such cases were found at Fujia. On the other hand, the male adults found in this cemetery (all seven cases) potentially have wives; however, they were buried with their maternal relatives rather than with their wives and her relatives. Of course, a deceased individual could be moved for burial back to their matrilineal lineage; but it is not be common. It seems likely that husbands were not incorporated into their wives' descent groups, at least at death.

The apparent de-emphasis of the bond of marriage at Fujia, at least expressed in mortuary ritual, is not unique in Neolithic China. Craniometric analysis at Shijia site, Yangshao Neolithic Culture (ca. 5000-3000 B.C), also suggest close relatedness of individuals in the same burial (Gao and Lee 1993). The number of individuals in each burial at Shijia ranged from 4 to 51, with an average of 18. It is likely that individuals found in the same burial included not just siblings, and possibly included people of several generations; they probably died at different times, and were buried together because of their relatedness. If affinal relatives were included, we would expect some individual(s), such as married-in husbands or wives, to have distinctive cranial metric measurements compared to most individuals in the burial, assuming exogamy, because everyone else is genetically closely related. However, this was not observed at Shijia: individuals from each burial clustered together and were obviously different from individuals from another burial (Gao and Lee 1993: Figure 7). It is very likely that only relatives from the same descent group were included in the same burial, and affinal links were de-emphasized in the Shijia community.

Similar observations are found at another late Neolithic community, Jiangjialiang site. Ancient DNA analysis was done on four multiple burials at Jiangjialiang (ADLJU 2001). The results show that individuals in the same burial are more closely related than among burials. If we look closely on the sequencing results, individuals within the same burial often only differ at one or two mutation sites from each other. It is likely that these discrepancies are DNA damage instead of genuine mutations. In other words, it seems individuals in the same burial shared the same mtDNA sequence. Hence they are siblings not married couples. Again affinal links were de-emphasized.

Contrary to Briffault and Malinowski (1956)'s claim for the centrality and universality of the 'individual family', it is likely that blood ties (i.e. brothers and sisters) were considered more important than affinal links (i.e. husband and wife) at this Dawenkou community. Individual family was previously prized mainly to the concern of provisioning young child and pregnant or breastfeeding mothers. However, recent research suggests that the hunt yields by males were usually shared among the community, leaving the hunter and his family the minimum share (O'Connell et al. 2002). In other words, the presence of male hunting, either by brothers or husbands would benefit the group in general, not a nuclear family per se. It is not mandatory to have nuclear family relationships to ensure the wellbeing of the mother or the infant. Ethnographic examples of subsistence practices and consumption patterns of matrilineal societies also support this hypothesis, such as the Nayar from India (Gough 1959; Gough 1965), the Mosuo people from southwestern China (Hua 2001), and Australian aborigines (Malinowski 1913). In these societies the husbands are not incorporated into their wives' descent groups and they work for their own descent groups instead. It is the responsibility of the brothers to take care of the women and their children. Schneider (1961) actually argued that strong bond of solidarity between husband and wife is not compatible with the maintenance of matrilineal descent groups.

Multiple theories have been proposed for the practice of matrilineal or matrilocal organization. Korotayev (2003) argues that low internal warfare frequency and high female contribution to subsistence favor matrilocal residence. Opie and Power (2008) argue that the role of grandmothers as foragers for, and care-givers to, their daughters' children were critical to the emergence of hunter-gatherer social adaptations; hence, the earliest human groups were matrilineal. Matrilineal societies found in ethnographic surveys tend to be horticultural instead of pastoral or mixed agricultural food producing economies (Aberle 1961). Holden and Mace (2003) also suggest that matrilineal descent is often associated with swidden cultivation, because women typically do much of the productive work in the fields. Whether Dawenkou agricultural subsistence was related to the matrilineal organization at Fujia site is unknown. Based on stable carbon isotope analysis, subsistence at Fujia was millet-based agriculture (Chapter 5). Faunal analyses of other Dawenkou sites suggest that pig was the dominant animal resource (Zhou, 2000; Yuan and Chen, 2001).

As discussed in Chapter 3, evidence for social ranking in Dawenkou sites comes largely from cemeteries. Interestingly, we can see significant variations in social stratification within late Dawenkou cemeteries: some communities had clearer signs of initial stratification (e.g. Xixiahou site, SAT IA CASS, 1964, 1986; Lingyanghe site, Wang, 1987), and others were more egalitarian (e.g. Wucun site, less than two miles away from Fujia, SPICRA and Guangrao

Museum, 1989). It is possibly that social organization, including kinship and marriage patterns were diverse among Dawenkou communities as well. Fujia is dated to late Dawenkou, during the end of the assumed transition period from matrilineal clans to patrilineal monogamous families. If this transition did occur, it did not occur simultaneously across all Dawenkou sites. More ancient DNA research, stable isotopic research, and archaeological research on social organization is needed to find out how Dawenkou and later communities were organized, and how the transition occurred. For example strontium isotope analysis could help determine whether individuals were buried in the area where they were born and raised, or if they came from a different region (Bentley et al. 2005; Bentley et al. 2012; Price et al. 2010; Wright 2012).

Another point worth noting is that despite the different body orientations at Fujia site, individuals oriented towards northeast or southeast all had the same mtDNA sequences. Therefore they probably all belong to the same maternal lineage. However, we cannot rule out the possibility that two lineages had split quite recently, and had not yet accumulated any genetic differences. Oxygen isotope analysis of human bone apatite reveals that those two groups of people may have used different drinking water sources possibly due to their residential patterns (Chapter 5). Body orientation did not seem to correlate with sex, grave type, or number of grave goods, but correlated with oxygen isotope values. Some ethnographic cases suggest that burial orientations are related to cause of death (Binford 1971). Cross-culture survey of mortuary practices of 31 societies from all over the world suggest that body orientation are more likely to represent philosophical-religious beliefs about the afterlife (Carr 1995). It is possible that those two groups of people with different orientations at Fujia site had different religious beliefs of afterlife despite genetic closeness. Considering their different oxygen isotope ratios, it is more likely that they are two groups of people living separately in space. Their different burial orientations are a way of reaffirm their group identities.

Summary

I attempted to extract DNA from human remains of both Liangwangcheng and Fujia sites. Unfortunately, the human remains from Liangwangcheng were not preserved well enough, and I could not get any reproducible sequencing result. Sixteen out of eighteen individuals from Fujia yielded usable results, and they all belong to mitochondrial haplogroup D. Haplogroup D appears in higher frequency in modern northern China than southern China (Wen et al. 2004).

Unfortunately, we do not know much about genetic structure of prehistoric Chinese populations. If we assume the same pattern holds in prehistory, Fujia people are more likely to be northern Chinese instead of southern immigrants. Stable isotope analyses also support this proposition: all the individuals from Fujia retained millet dominant diets which were northern traditions (Chapter 5). However, we need to learn more about the genetic structure of prehistoric population to be more certain about this proposition.

On the other hand, the sequencing results from Fujia human remains allow me to discuss the social organization at this community. Contrary to the previous assumption that the social organization was patrilineal/patriarchal/patrilocal by late Dawenkou (5000~4600 BP), ancient DNA analyses suggest that matrilineal links were quite important at Fujia, and the community was very likely a matrilineal one. In addition, it seems husbands were not incorporated in to their wives' descent group but stayed at their own matrilineal descent groups instead.

One common belief held among Chinese archaeologists is that when the society was more stratified men began to gain power and the descent system gradually changed from matrilineal to patrilineal. Since Fujia is relatively egalitarian, this case study cannot argue against the belief specifically. The social organization of prehistoric communities could be very diverse just like modern ones; we do not know what the social organization was like in other late Neolithic communities. However, this research demonstrates the great potential of ancient DNA analysis in prehistoric kinship studies. More research like this should be done, in conjunction with strontium, and light stable isotope analyses, in order to further discern how ancient societies were organized and maybe how that organization was gradually transformed.

Tables

Table 6.1. Primers used in this study

HVSI fragments	Primers		Length (bp)
HVSI-AB	L16017 5'-TTCTCTGTTCTTTCATGGGGA H16251 5'-GGAGTTGCAGTTGATGTGTGA		235
HVSI-CD	L16201 5'-CAAGCAAGTACAGCAATCAAC H16409 5'-AGGATGGTGGTCAAGGGA		209
Mitochondrial haplogroups	**APLP Primers**	**Sites**	**Length (bp)**
D	5178A 5'-TGATCAACGCACCTGAAACAAGA 5178C 5'-GTCGCACCTGAAGCAAGC 5178R 5'-CCCATTTGAGCAAAAAGCC	5178A/C	107 (D)/102
Y chromosome haplogroups	**Primers**	**Sites**	**Length (bp)**
F	M89S 5'-CCACAGAA GGATGCTGCTCA M89A 5'-CACACTTTGGGTCCAGGATCAC	M89	125
K	M9S 5'-GGACCCTGAAATACAGAAC M9A 5'-AAGCGCTACCTTACTTACAT	M9	128
NO	M214S 5'-TATATGTAAGCTTTCTACGGCA M214A 5'-GGGGAAAAAACCATGTACG	M214	109
O	M175S 5'-GGACCCTGAAATACAGAAC M175A 5'-AAGCGCTACCTTACTTACAT	M175	128
N	M231A 5'-TTCTTTGACGATCTTTCCCC M231S 5'-CCTGGAAAATGTGGGCTC	M231	113
Sex Identification	**Primers**		**Length (bp)**
AMG gene	XBamel-1 5'-CCTGGGCTCTGTAAAGAATAG XBamel-2 5'-CAGAGCTTAAACTGGGAAGCTG		103 (F)/ 103 and 109 (M)

Table 6.2. Mitochondrial and Y-chromosome SNPs and haplogroup designation of Fujia samples

LabNo	Mutations in HVSI (16000+)	mtDNA -coding region SNPs	mtDNA haplo-groups	Y-CH coding region SNPs	Y-CH haplo-groups
DWK161	129-189-223-362	5178A	D5/D6		
DWK165	129-189-223-362	5178A	D5/D6	M89T, M9G, without M175 (5bp del)	K*(XO)
DWK167	129-189-223-362	5178A	D5/D6	M89T, M9G, M214C, M231A	N
DWK169	129-189-223-362	5178A	D5/D6		
DWK171	129-189-223-362	5178A	D5/D6		
DWK173	129-189-223-362	5178A	D5/D6		
DWK177	129-189-223-362	5178A	D5/D6		
DWK179	129-189-223-362	5178A	D5/D6	failed	
DWK181	failed				
DWK183	129-189-223-362	5178A	D5/D6	failed	
DWK185	failed				
DWK187	129-189-223-362	5178A	D5/D6		
DWK235	129-189-223-362	5178A	D5/D6	failed	
DWK237	129-189-223-362	5178A	D5/D6	M89T, M9G, M175 (5bp del)	O
DWK193	129-189-223-362	5178A	D5/D6	molecular identification as female	
DWK195	129-189-223-362	5178A	D5/D6		
DWK197	129-189-223-362	5178A	D5/D6		
DWK199	129-189-223-362	5178A	D5/D6	M89T, M9G, M214C, M231A	N

Table 6.3. Expected male and female genetic expressions in three kinds of ideal communities.

Ideal Community Label	Females' maternal origin and mtDNA expressions	Males' maternal origin and mtDNA expressions	Males' paternal origin and NRY expressions
matrilineal community without married-in males	similar maternal origins, hence similar mtDNA sequences	similar maternal origins, hence similar mtDNA sequences	diverse paternal origins and diverse Y-chromosome sequences
matrilineal community with married-in males	similar maternal origins, hence similar mtDNA sequences	diverse maternal origins and diverse mtDNA sequences	diverse maternal origins and diverse mtDNA sequences
patrilineal community with or without married-in females	diverse maternal origins and diverse mtDNA sequences	diverse maternal origins and diverse mtDNA sequences	similar paternal origins and Y-chromosome sequences

CHAPTER 7
CONCLUSIONS

Major Findings

In this dissertation I studied four late Dawenkou Neolithic sites (Dongjiaying, Fujia, Huating, and Liangwangcheng) in Shandong and Jiangsu Provinces to understand several fundamental changes during this period that foreshadow the development of early Bronze Age complex stratified society in northern China. These changes include the appearance of incipient social stratification among previously egalitarian communities, the initial spread of rice from southern China to the millet agriculture-based societies of the Yellow River Valley, and the assumed transition from matrilineal/matriarchal clans to patrilineal/patriarchal families.

Based on the changes in pottery typology and other cultural traits, the Dawenkou culture can be divided into three phases. Early, middle, and late Dawenkou are dated to approximately 4300-3500 cal. BC, 3500-3000 cal. BC, and 3000-2600 cal. BC, respectively (SPICRA 2005: 167). Fujia and Dongjiaying are Dawenkou sites located further north in Shandong Province, and Huating and Liangwangcheng are further south in Jiangsu Province. My radiocarbon dating results suggest that Liangwangcheng, Fujia, and Huating all date to 2800-2500 cal. BC, while Dongjiaying is a few centuries later (2600-2300 cal. BC). Their contemporaneity permits synchronic and diachronic comparisons of diet composition and burial customs among communities over a few centuries.

Linking my discussion to the three critical changes that took place in the Dawenkou culture and the three theoretical issues that I reviewed in Chapter 2, below I will summarize my major findings in three sections: the development of social ranking, kinship and gender relationships, and food consumption. Then I will briefly discuss how food consumption is related to gender relationships and social organization at the Liangwangcheng site.

Development of social ranking

Very few well preserved residential sites of Dawenkou culture have been excavated, and no significant differences in wealth among households were identified (SPICRA and ZMCB 1996; IA CASS 2001). Most evidence of incipient social stratification comes from Dawenkou burials.

Mortuary traditions became more elaborate from early to late Dawenkou. Numbers of grave goods increased dramatically, and some graves became larger and structurally complex, exemplified by *ercengtai* (graves with ledges), wooden coffins, and jade and other exotic prestige objects. The chronological and geographic distribution pattern of elaborate burials with *ercengtai* and coffins suggests that this tradition probably started in the region to the southwest of Tai Mountain during early Dawenkou (at the Dawenkou type site), gradually spreading to the region east of Tai Mountain during middle Dawenkou (e.g. Sanlihe and Lingyanghe sites), and reaching northern Jiangsu during late Dawenkou at Liangwangcheng (Nanjing Museum, Xuzhou Museum and Pizhou Museum n. d.). On the other hand, the tradition of including delicate jade objects as grave goods probably started in northern Jiangsu (at Liulin) during early Dawenkou, and expanded into the region to southwest of Tai Mountain (at the Dawenkou type site) during late Dawenkou.

Based on mortuary evidence, I find that the development of social ranking varies in different regions and among sites in the same region. Although Dongjiaying, Fujia, Huating, and Liangwangcheng are contemporary there is significant variation in the development of social ranking. Huating seems to be the most stratified with evidence of human sacrifices in some burials (Nanjing Museum 2003). Both Dawenkou and Liangzhu style artifacts are found at Huating, sometimes in the same burial. Liangzhu style jade artifacts included highly symbolic jade *cong* (a tube with a circular inner section and square or circular outer section), *bi* (a flat jade disc with a circular hole in the center), and *yue* ("battle axe"). They are believed to be ritual objects. Their presence at Huating suggests the possible influence of Liangzhu ideology. The development of social ranking at Huating may have been fueled by contact with Liangzhu people. Liangwangcheng also shows signs of social ranking judging by the richness of some burials, and the inclusion of exotic goods that suggest long distance trade. Unfortunately, the excavation reports of Dongjiaying and Fujia are not available. Based on the limited information available for this study the Fujia community seems to be quite egalitarian.

Kinship and gender relationships

Despite much attempt to reconstruct kinship and gender relationships in previous research, the argument that societies were organized into patrilineal/patriarchal nuclear families is not well tested. Based on mortuary and genetic evidence from Liangwangcheng and Fujia, this argument is not supported, at least at these two sites.

Contrary to the previous expectation that patriarchal organization characterized later

Dawenkou sites (Chapter 3), some females seem to have had privilege over others at Liangwangcheng. Red pigment is rare at Liangwangcheng and it is only found in rich burials, so it may be a marker of high status. The sex of one burial (M110) is undetermined. The other four burials with red pigments all belong to females, possibly suggesting they had special status. In addition, female burials are generally more elaborate than male burials (Chapter 4). No evidence supports the hypothesis that a transition to patriarchal families occurred with increasing social complexity at this late Neolithic site. However, this conclusion may not hold in other Dawenkou sites. We need to test this hypothesis at other sites with signs of increased social ranking and examine gender relationships at each site to see whether males or females had special status.

In addition, I reconstructed the kinship system at Fujia using ancient DNA evidence (Chapter 6). Contrary to the longstanding conventional assumption that social organization was patrilineal by late Dawenkou, my ancient DNA analysis results suggest that all male and female individuals tested from Fujia (8 females, 7 males, one sex unknown) shared the same mtDNA sequences. In other words, matrilineal links were evidently important at Fujia, and this community was very likely matrilineal. In addition, it seems that husbands were not incorporated into their wives' descent groups at death but were buried with their own matrilineal descent groups instead. The results are only preliminary; more samples from this site and more contemporary sites need to be tested to confirm this proposition.

Due to the poor preservation of human bones from Huating and Dongjiaying, sex identification at both sites is problematic. Hence, I did not attempt to discuss gender relationships or extract ancient DNA and reconstruct kinship systems at either site.

Food consumption

Based on evidence of archaeobotany, archaeozoology, and stable isotope analysis of human remains, the subsistence of Dawenkou culture probably varied through time and across the landscape (Chapter 3). Pigs and deer were dominant in the faunal assemblage in most Dawenkou sites, supplemented by other terrestrial and aquatic resources, which is similar to other Neolithic sites in northern China (Yuan et al. 2008). During early Dawenkou, we do not have much evidence for rice consumption; millets were generally present (Zhao 2009; Wang et al. 2012). During late Dawenkou, we have more evidence of rice consumption (e. g. Xujiacun, Yuchisi, Lingyanghe, and Xigongqiao).

Stable isotopic analysis of human and faunal remains from my four late Dawenkou sites suggests that food consumption varied across the landscape and even among different individuals within the same site. Populations from Fujia and Dongjiaying had diets dominated by millets and millet-fed pigs, while the populations from Huating and Liangwangcheng had more diverse diets, including significant amount of C_3 plants such as rice and C_3-feeding animals and/or aquatic resources. Dietary reconstruction with stable isotopes, combined with archaeological evidence, supports my model of a late Dawenkou population with well-established millet agriculture that gradually adopted rice that was introduced from southern China and gradually spread north. The observation that more individuals consumed rice during the last phase of occupation at Liangwangcheng supports this proposition. None of the individuals from Dongjiaying consumed significant amounts of rice. However, rice may have been available in the region judging from the collagen $\delta^{13}C$ value of one individual from Lingyanghe, a late Dawenkou site, 40 km from Dongjiaying (Cai and Qiu 1984). It is interesting to note that Lingyanghe burials show signs of greater social ranking (Wang 1987). A larger sample set from other contemporary Dawenkou sites in the region could reveal the extent to which rice was available in the northern Dawenkou region.

If flotation or phytolith analyses can be done at more Dawenkou sites in the future, it can certainly help us refine the timing and routes by which rice spread. Pot residue isotopic and starch grain analyses may also help reveal when rice was introduced and cooked at Dawenkou sites. We could also examine possible feasting vessels for evidence of ritual foods, and drinks, so that we have a better understanding of under what circumstances rice was introduced and consumed. In addition, we may also look for possible changes in stone tools or cooking pots that may be related to the introduction of rice. However, no observable differences exist between rice and millet processing tools or cooking pots at Jiahu site, Henan Province (Peiligang Culture, 9000-7000 BP; HPICRA 1999).

Food, gender, and social organization

Because the excavation reports of Fujia and Dongjiaying are not available, and the sample size of Huating is too small, I will focus my discussion on Liangwangcheng in this section.

Stable isotope analysis of human remains from Liangwangcheng suggests that the introduction of rice provided a new venue for social diversification, and identity affirmation and reformulation. The majority of the population in the community retained the traditional millet-dominated diet, while some women consumed significant amounts of the new staple food. They could have actively utilized this new venue to differentiate themselves from others in their communities, which might have eventually led to further stratification. The use of *ercengtai* and *mingqi* increased during later phases at Liangwangcheng, and more people consumed rice during the last phase. This may suggest that there was more intense competition for social status during later phases. Rice consumption could have been used as one of the venues for people to differentiate themselves from others. This study provides a new dimension to a model for the initial development of social stratification among Dawenkou communities. It complements the theory of social ranking emerging from graveside competitive feasting (Fung 2000; Underhill 2002). This model can be further tested using materials from other Dawenkou communites to determine if rice played a critical role in the process of social stratification.

It is unclear whether social stratification made rice consumption possible or the introduction of rice lead to greater social stratification. On one hand, at least some individuals in more stratified societies can organize human labor to construct water control systems that are usually needed for rice production in northern China. For more egalitarian societies, however, it may not have been easy to get communal support for construction of water control systems. Therefore rice production may have been more feasible in more stratified societies. On the other hand, as I discussed in this dissertation, the introduction of rice potentially provided a new venue for some individuals to gain power and differentiate themselves from others, thus facilitating the development of social ranking. In order to find out which is the case, we may need more finely dated sample sets in order to examine whether the signs of social ranking appeared first or if rice was introduced earlier. My results from Liangwangcheng are only preliminary. It seems the community already showed signs of social ranking starting from Phase A, judging from the differences in the number of grave goods among burials. Rice consumers were rare during Phase A. During later phases, the competition for social status were more fierce and more rice consumers were identified. I need to test more individuals from each phase at Liangwangcheng to draw any conclusion. If flotation results of this site become available in the future, radiocarbon dating on carbonized rice remains could also help reveal when rice was first introduced into the community and its abundance during different phases.

To return to the hypotheses that were formulated at the beginning of my research, I find that some are supported and some are not. Hypothesis 1—rice consumption among different individuals from the same site varies independently with the identities of individuals—was not applicable for Dongjiaying and Fujia because rice was not consumed at these sites; the sample size from Huating is too small to test this hypothesis. This hypothesis was not supported based on evidence from Liangwangcheng. Instead, there was difference in rice consumption among difference individuals at Liangwangcheng, and rice consumption seems to correlate with individual's certain identities.

In order to determine the identities of people that consumed more rice, I further tested Hypotheses 2-4.

Hypothesis 2: Due to the poor preservation of human remains from Liangwangcheng, I could not get reproducible sequencing results and could not determine the geographic origins of rice and millet consumers. It is not possible to determine for this site whether rice consumption is related to the southern origin of individuals or if millet consumption is related to the northern origin of individuals.

Hypothesis 3: Regardless of the geographic origins of individuals, rice was regarded as a high status food, and only people of higher social status had access to rice or consumed more rice. This hypothesis was supported at Liangwangcheng by stable carbon and nitrogen isotope analysis.

Hypothesis 4: If males played a special role in the adoption of rice then they should have eaten more rice and/or meat compared to women. This hypothesis was not supported. Rather, my stable isotope data shows that women played a special role in the adoption of rice at Liangwangcheng.

Hypothesis 5: The society had changed from matrilineal/matriarchal clans to patrilineal/patriarchal families during late Dawenkou. This hypothesis was not supported. (a) Contrary to the longstanding conventional assumption that social organization was patrilineal by late Dawenkou, my ancient DNA analysis results suggest that matrilineal links were important at Fujia, and this community was very likely matrilineal. (b) Females seem to have higher social status than males at Liangwangcheng, as indicated by mortuary evidence and stable isotope evidence. (c) Nuclear families were not considered important at Fujia. It seems that husbands were buried with their own matrilineal descent groups rather than their wives' descent groups at death. This distinctive pattern of post-mortem burial location was not anticipated among the potential alternative hypotheses. It is, however, consistent with the matrilineal organization pattern of the modern Moso (Mosuo or Na) of Yunnan and Sichuan provinces of China (Hua

2001).

Directions for Future Research

My dissertation research demonstrates that the development of social ranking, the staple food consumed within some sites, and the forms of social organization varied among sites within the Dawenkou culture. Some Dawenkou sites have a greater range of mortuary treatments, including differences in size and complexity of tombs, presence or absence of human sacrifices, numbers of exotic prestige goods and specialized ceramic artifacts that likely were used for fermented beverages that may have been consumed at graveside feasts. These lines of evidence suggest more pronounced social ranking through time. Competitive graveside feasting could have played a critical role at some sites, while the introduction of rice may be significant at others (e.g. Lingyanghe, and possibly as shown by my analysis for Liangwangcheng). The combination of these and perhaps other factors could have contributed to the development of incipient social stratification.

In future research, we need to examine each site more carefully to find out the specific driver(s) for the development of social complexity. The adoption of rice is hypothesized to be a critical driver promoting the development of complexity because it is a labor-intensive staple crop that may have been consumed by wealthier individuals, and by those that aspired to higher social status. However, the reasons that rice was adopted at a specific site could have varied. Combining mortuary evidence and staple isotope analysis in this dissertation has proven very informative in revealing the identity of rice consumers and evaluating how rice was adopted at some sites but not at others.

Based on limited genetic evidence, I was only able to determine the kinship system at Fujia, which was very likely a matrilineal community. When the excavation report of Fujia is published, I will further investigate the spatial distributions of the samples I have tested and examine how the burials are related to each other in space. In this research, I have only examined the mtDNA and Y-chromosome, and I found that individuals were maternally closely related. In the future, I will consider including autosomal marker analyses, such as human identification kit AmpFLSTR® MiniFiler™, which can examine kinship relations among individuals in more details and potentially can reveal sibling and parent-offspring relations.

The kinship systems of prehistoric communities could have been very diverse, just like modern ones. We do not know what kinds of kinship systems prevailed in other late Neolithic communities. However, this research demonstrates the great potential of ancient DNA analysis in prehistoric kinship studies. More genetic research should be done in order to further discern how ancient societies were organized and how organization was gradually transformed during this formative era.

Due to the poor preservation condition of human remains at several sites, I was not able to amplify ancient DNA from human remains and failed to determine individuals' geographic origins. In future research, I plan to incorporate strontium and oxygen isotope analysis, which can be useful in identifying the geographic origin of a specific individual, and can reveal the post-marital residence pattern at the community. I also plan to try ancient DNA analysis with Next Generation Sequencing techniques, especially on human remains from Liangwangcheng that have shown great diversity in food consumption patterns. Due to the constrain of the traditional Sanger Sequencing method that I used in this research, DNA fragments in archaeological samples have to be at least 100 bp to be sequenced (Sanger et al. 1977; Sanger, Nicklen, and Coulson 1977). Next Generation Sequencing can sometimes work better with degraded samples because it often works with fragments of less than 100 bp (e. g. Knapp et al. 2012). I may thus be able to get sequencing results from Liangwangcheng human remains and determine their geographic origins.

Flotation to recover archaeobotanical remains is not a routine practice in China, so the evidence for prehistoric agricultural practices is limited. No flotation results are available for the sites studied in this dissertation. However, my isotopic analysis partly overcomes this problem because it provides a quantitative method to study agricultural food consumption of individuals. More similar research can be done as an alternative method of studying agriculture practices when flotation results are not available. Many previous stable isotope analyses of human skeletons in China have focused on collagen isotope ratios. This dissertation demonstrates the importance of studying both collagen and apatite isotope ratios because they reflect isotopic ratios of different food types (protein sources versus whole diet). Only by integrating collagen and apatite isotope analyses that we can accurately reconstruct individuals' diets, particularly whether they consumed C_3 or C_4 plants foods or animals that fed on these resources.

Another interesting observation is the elevated carbon isotope values of cattle found at Liangwangcheng suggesting that cattle had been feeding in millet fields and/or were provisioned with millet fodder. We do not know when and where cattle were first domesticated in China. It is argued that cattle were not domesticated until the terminal Neolithic in northern China (Lyu 2010; Yuan et al. 2007). Confirmed cases of domestic cattle dated to the Neolithic era are all located in northwestern and central China. My isotopic evidence suggests that cattle may have been domesticated earlier in the Dawenkou region in eastern China. Cattle sacrifice is a critical component of Shang royal ritual practices (Yuan and Flad 2005). Considering the amount of meat that cattle provide, they may have been a good choice for feasting food during the Dawenkou period. More stable isotope analysis should be done on cattle to determine their relationship with humans during the Neolithic and how it may have changed through time.

Broader Implications and Contributions

This dissertation research demonstrates the great potential of multidisciplinary approaches in addressing archaeological questions. Each approach—mortuary evidence, stable isotope analysis, and ancient DNA analysis—provides a different perspective on the same set of questions. By combining these methods, I was able to obtain a more comprehensive understanding of the social organization and gender relationships at Dawenkou sites. More research like this can be done in addressing anthropological archaeological problems in China and elsewhere. It is especially useful for researchers studying prehistoric cultures that often struggle with the lack of detailed written records.

Many more archaeologists have been paying attention to food studies in the last two decades (Twiss 2012). This dissertation adds to this growing literature and introduces a new perspective on food studies in late Neolithic China. I have tried to understand food consumption in its social context, including individual gender, social, and ethnic identities. In addition, this study suggests that food consumption practices can play a critical role in marking social differences and facilitating the development of social stratification. For scholars studying other regions of the world, this research may shed light on food studies of one population encountering another population with different traditional staple food, for example, when Native Americans met Europeans, or when farmers met hunter-gatherers. This research provides an example on how local population may respond in these encounters, and how the contact might affect many aspects of the society, including food practices and social organization.

This research also provides insights on gender studies. People often have many assumptions about gender relations and gender roles in ancient societies (e. g. Brumfiel 1991; Sun and Yang 2004; Robin 2006; Shelach 2008). This research proves again the necessity to carefully test hypotheses before accepting those assumptions. This research also suggests that there might be great variations in gender relations and gender roles among contemporary communities within the same culture. Men may be dominant at one community and not at another, we should be mindful of these variations when studying ancient societies.

Even though Dawenkou people interacted with their neighbors—the Yangshao and Liangzhu peoples, it is clear that Dawenkou developed initial social stratification relatively independently. It provides a model for how social ranking may have developed that is potentially useful to researchers studying other parts of the world. Dawenkou is famous for its elaborate burials. On the other hand, there is no clear sign of social ranking based on limited residential evidence (Chapter 3). Dawenkou culture may not be unique among worldwide prehistoric cultures. It provides an example of initial development of social stratification in one aspect of the society (mortuary in the case of Dawenkou) before stratification of residential and other architectural features and activity areas. Excavations focusing on certain kinds of features, for example cemeteries versus residential areas in the Dawenkou sites that I studied, may lead to biases in our understanding of past forms of social organization and development of social ranking. We need comprehensive information from all components of sites to thoroughly understand ancient societies.

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